Geopolitical Situation Assessment and Climate Actions

Snow's Library Adult Education Program

November 9, 2016

Part 2

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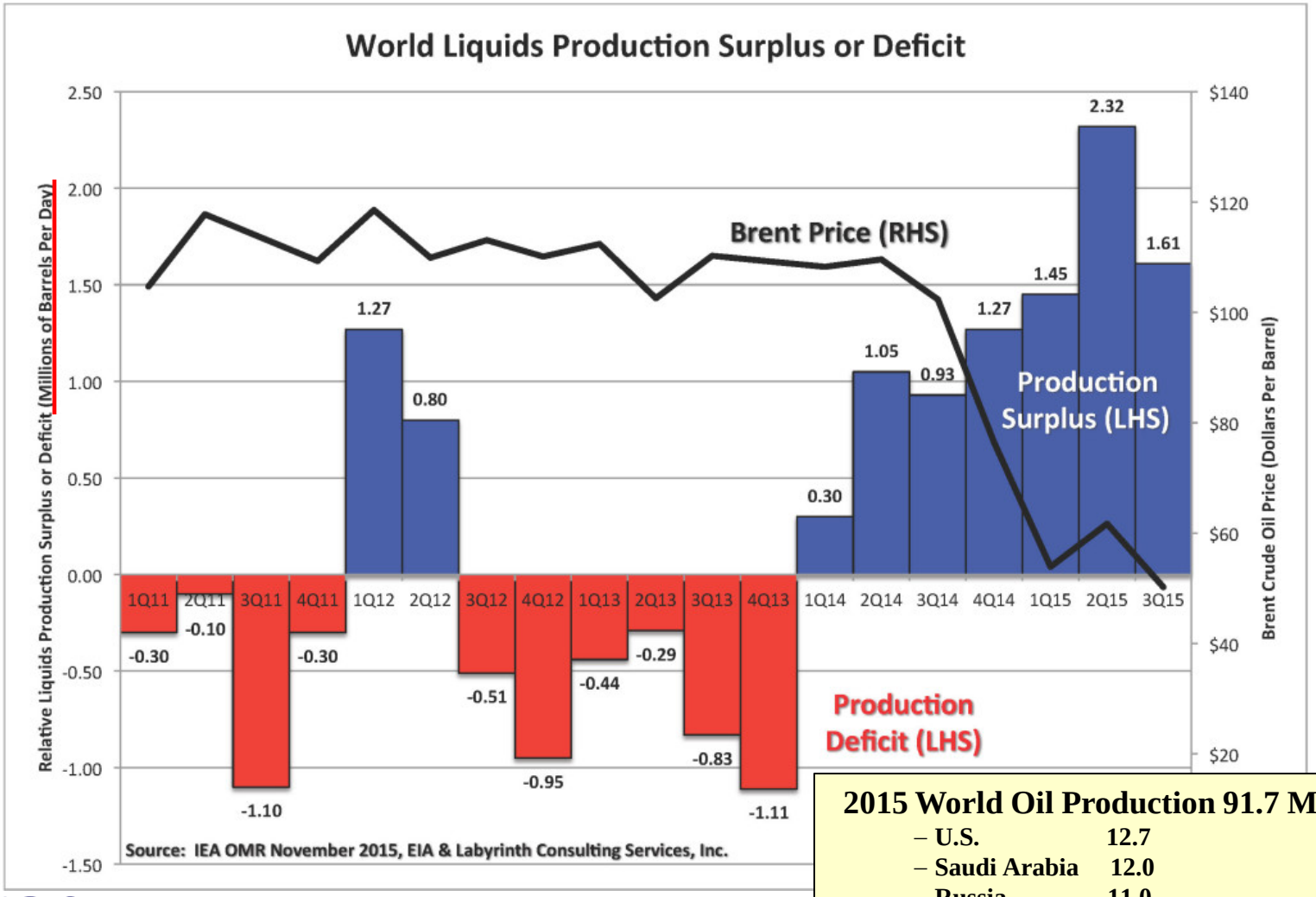
Supply Management

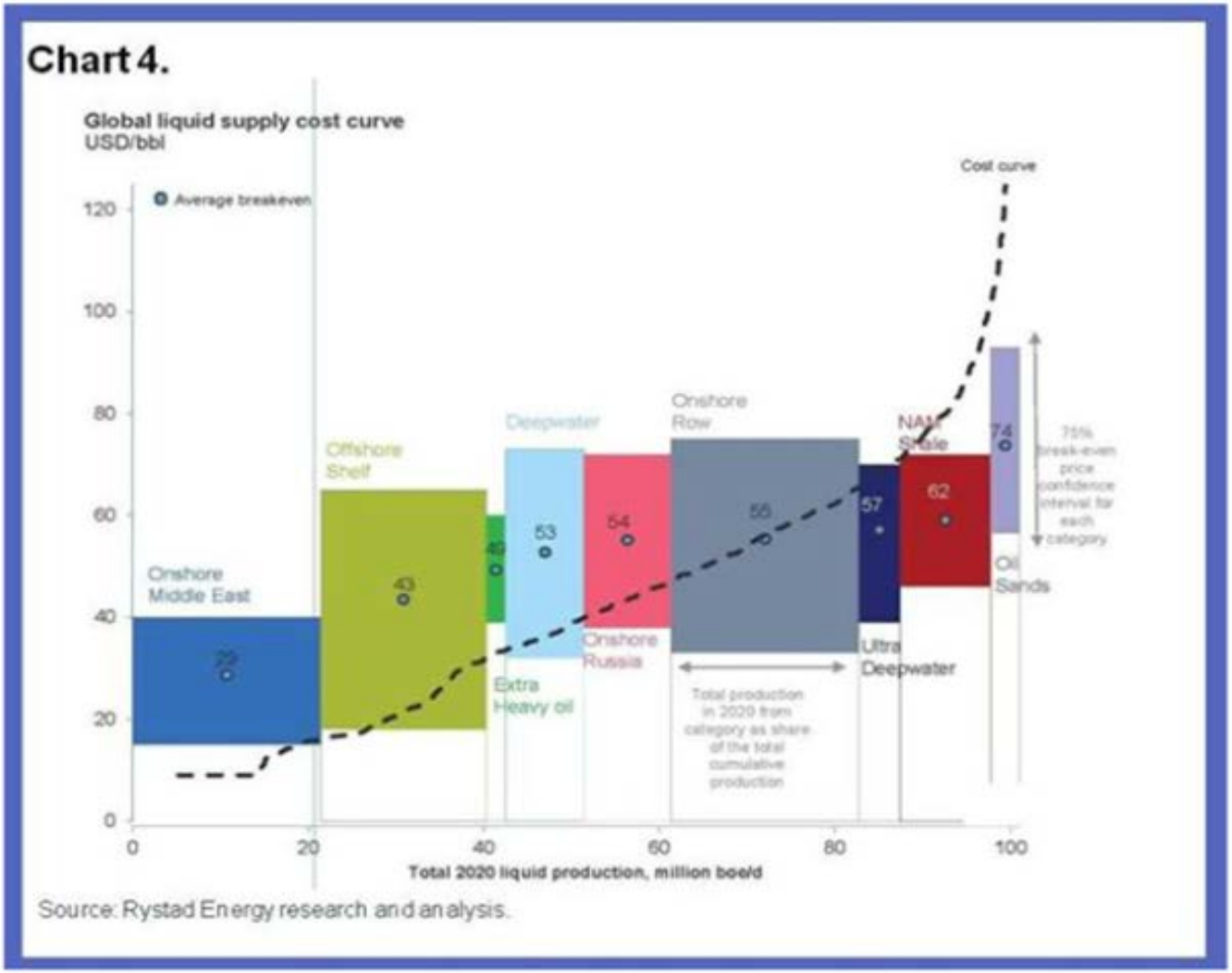
Oil Price – The Supply/Demand Balance



2015 World Oil Production 91.7 MMbbl/d

- U.S. 12.7
- Saudi Arabia 12.0
- Russia 11.0
- Iran 3.9

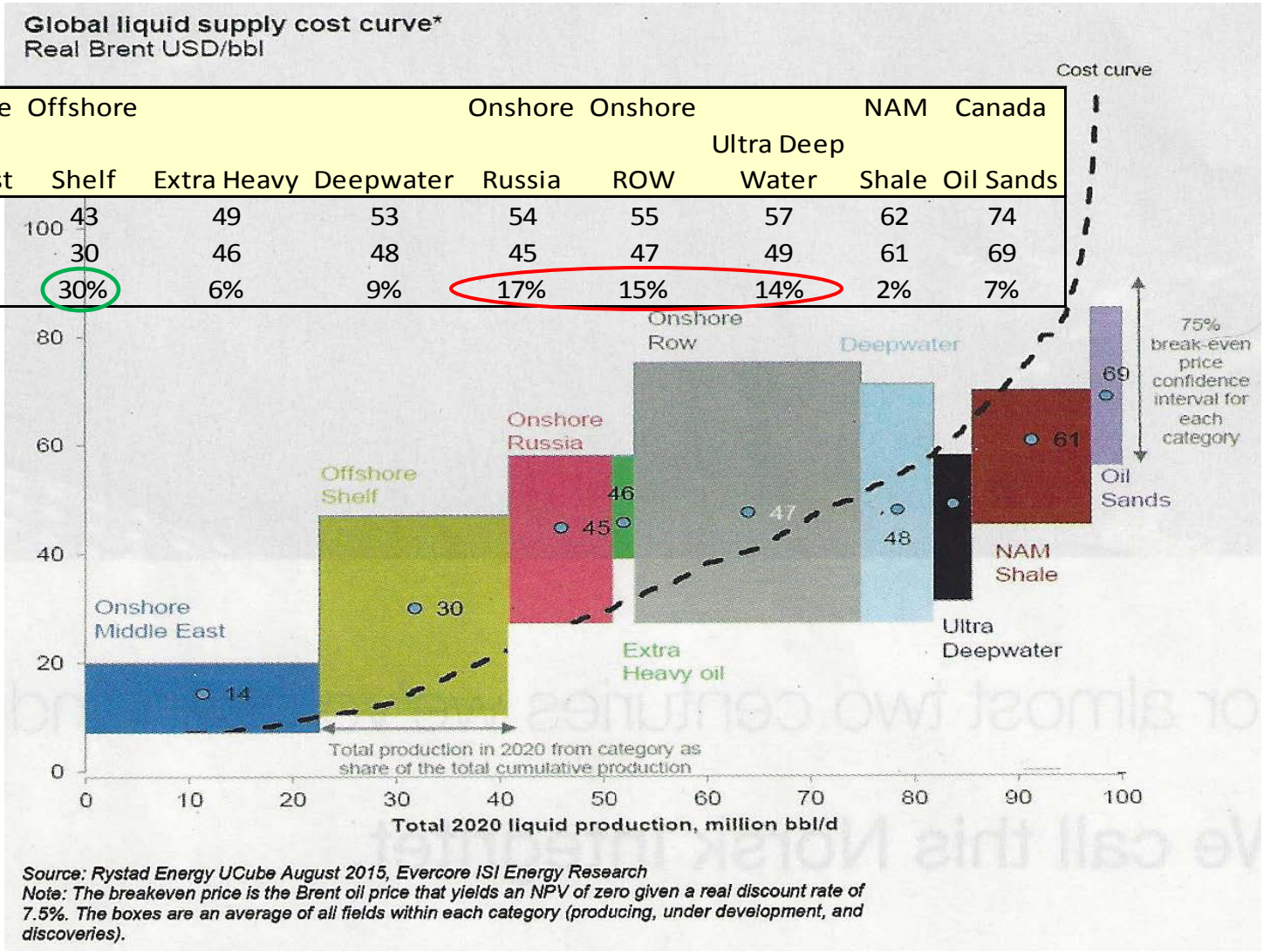
Global Liquid Supply Cost Curve December 2014



Source: Rabah Arezki, Oliver Blanchard, IMF blog Dec. 22, 2014

Global Liquid Supply Cost Curve August 2015

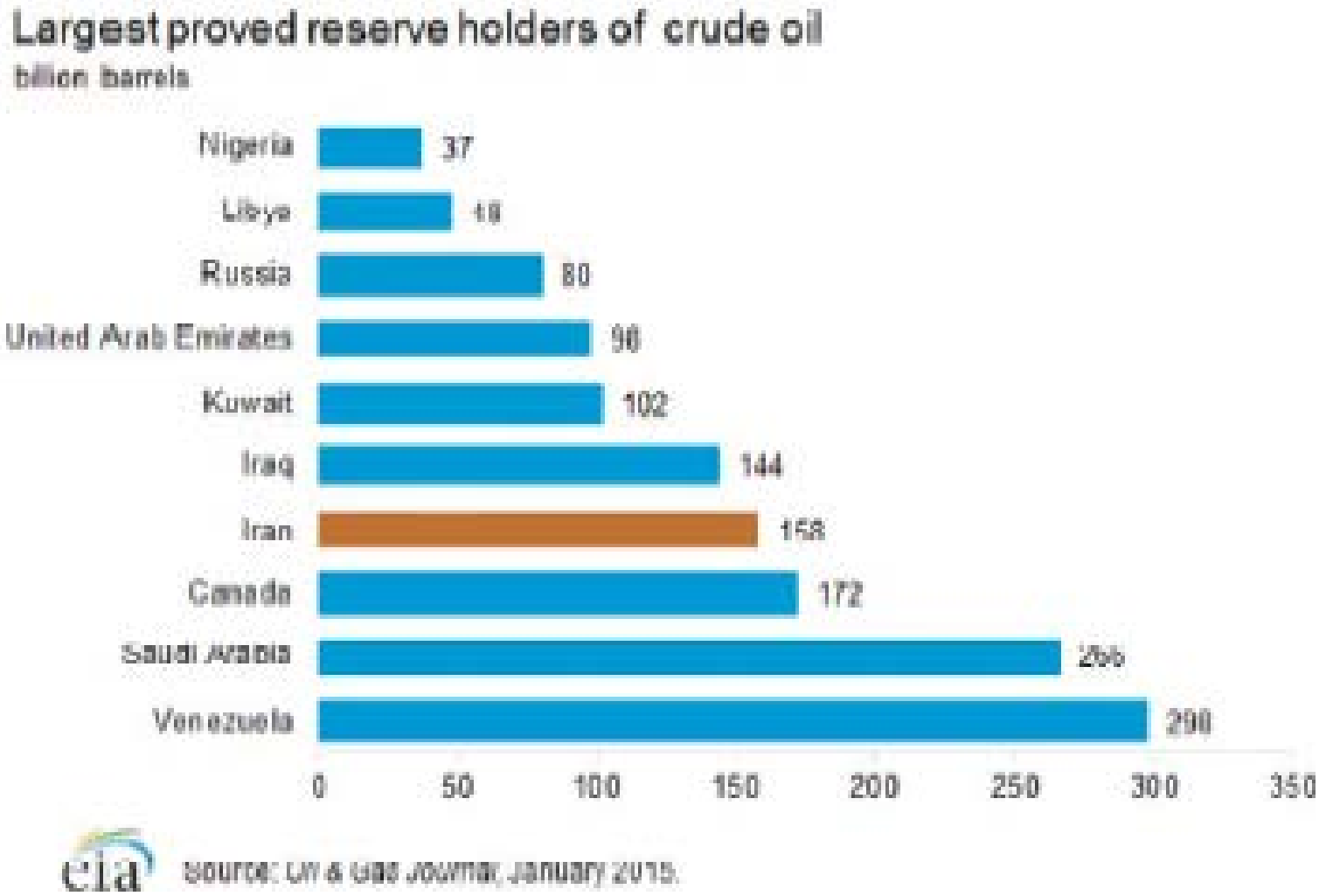
	Onshore Mid-East	Offshore Shelf	Extra Heavy	Deepwater	Onshore Russia	Onshore ROW	Ultra Deep Water	NAM Shale	Canada Oil Sands
Dec-14	29	43	49	53	54	55	57	62	74
Aug-15	14	30	46	48	45	47	49	61	69
Reduction	52%	30%	6%	9%	17%	15%	14%	2%	7%



Source: Rystad Energy UCube August 2015, Evercore ISI Energy Research
Note: The breakeven price is the Brent oil price that yields an NPV of zero given a real discount rate of 7.5%. The boxes are an average of all fields within each category (producing, under development, and discoveries).

Source: Rystad Energy UCube through Offshore January 2016

Largest Proven Crude Oil Reserves



OPEC Net Oil Export Revenue

OPEC net oil export revenues

	Nominal (billion $)					Real (billion 2015$)				
Country	2014	2015	2016	2017	Jan-May 2016	2014	2015	2016	2017	Jan-May 2016
Algeria	$48	$24	--	--	$7	$48	$24	--	--	$7
Angola	$23	$13	--	--	$4	$23	$13	--	--	$4
Ecuador	$10	$5	--	--	$2	$10	$5	--	--	$2
Indonesia	-$29	-$15	--	--	-$4	-$29	-$15	--	--	-$4
Iran	$47	$27	--	--	$11	$47	$27	--	--	$11
Iraq	$89	$57	--	--	$19	$89	$57	--	--	$18
Kuwait	$80	$40	--	--	$11	$80	$40	--	--	$11
Libya	$9	$4	--	--	$1	$9	$4	--	--	$1
Nigeria	$78	$39	--	--	$10	$78	$39	--	--	$10
Qatar	$38	$20	--	--	$6	$38	$20	--	--	$6
Saudi Arabia	$247	$130	--	--	$39	$247	$130	--	--	$39
UAE	$53	$29	--	--	$8	$53	$29	--	--	$8
Venezuela	$58	$32	--	--	$9	$58	$32	--	--	$9
OPEC	$753	$404	$341	$427	$121	$754	$404	$338	$415	$120

View nominal or real data (2005-17)
Note: Iranian net oil export revenues do not account for any discounts Iran may have offered its oil customers between end-2011 and January 2016.
Source: U.S. Energy Information Administration, derived from EIA's June 2016 Short-Term Energy Outlook.

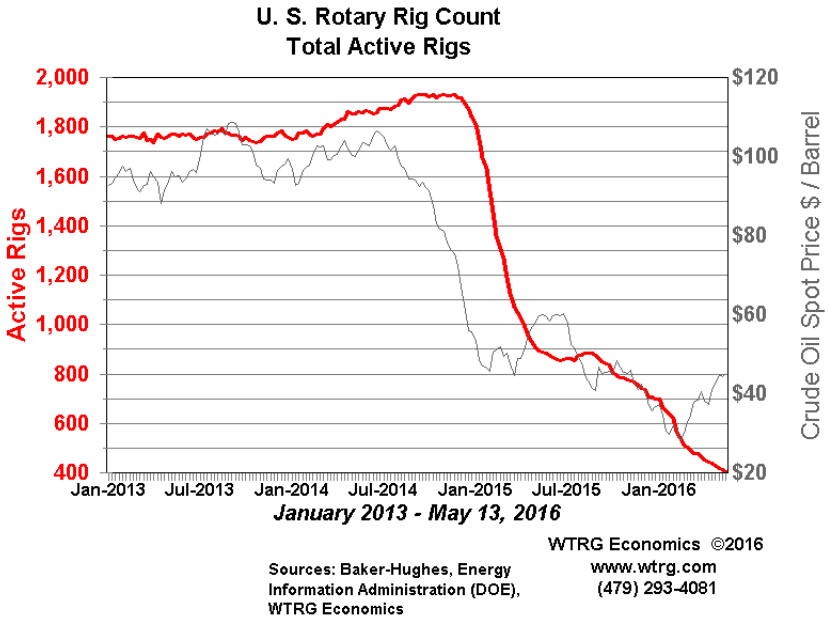
OPEC per Capita Export Revenue

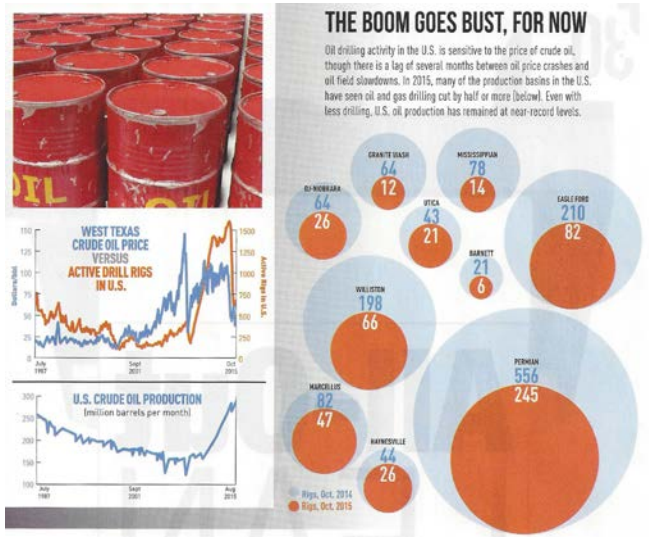
OPEC per capita net oil export revenues

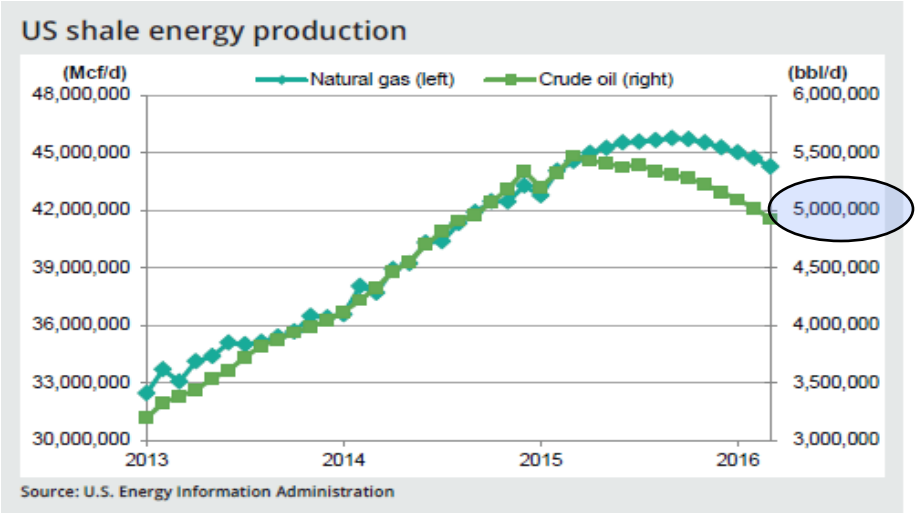
	Nominal (billion $)					Real (billion 2015$)				
Country	2014	2015	2016	2017	Jan-May 2016	2014	2015	2016	2017	Jan-May 2016
Algeria	$1,331	$652	--	--	$184	$1,332	$652	--	--	$183
Angola	$1,646	$898	--	--	$263	$1,648	$898	--	--	$261
Ecuador	$693	$338	--	--	$103	$694	$338	--	--	$103
Indonesia	-$116	-$59	--	--	-$17	-$116	-$59	--	--	-$17
Iran	$679	$384	--	--	$153	$680	$384	--	--	$152
Iraq	$2,740	$1,718	--	--	$547	$2,743	$1,718	--	--	$542
Kuwait	$25,297	$12,133	--	--	$3,327	$25,327	$12,133	--	--	$3,299
Libya	$1,253	$517	--	--	$84	$1,254	$517	--	--	$83
Nigeria	$492	$240	--	--	$62	$492	$240	--	--	$62
Qatar	$36,812	$18,658	--	--	$5,430	$36,855	$18,658	--	--	$5,384
Saudi Arabia	$7,925	$4,125	--	--	$1,223	$7,934	$4,125	--	--	$1,212
UAE	$9,434	$4,940	--	--	$1,377	$9,445	$4,940	--	--	$1,366
Venezuela	$2,016	$1,088	--	--	$307	$2,019	$1,088	--	--	$304
OPEC	$1,146	$606	$503	$621	$180	$1,147	$606	$499	$603	$178

View nominal or real data (2005-2017)
Note: Iranian per capita net oil export revenues do not account for any discounts Iran may have offered its oil customers between end-2011 and January 2016.
Source: U.S. Energy Information Administration, derived from EIA's June 2016 Short-Term Energy Outlook.

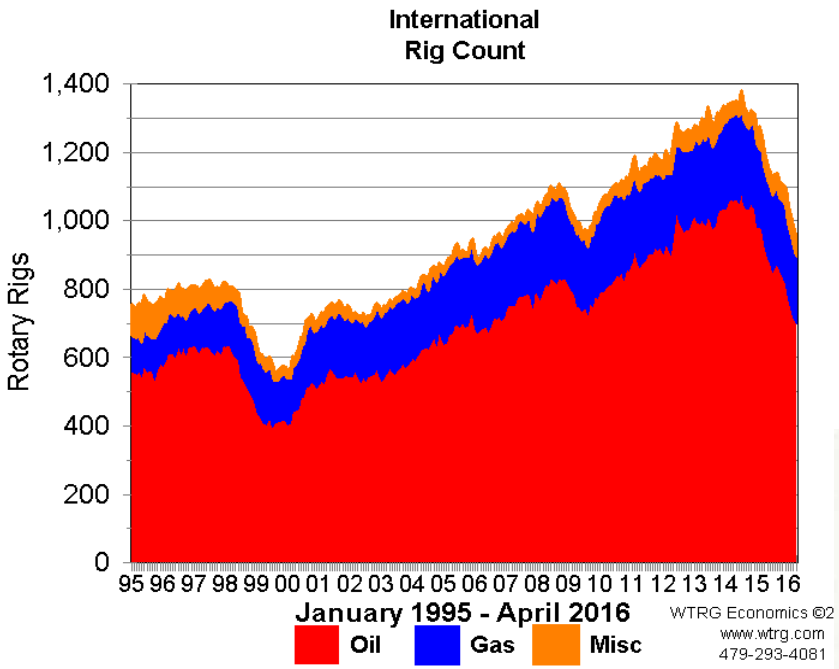
Rig Count

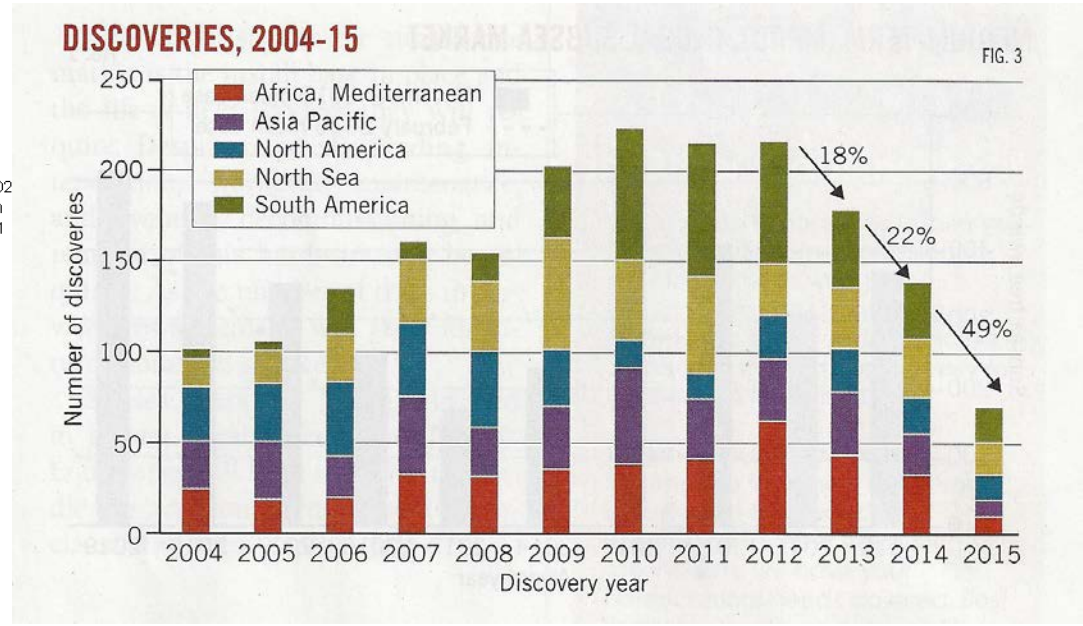

U. S. Rotary Rig Count
Total Active Rigs
Active Rigs
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
$120
$100
$80
$60
$40
$20
Crude Oil Spot Price $ / Barrel
Jan-2013
Jul-2013
Jan-2014
Jul-2014
Jan-2015
Jul-2015
Jan-2016
January 2013 - May 13, 2016
WTRG Economics ©2016
www.wtrg.com
(479) 293-4081
Sources: Baker-Hughes, Energy Information Administration (DOE), WTRG Economics


THE BOOM GOES BUST, FOR NOW
Oil drilling activity in the U.S. is sensitive to the price of crude oil, though there is a lag of several months between oil price crashes and oil field slowdowns. In 2015, many of the production basins in the U.S. have seen oil and gas drilling cut by half or more (below). Even with less drilling, U.S. oil production has remained at near-record levels.
WEST TEXAS CRUDE OIL PRICE VERSUS ACTIVE DRILL RIGS IN U.S.
U.S. CRUDE OIL PRODUCTION
(million barrels per month)
GRANITE WASH 64 12
MISSISSIPPIAN 78 14
DJ-NIOBRARA 64 26
UTICA 43 21
EAGLE FORD 210 82
BARNETT 21 6
WILLISTON 198 66
PERMIAN 556 245
MARCELLUS 82 47
HAYNESVILLE 44 26


US shale energy production
(Mcf/d)
(bbl/d)
Natural gas (left)
Crude oil (right)
48,000,000
45,000,000
42,000,000
39,000,000
36,000,000
33,000,000
30,000,000
6,000,000
5,500,000
5,000,000
4,500,000
4,000,000
3,500,000
3,000,000
2013
2014
2015
2016
Source: U.S. Energy Information Administration

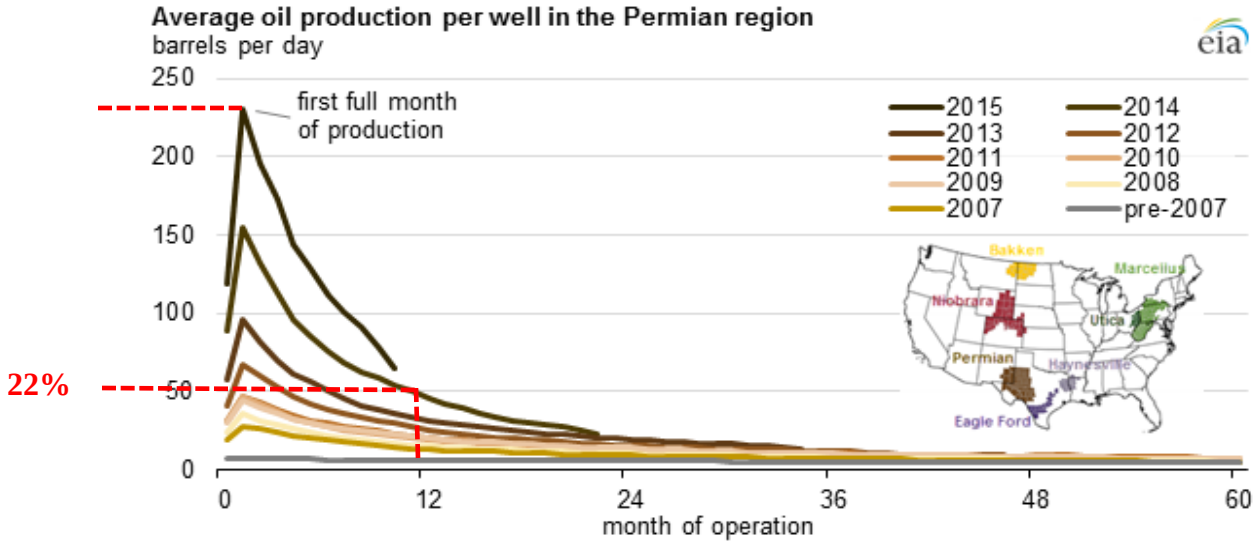
Discoveries

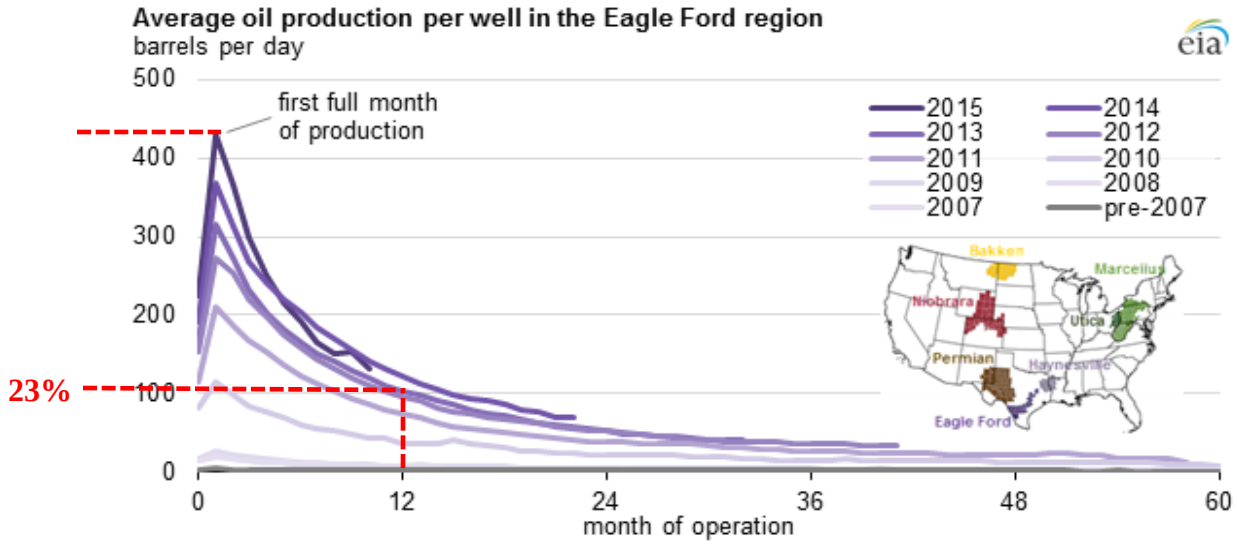




Source: Hydrocarbon Processing February 2016

Production Well Decline Rate





World Oil Choke Points

Table 1. Volume of crude oil and petroleum products transported through world chokepoints, 2009-13

Location	2009	2010	2011	2012	2013
Strait of Hormuz	15.7	15.9	17.0	16.9	17.0
Strait of Malacca	13.5	14.5	14.6	15.1	15.2
Suez Canal and SUMED Pipeline	3.0	3.1	3.8	4.5	4.6
Bab el-Mandab	2.9	2.7	3.4	3.7	3.8
Danish Straits	3.0	3.2	3.3	3.1	3.3
Turkish Straits	2.8	2.8	3.0	2.9	2.9
Panama Canal	0.8	0.7	0.8	0.8	0.8
World maritime oil trade	53.9	55.5	55.6	56.7	56.5
World total oil supply	84.9	87.5	87.8	89.7	90.1

- 36% of World Oil Supply
- 57% of World Maritime Oil Trade

Figure 2. Map of the Strait of Hormuz

Source: U.S. Government (See full map for alternate routes)

Figure 3. Map of the Strait of Malacca

Source: CIA Factbook (See closer view of Strait of Malacca)

Coal Consumption – 3839.9 Mtoe

- Coal consumption declined by 1.8% in 2015
- India grew by 10.6%
- China declined by 1.5%
- 100+ years worldwide reserves (275 U.S.)

Coal: Consumption*

Million tonnes oil equivalent	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**2015**	Change 2015 over 2014	2015 share of total
US	574.5	565.7	573.3	564.2	496.2	525.0	495.4	437.9	454.6	453.8	**396.3**	-12.7%	10.3%
Total North America	**616.9**	**608.1**	**615.8**	**604.5**	**530.7**	**563.0**	**532.3**	**472.0**	**488.1**	**487.9**	**429.0**	**-12.1%**	**11.2%**
Total S. & Cent. America	**21.0**	**24.5**	**25.7**	**28.6**	**23.7**	**28.7**	**30.6**	**32.1**	**34.8**	**36.7**	**37.1**	**1.2%**	**1.0%**
Czech Republic	20.2	21.0	21.4	19.7	17.6	18.4	18.1	17.2	16.4	15.9	**15.6**	-2.0%	0.4%
Germany	81.3	84.5	86.7	80.1	71.7	77.1	78.3	80.5	82.8	78.8	**78.3**	-0.6%	2.0%
Kazakhstan	26.9	28.3	31.1	33.8	30.9	33.4	36.3	36.5	36.3	35.5	**32.6**	-8.3%	0.8%
Poland	55.1	57.4	55.9	55.2	51.8	55.1	55.0	51.2	53.4	49.4	**49.8**	0.7%	1.3%
Russian Federation	94.6	97.0	93.9	100.7	92.2	90.5	94.0	98.4	90.5	87.6	**88.7**	1.3%	2.3%
Spain	20.5	17.9	20.0	13.5	9.4	6.9	12.8	15.5	11.4	11.6	**14.4**	23.9%	0.4%
Turkey	22.5	26.6	29.5	29.6	30.9	31.4	33.9	36.5	31.6	36.1	**34.4**	-4.7%	0.9%
Ukraine	37.5	39.8	39.8	41.8	35.9	38.3	41.5	42.5	41.6	35.6	**29.2**	-18.0%	0.8%
United Kingdom	37.4	40.9	38.4	35.6	29.8	30.9	31.4	39.0	37.1	29.9	**23.4**	-21.6%	0.6%
Other Europe & Eurasia	20.7	21.2	21.8	22.4	21.4	22.5	24.6	22.9	23.8	22.0	**23.4**	6.3%	0.6%
Total Europe & Eurasia	**514.9**	**536.3**	**540.2**	**528.0**	**475.4**	**491.6**	**514.1**	**527.4**	**507.2**	**481.0**	**467.9**	**-2.7%**	**12.2%**
Total Middle East	**9.8**	**9.8**	**9.9**	**9.7**	**9.9**	**10.1**	**11.1**	**12.3**	**10.8**	**10.7**	**10.5**	**-1.7%**	**0.3%**
South Africa	80.1	81.5	83.6	93.3	93.8	92.8	90.4	88.3	88.9	90.1	**85.0**	-5.6%	2.2%
Total Africa	**89.4**	**90.6**	**92.0**	**101.4**	**100.8**	**100.4**	**98.5**	**95.8**	**97.8**	**102.4**	**96.9**	**-5.4%**	**2.5%**
Australia	53.9	56.6	54.9	55.4	53.4	50.6	50.2	47.3	45.0	44.7	**46.6**	4.3%	1.2%
China	1318.2	1448.4	1576.9	1603.1	1680.4	1743.4	1899.0	1923.0	1964.4	1949.3	**1920.4**	-1.5%	50.0%
India	211.3	219.4	240.1	259.4	282.8	292.9	300.4	330.0	355.6	388.7	**407.2**	4.8%	10.6%
Indonesia	24.4	28.9	36.2	31.5	33.2	39.5	46.9	53.0	57.6	69.8	**80.3**	15.0%	2.1%
Japan	114.0	112.3	117.7	120.3	101.6	115.7	109.6	115.8	120.7	118.7	**119.4**	0.6%	3.1%
Malaysia	6.9	7.3	8.8	9.8	10.6	14.8	14.8	15.9	15.1	15.4	**17.6**	14.8%	0.5%
South Korea	54.8	54.8	59.7	66.1	68.6	75.9	83.6	81.0	81.9	84.6	**84.5**	-0.2%	2.2%
Taiw an	35.3	37.0	38.8	37.0	35.2	37.6	38.9	38.0	38.6	39.0	**37.8**	-3.1%	1.0%
Thailand	11.6	12.4	13.9	15.1	15.1	15.5	15.8	16.4	15.8	17.9	**17.6**	-1.8%	0.5%
Vietnam	9.0	5.3	5.8	11.4	10.7	14.0	16.5	15.0	15.8	19.3	**22.2**	15.4%	0.6%
Total Asia Pacific	**1878.6**	**2022.9**	**2192.3**	**2251.7**	**2333.2**	**2440.4**	**2613.5**	**2674.8**	**2752.0**	**2792.5**	**2798.5**	**0.2%**	**72.9%**
Total World	**3130.6**	**3292.2**	**3476.0**	**3523.9**	**3473.6**	**3634.3**	**3800.0**	**3814.4**	**3890.7**	**3911.2**	**3839.9**	**-1.8%**	**100.0%**

China 50.0%

Asia 72.9%

base e

"Practical Strategies for Emerging Energy Technologies"

Source: BP Statistical Review of World Energy 2016

Coal Company Bankruptcies

Largest mines owned by companies recently in bankruptcy

Mine name*	Ultimate owner	Coal produced (tons) 2015	Q4'14	Q4'15
North Antelope Rochelle	Peabody Energy Corp.	109,343,913	30,671,497	28,153,722
Black Thunder	Arch Coal Inc.	99,450,689	26,506,223	22,502,481
Eagle Butte	Alpha Natural Resources Inc.	19,649,723	5,210,041	4,873,247
Belle Ayr	Alpha Natural Resources Inc.	18,318,629	4,625,701	3,775,390
Rawhide	Peabody Energy Corp.	15,167,996	3,959,328	3,784,091
Caballo	Peabody Energy Corp.	11,402,062	2,239,334	2,794,723
Bear Run	Peabody Energy Corp.	7,878,025	2,145,839	1,739,479
Coal Creek	Arch Coal Inc.	7,840,491	2,412,109	2,200,692
Cumberland	Alpha Natural Resources Inc.	7,490,061	2,008,118	2,086,848
El Segundo	Peabody Energy Corp.	7,476,237	2,173,207	1,866,494
Kayenta	Peabody Energy Corp.	6,804,555	2,071,901	1,375,829
Lively Grove	Multi-owned1	5,953,533	1,187,294	1,281,696
West Elk	Arch Coal Inc.	5,074,821	1,668,373	854,076
Foidel Creek	Peabody Energy Corp.	4,122,448	1,200,546	1,186,340
Leer	Arch Coal Inc.	3,383,885	898,667	655,893
Prairie Eagle - Underground	Arch Coal Inc.; CBR Investments LLC	3,353,038	879,050	769,690
No. 7	Walter Energy	3,035,681	1,110,442	362,666
Francisco Underground Pit	Peabody Energy Corp.	2,935,577	810,675	704,954
No. 4	Walter Energy	2,416,556	720,849	316,649
Coal-Mac Inc. Holden No. 22 Surface	Arch Coal Inc.	2,259,286	628,888	504,244
Viper	Arch Coal Inc.	2,155,473	467,453	491,455
Somerville Central	Peabody Energy Corp.	2,143,884	470,800	490,245
Wild Boar	Peabody Energy Corp.	2,041,888	544,416	509,813
Wildcat Hills - Underground	Peabody Energy Corp.	2,026,081	538,322	447,865
Mountaineer II	Arch Coal Inc.	1,923,968	560,493	373,767

As of March 1, 2016.

Source: SNL April 13, 2016

- **44.3% of the coal produced in the U.S. came from a company that has filed for bankruptcy court protection since 2012.**
- More than 69% of the coal produced in the Powder River Basin came from coal companies recently filing bankruptcy.
- Three of every four tons mined in Wyoming came from a coal company on the bankruptcy list.
- 28.9% of coal from the Illinois Basin comes from a coal company recently filing for bankruptcy court protections.

Q4'15 coal production by major coal basins

Coal basin	Coal produced (tons) Total	From mines of companies recently in bankruptcy*	% production from companies recently in bankruptcy*
Powder River Basin	98,013,293	68,084,346	69.46
Illinois Basin	26,410,510	7,628,394	28.88
Northern Appalachia	27,356,159	3,772,808	13.79
Central Appalachia	18,699,925	6,364,752	34.04
Entire U.S.	207,355,826	91,946,261	44.34

As of March 1, 2016.
Includes coal production for bankrupt coal companies as operator, owner and ultimate owner of mines that have filed bankruptcy since 2012.
* Mines in bankruptcy are defined as mines owned by companies in bankruptcy since 2012 as tracked by S&P Global Market Intelligence compared to ownership and production data from the U.S. Mine Safety and Health Administration as of the end of the fourth quarter of 2015. Some mines may have since been transferred to solvent companies and some companies may have since emerged from bankruptcy.
Source: S&P Global Market Intelligence

Natural Gas Prices ($/mmBtu) – March 2013

Demand:

Japan

- Fukushima = Japan 36% WW LNG
- Oil-price-linked formula

China

- Demand Growth
- Oil-price-linked formula

Europe

- Concern over Russian dependency
- Oil-price-linked formula
- UK declining indigenous supply

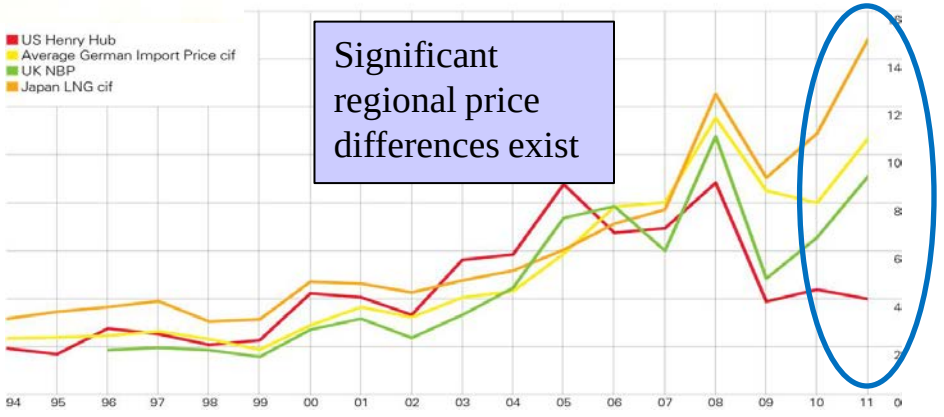
Supply:

North America

- Significant shale resource
- Significant associated gas production

Australia & East Africa

- Project cost/timing uncertainties



Significant regional price differences exist

LNG Projected Capacity & Demand

907.87 BCM

430 MMtpy @
456 kg/m3 & 600:1 as a gas
565.78 BCM

250 MMtpy @
456 kg/m3 & 600:1 as a gas
328.94 BCM

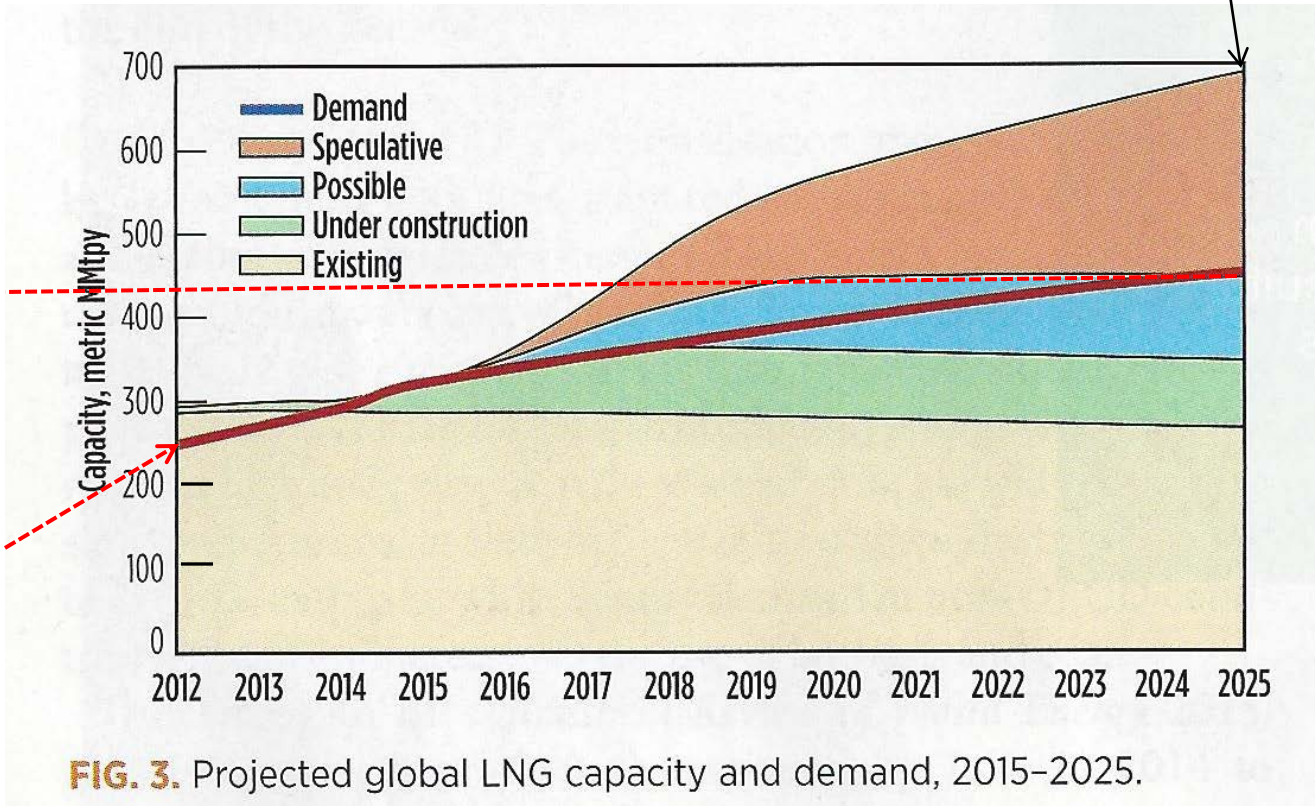
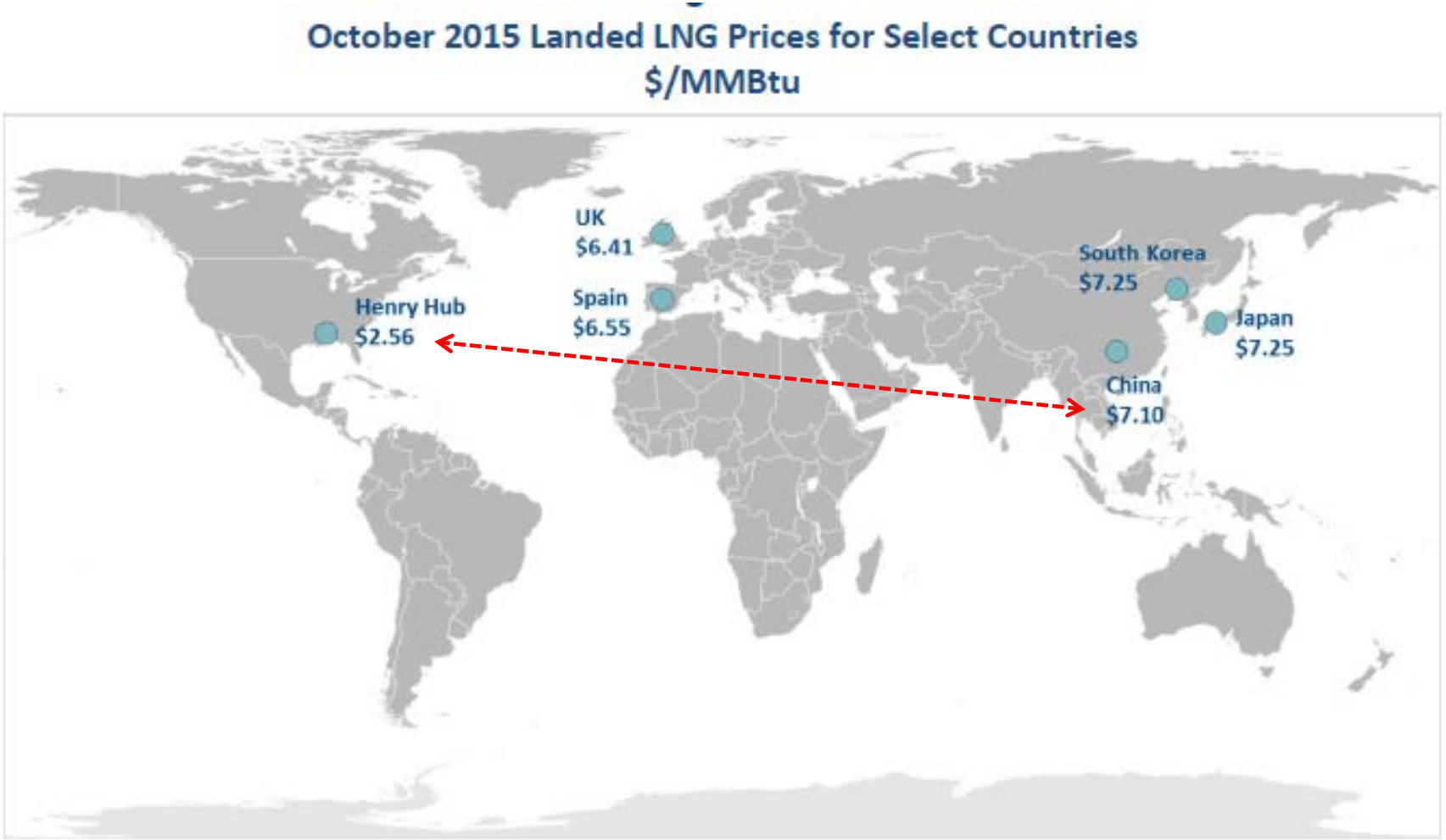


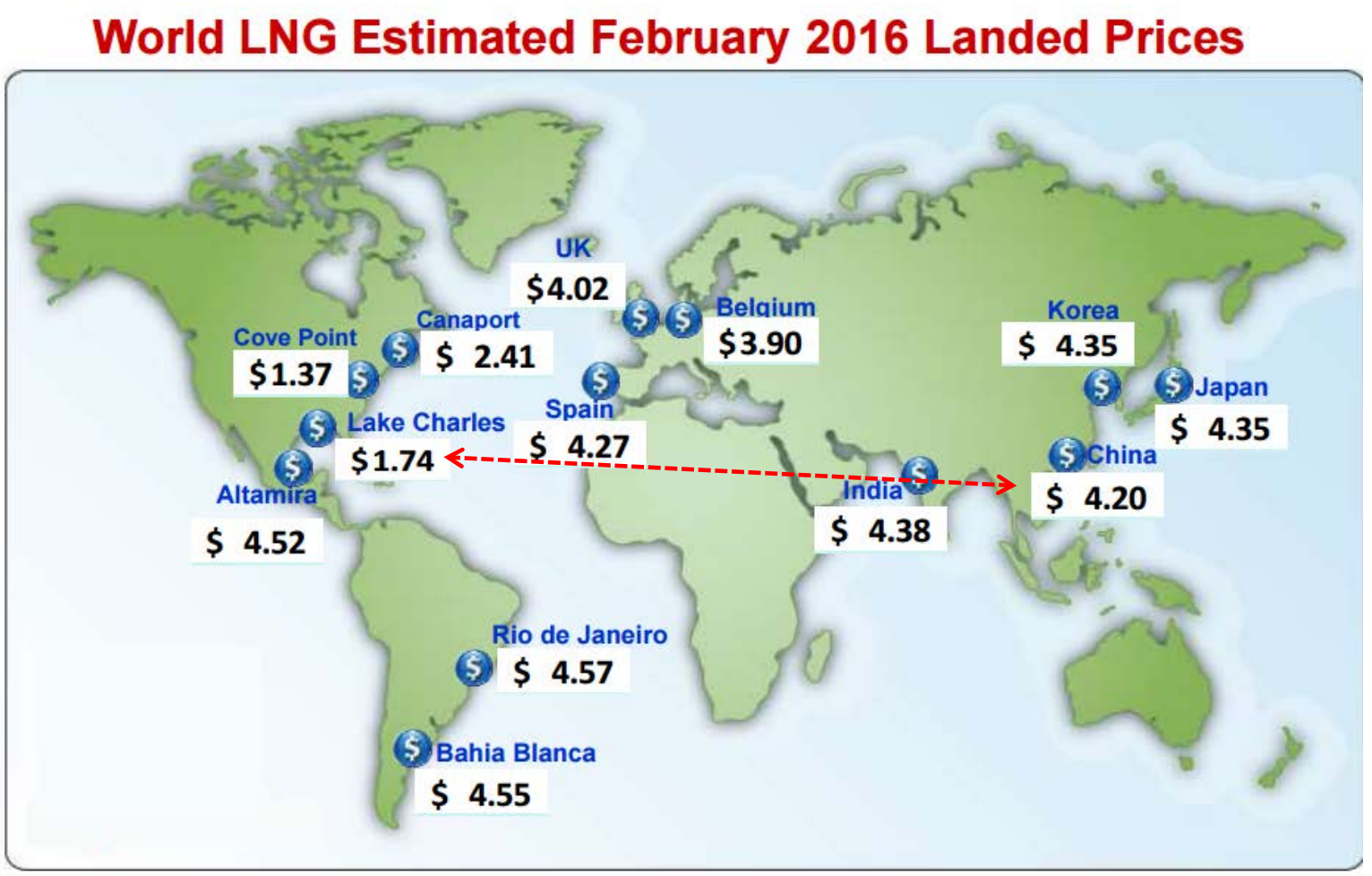
FIG. 3. Projected global LNG capacity and demand, 2015–2025.

Source: Hydrocarbon Processing December 2015

LNG Landed Prices - October 2015



LNG Landed Prices - April 2016



Source: *Waterborne Energy, Inc.* Data in $US/MMBtu. Landed prices are based on a netback calculation.
Note: Includes information and Data supplied by IHS Global Inc. and its affiliates ("IHS"); Copyright (publication year) all rights reserved.
Prices are the monthly average of the weekly landed prices for the given month.

Updated: Apr-16

Recoverable Shale Resources - 2013

Table 5. Top 10 countries with technically recoverable shale oil resources

Rank	Country	Shale oil (billion barrels)	
1	Russia	75	
2	U.S.[1]	58	(48)
3	China	32	
4	Argentina	27	
5	Libya	26	
6	Venezuela	13	
7	Mexico	13	
8	Pakistan	9	
9	Canada	9	
10	Indonesia	8	
	World Total	345	(335)

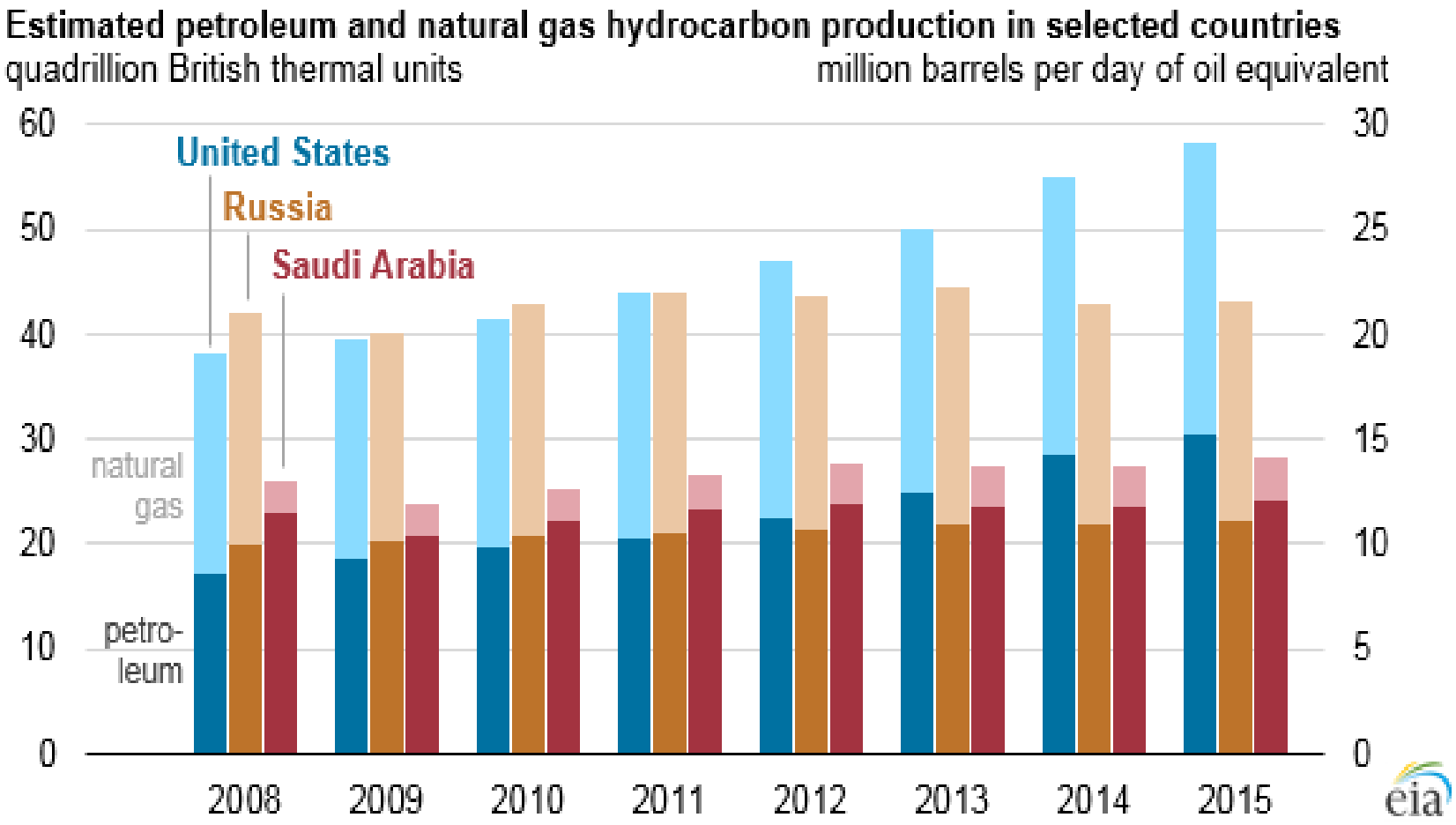
[1] EIA estimates used for ranking order. ARI estimates in parentheses.

Table 6. Top 10 countries with technically recoverable shale gas resources

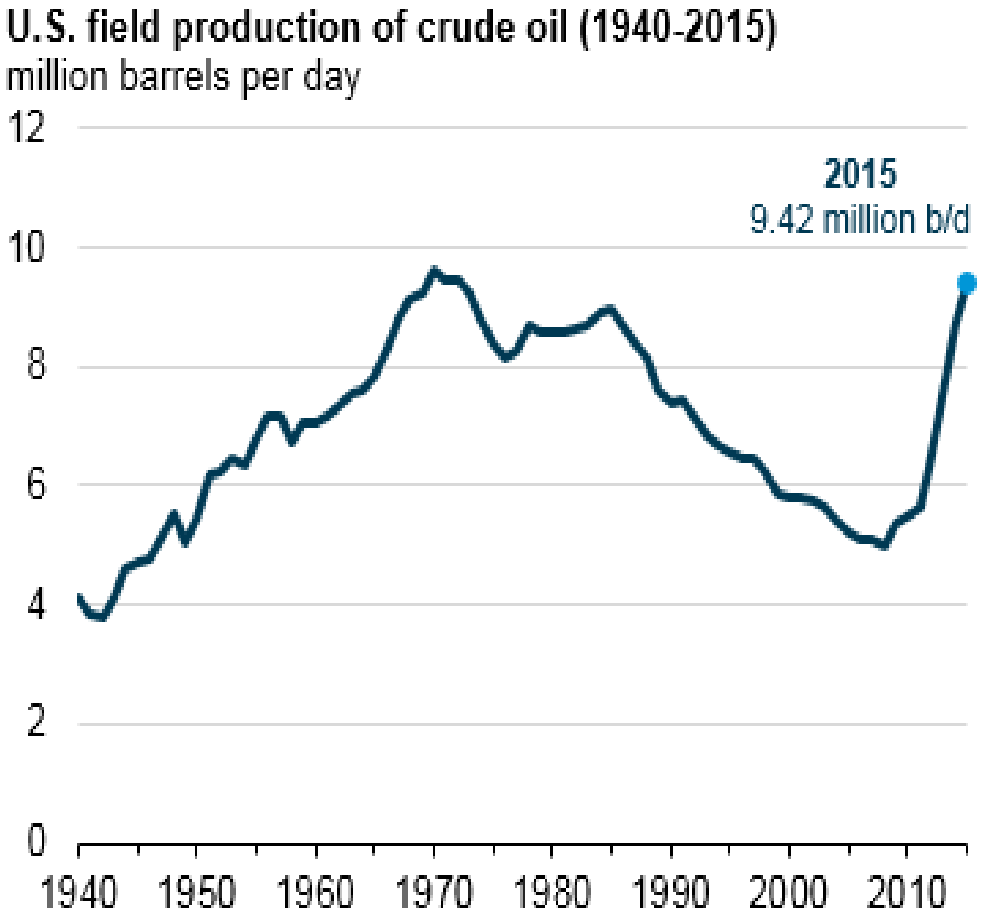
Rank	Country	Shale gas (trillion cubic feet)	
1	China	1,115	
2	Argentina	802	
3	Algeria	707	
4	U.S.[1]	665	(1,161)
5	Canada	573	
6	Mexico	545	
7	Australia	437	
8	South Africa	390	
9	Russia	285	
10	Brazil	245	
	World Total	7,299	(7,795)

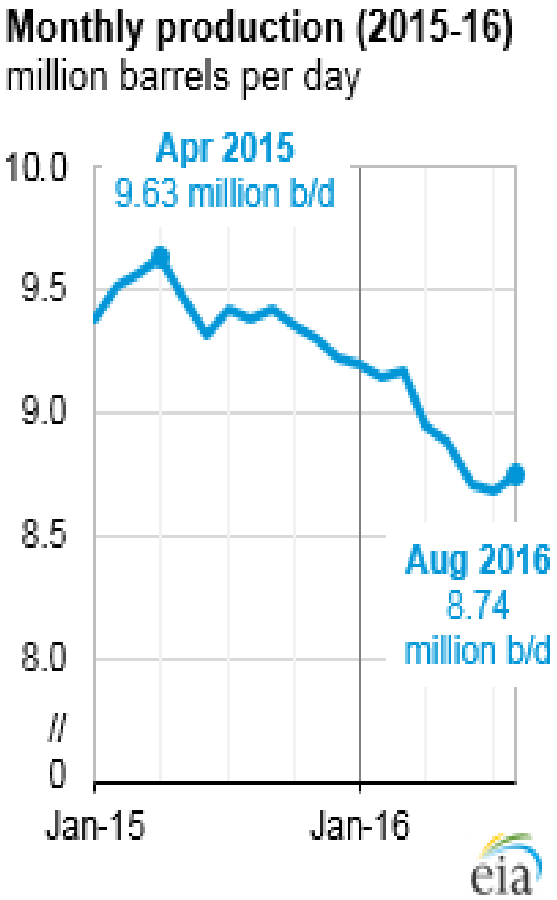
[1] EIA estimates used for ranking order. ARI estimates in parentheses.

U.S. Remains Largest Producer of O&G Hydrocarbons

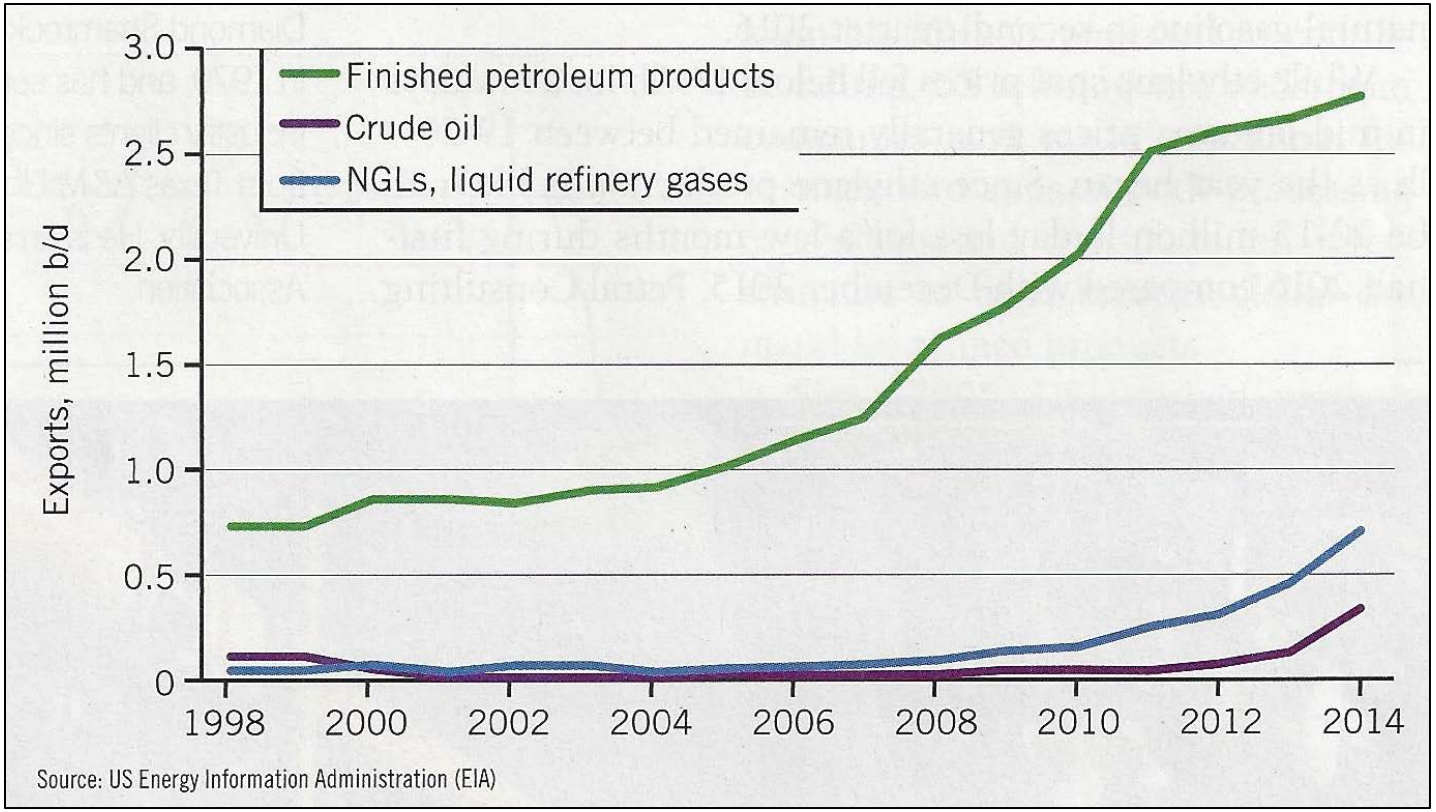


U.S. Crude Production





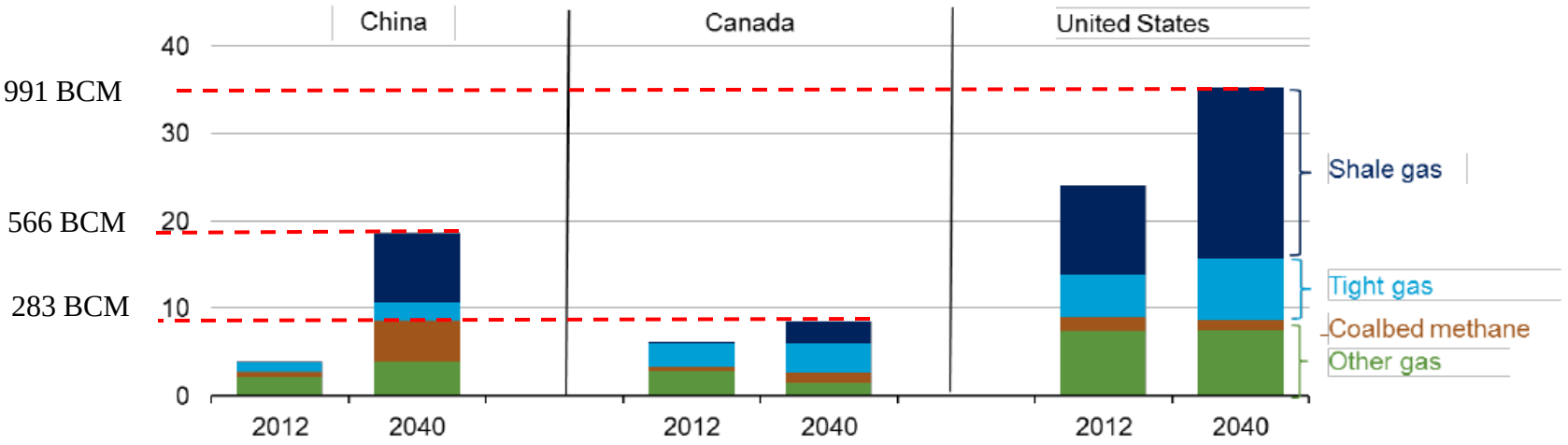
U.S. Petroleum Exports



Shale Gas, Tight Gas and Coalbed Methane

Shale gas, tight gas, and coalbed methane will become increasingly important to gas supplies, not only for the U.S., but also China and Canada

natural gas production by type
trillion cubic feet

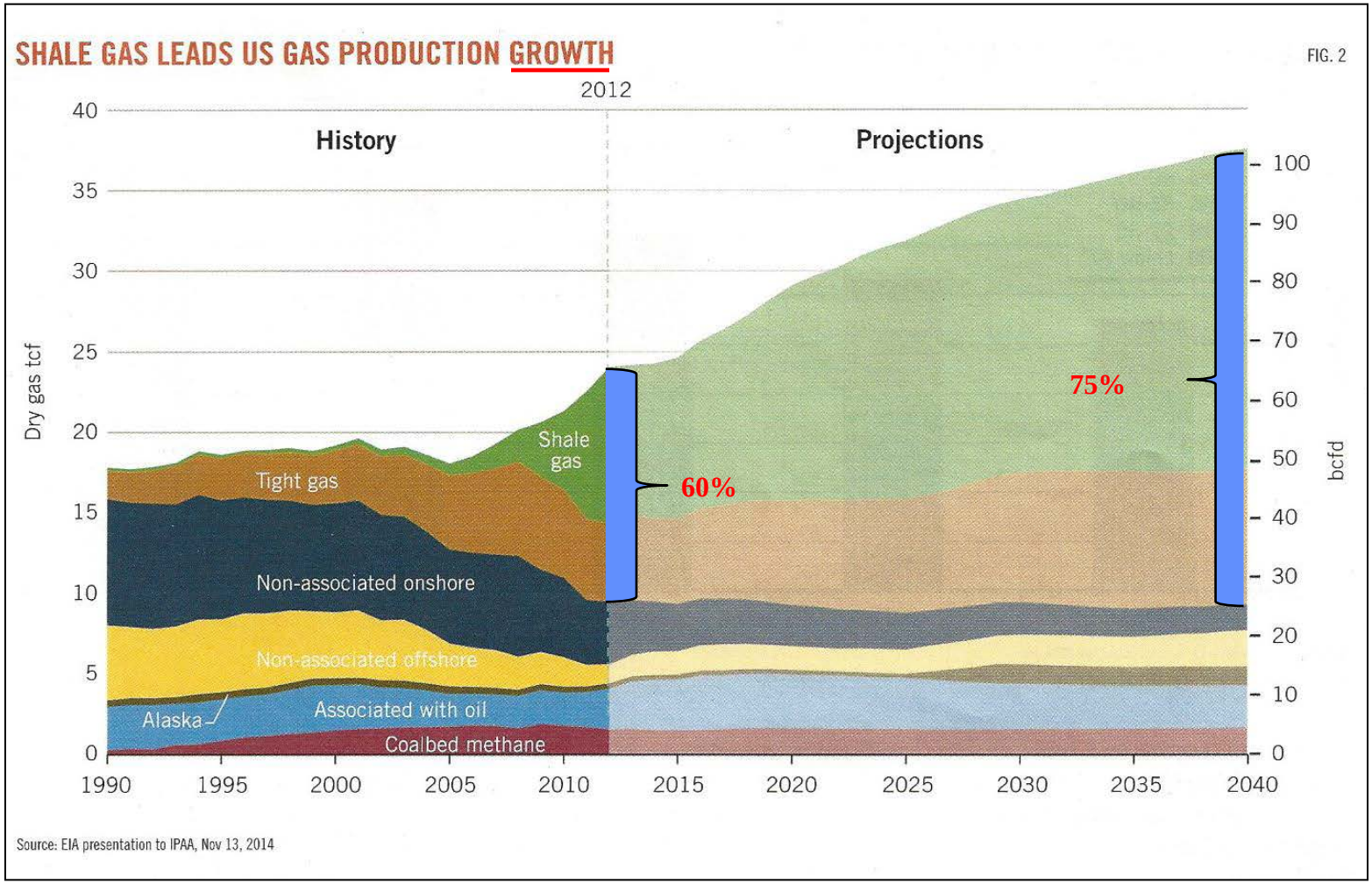


	China		Canada		United States	
Production	114 BCM	509 BCM	156 BCM	255 BCM	681 BCM	991 BCM

Note: Other natural gas includes natural gas produced from structural and stratigraphic traps (e.g. reservoirs), historically referred to as 'conventional' production.

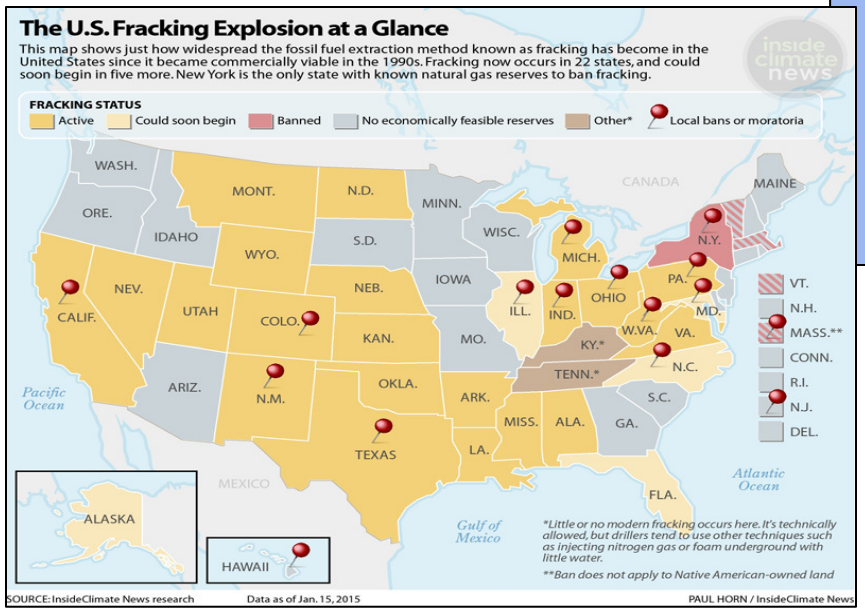
Source: EIA, International Energy Outlook 2016

Tight Gas & Shale Gas



Fracking

- Fracking Issues
  - Fracking fluids
  - Produced (waste) water disposal
  - Induced seismicity, aka “earthquakes”
- Requirements to succeed
  - Environmentally acceptable fracking fluids
  - Re-cycle waste water

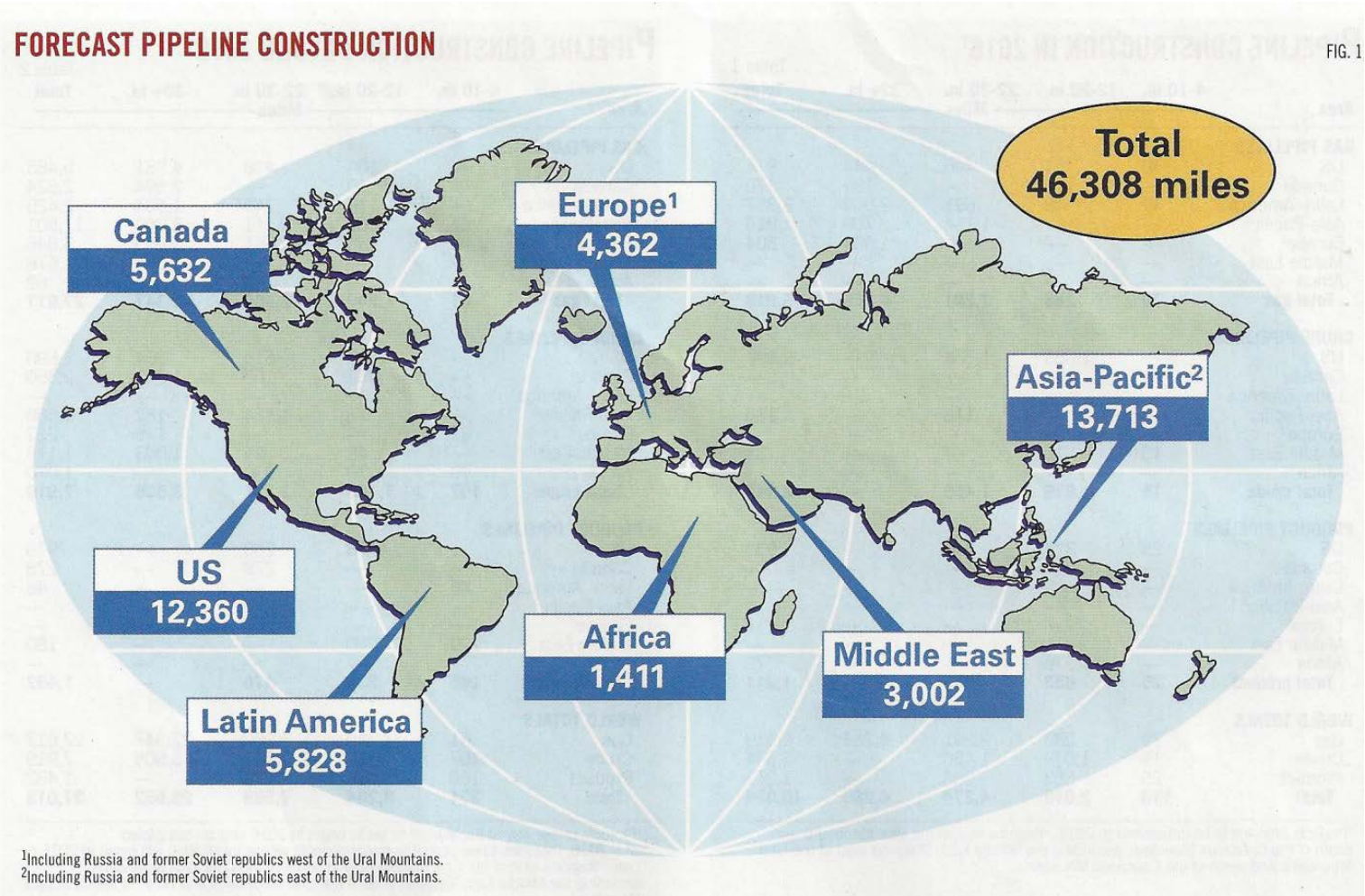


Flaring

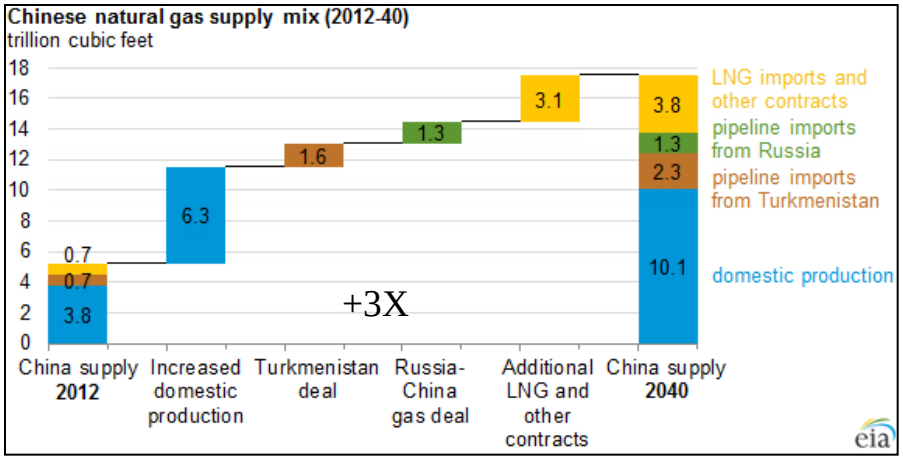
Figure 4: Development of associated gas production and gas flared in North Dakota in the last years. Source: NDIC and rbnenergy.com

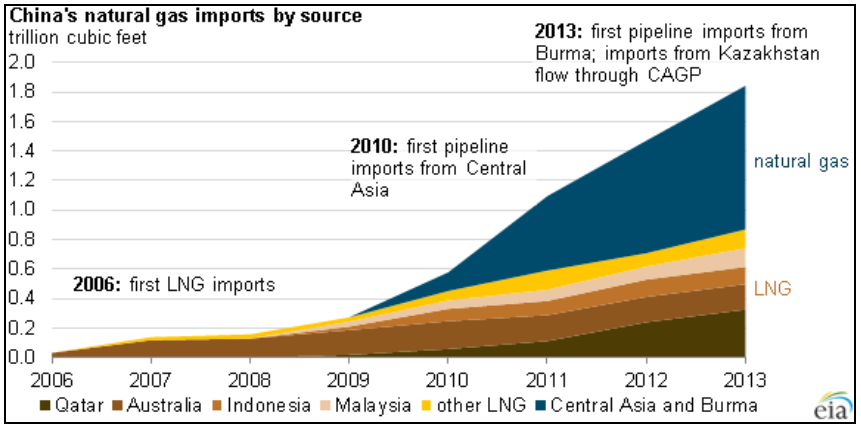
This is a big number

Pipeline Construction



China Natural Gas





Russian Gas - 607 BCM Production

44,600 BCM Reserves
Reserves/Production Ratio - 73.5

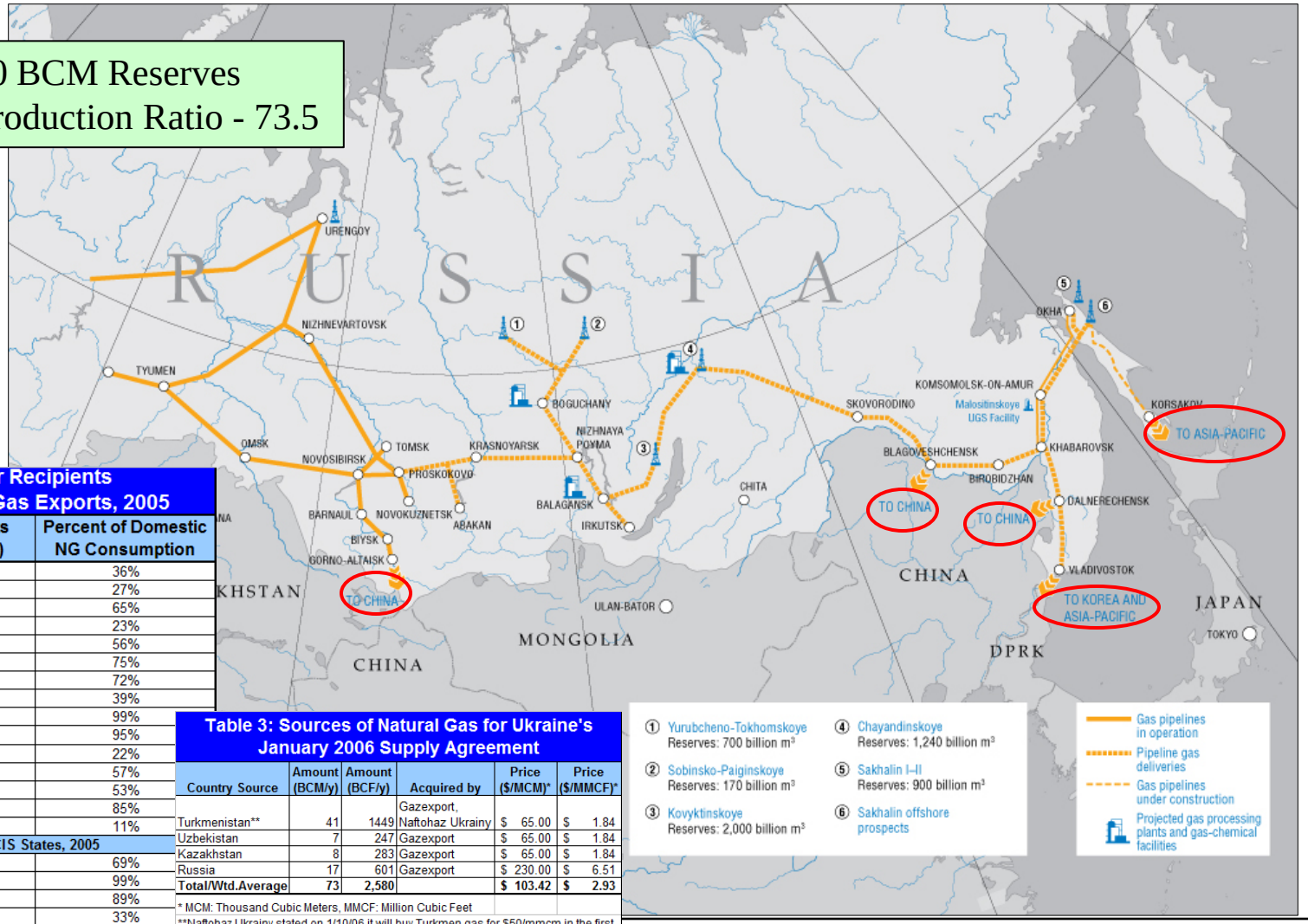


Table 2: Major Recipients of Russian Natural Gas Exports, 2005

Rank	Country	Imports (bcf/y)	Percent of Domestic NG Consumption
1	Germany	1,291	36%
2	Italy	824	27%
3	Turkey	630	65%
4	France	406	23%
5	Hungary	294	56%
6	Czech Republic	252	75%
7	Austria	246	72%
8	Poland	226	39%
9	Slovakia	226	99%
10	Finland	148	95%
11	Romania	140	22%
12	Fmr Yugoslavia	134	57%
13	Bulgaria	101	53%
14	Greece	85	85%
15	Switzerland	13	11%
	Sales to Baltic & CIS States, 2005		
	Ukraine	2,113	69%
	Belarus	710	99%
	Baltic States	205	89%
	Azerbaijan	120	33%
	Georgia	46	88%

Sources: Domestic Consumption: EIA International Energy Annual, 2005; Imports: Cedigaz 2006 and BP Statistical Review 2007.

Table 3: Sources of Natural Gas for Ukraine's January 2006 Supply Agreement

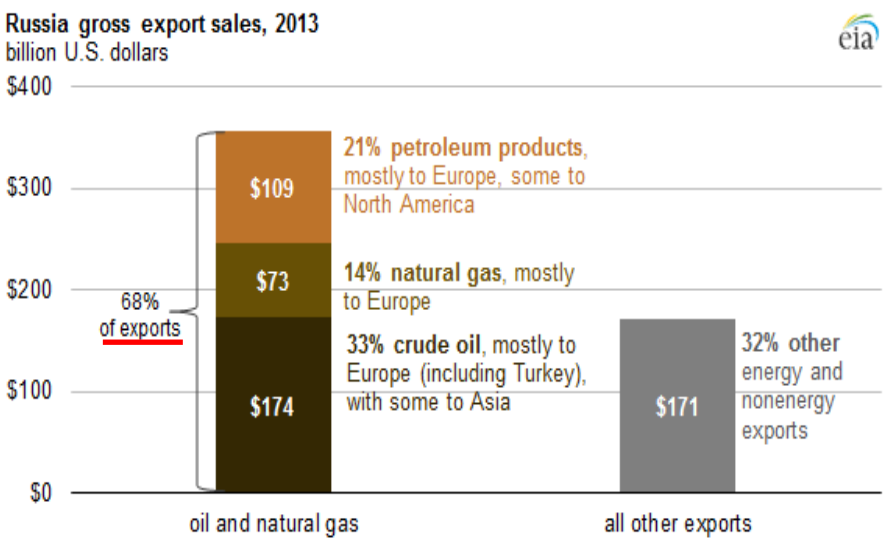
Country Source	Amount (BCM/y)	Amount (BCF/y)	Acquired by	Price ($/MCM)*	Price ($/MMCF)*
Turkmenistan**	41	1449	Gazexport, Naftohaz Ukrainy	$ 65.00	$ 1.84
Uzbekistan	7	247	Gazexport	$ 65.00	$ 1.84
Kazakhstan	8	283	Gazexport	$ 65.00	$ 1.84
Russia	17	601	Gazexport	$ 230.00	$ 6.51
Total/Wtd.Average	**73**	**2,580**		**$ 103.42**	**$ 2.93**

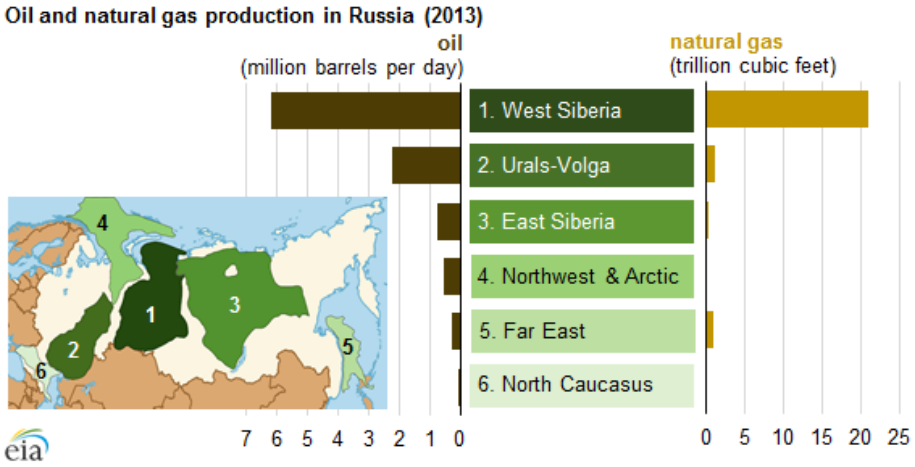
* MCM: Thousand Cubic Meters, MMCF: Million Cubic Feet

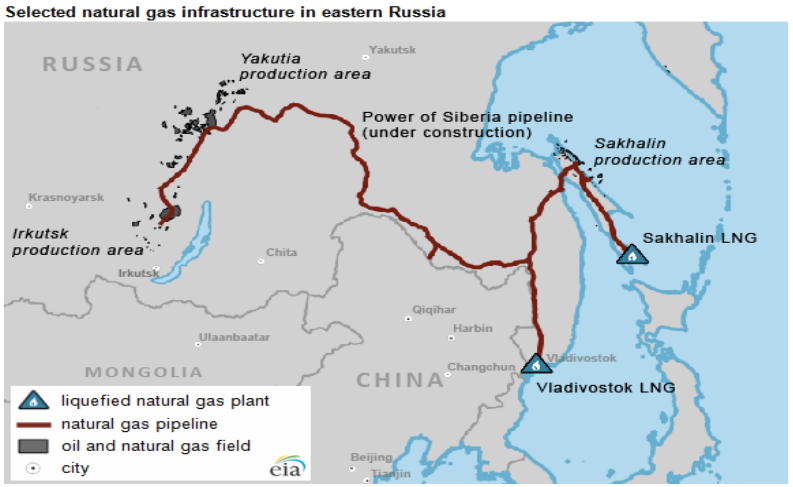
**Naftohaz Ukrainy stated on 1/10/06 it will buy Turkmen gas for $50/mmcm in the first half of 2006 and $60 during the second half, but the final agreement's price was higher. Using the lower price for Turkmen gas, the wtd. average price is $97.8/MCM.

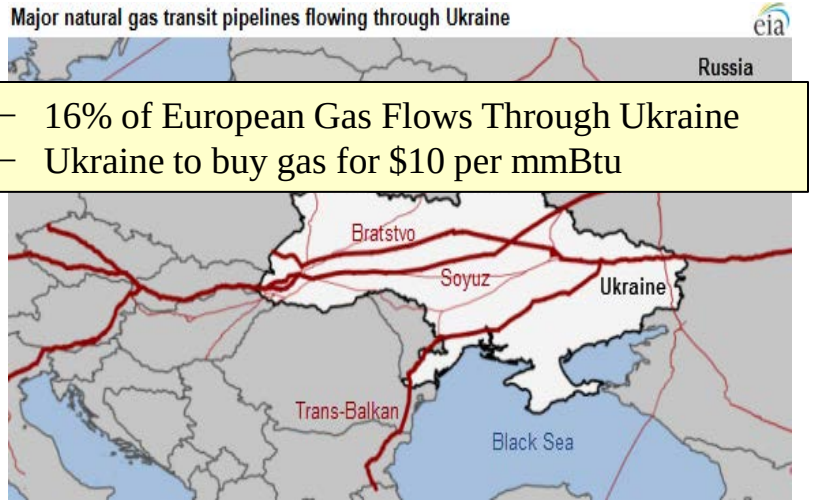
Source: Russian Energy Monthly, January 2006

Russia





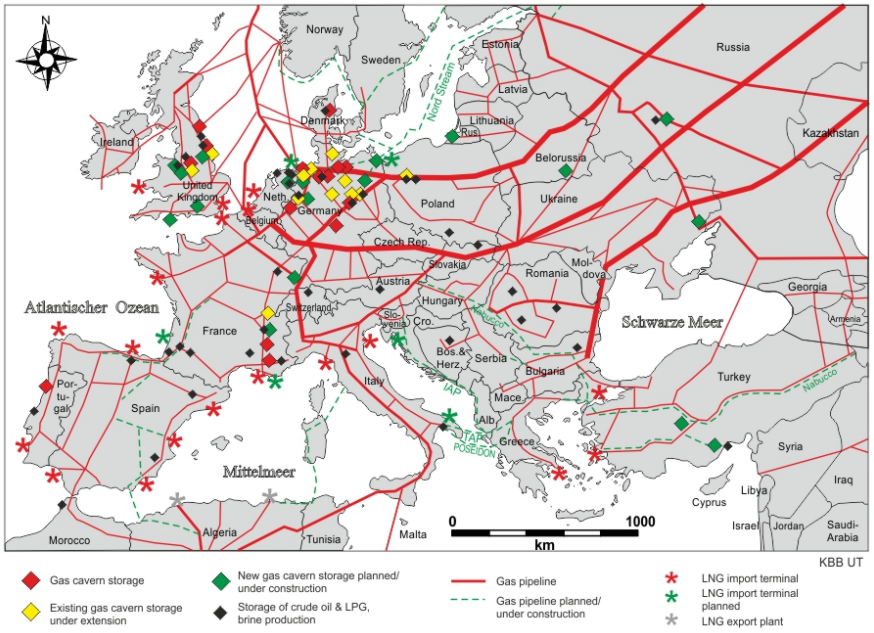




- 16% of European Gas Flows Through Ukraine
- Ukraine to buy gas for $10 per mmBtu

Gas to Europe - 1101 BCM Demand

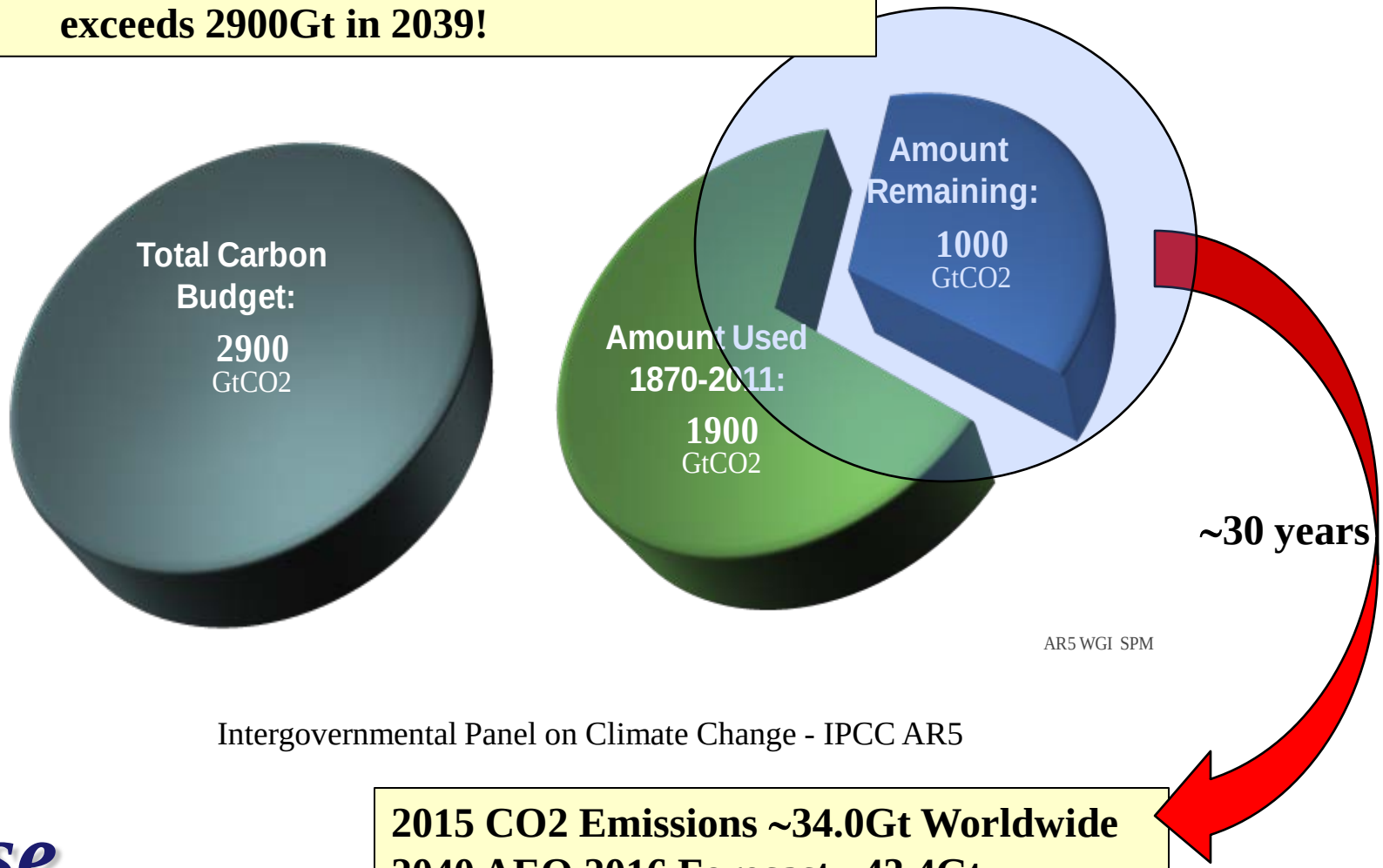
- Europe/Eurasia Pipeline Imports - 470 BCM
  - Russia 208
  - Norway 93
  - The Netherlands 50
  - Algeria 33
- Europe/Eurasia LNG Imports - 91 BCM
  - Qatar 43
  - Algeria 16
  - Nigeria 16



Demand Management

The CO_2 Budget – 65% Already Used

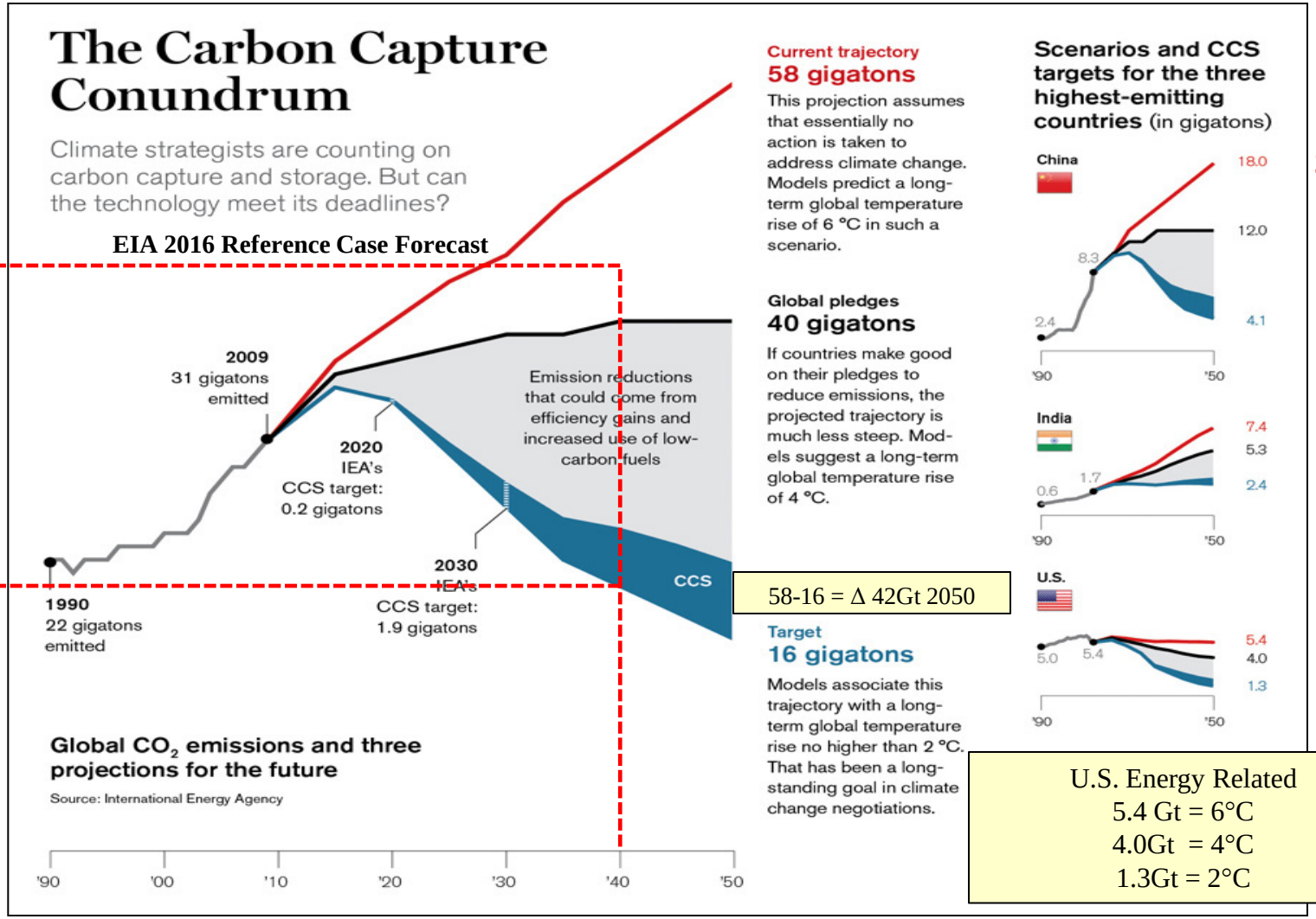
EIA 2016 Forecast with Clean Power Plan….
exceeds 2900Gt in 2039!



Intergovernmental Panel on Climate Change - IPCC AR5

2015 CO2 Emissions ~34.0Gt Worldwide
2040 AEO 2016 Forecast ~43.4Gt

The 2050 Carbon Conundrum Looking for 42Gt Δ



58-16 = Δ 42Gt 2050

31.0%

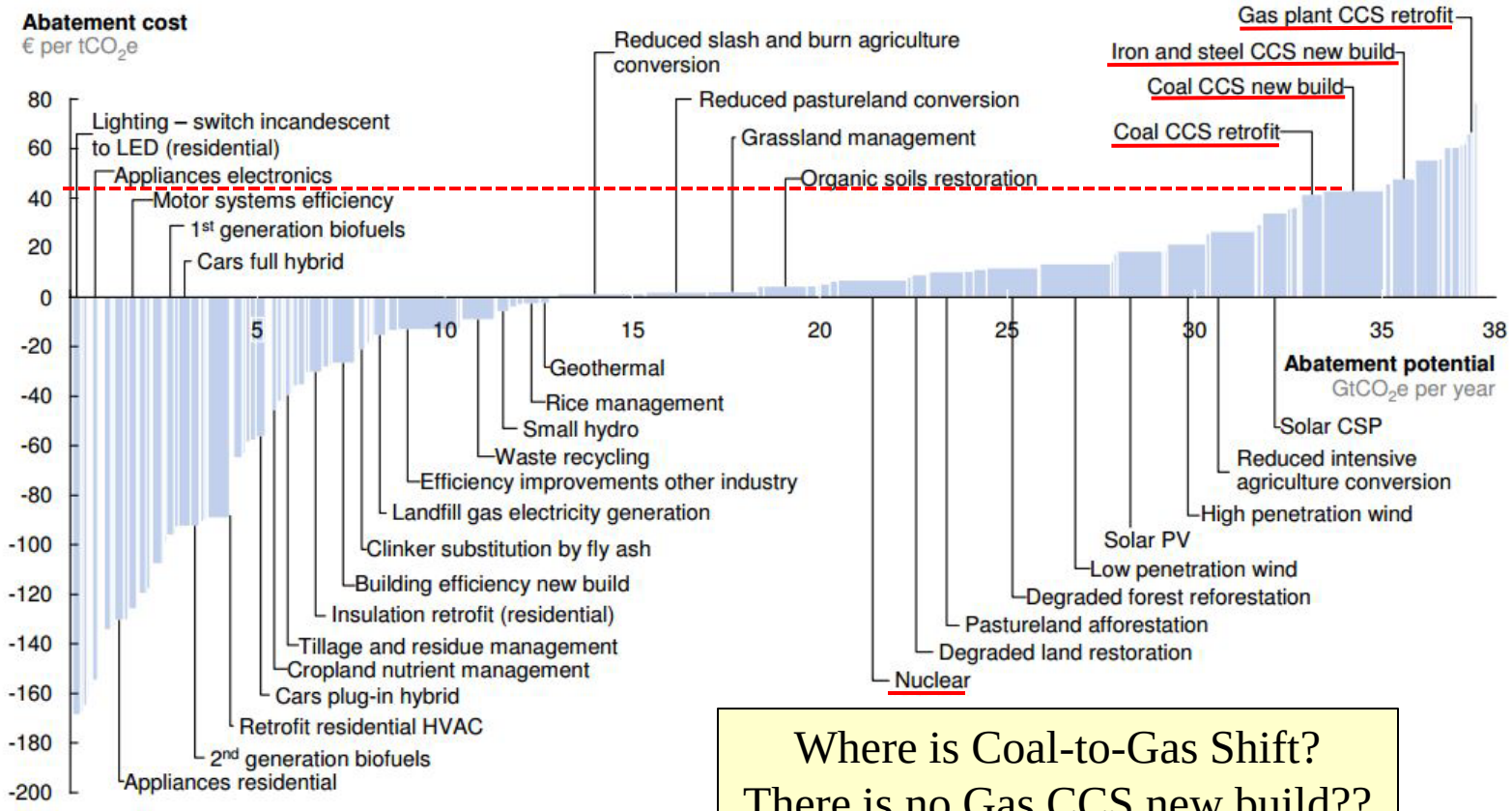
12.7%

9.3%

U.S. Energy Related
5.4 Gt = 6°C
4.0Gt = 4°C
1.3Gt = 2°C

MIT Technology Review – Mike Orcott

McKinsey Global GHG Cost Curve V2.1

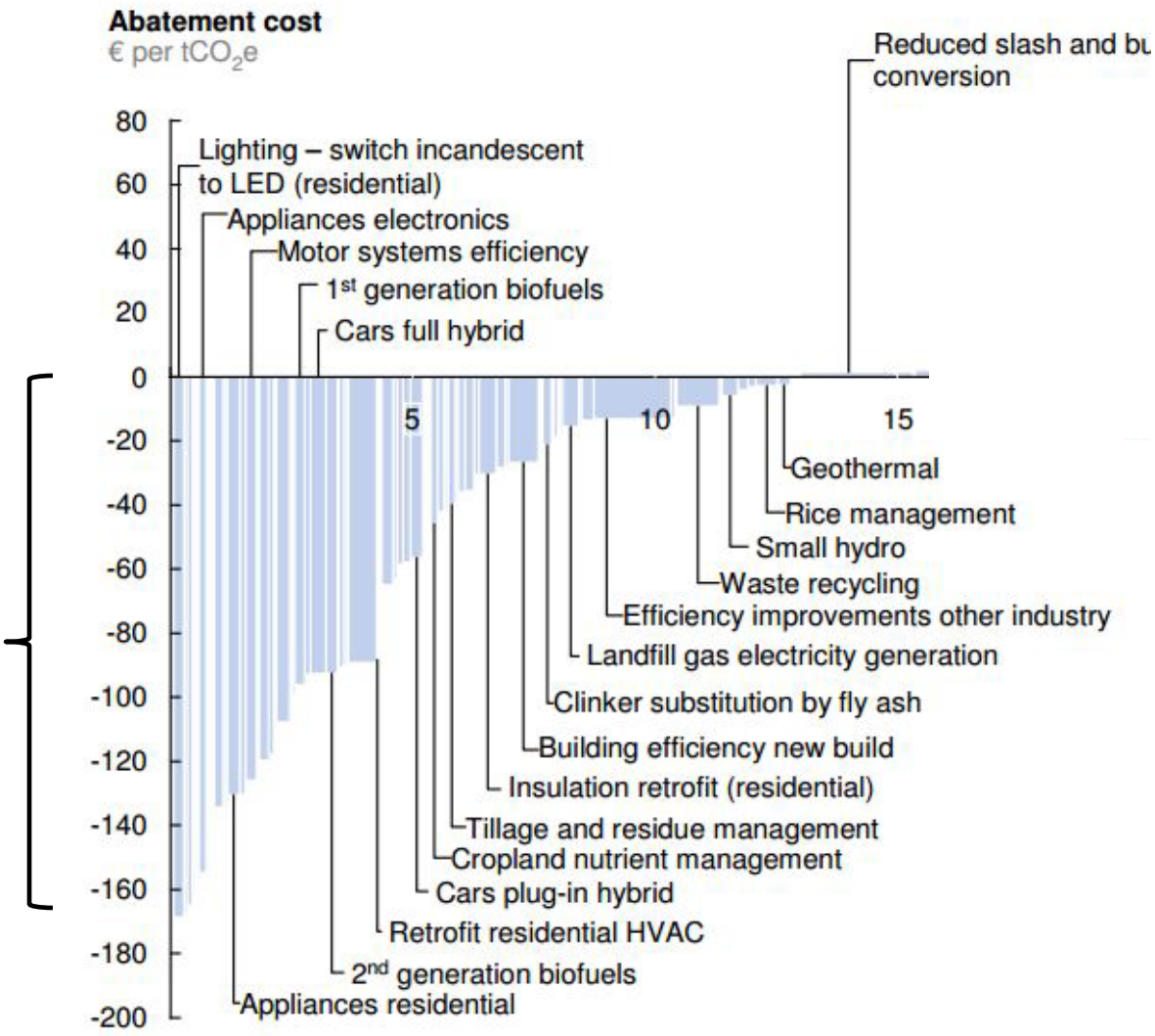


Where is Coal-to-Gas Shift?
There is no Gas CCS new build??

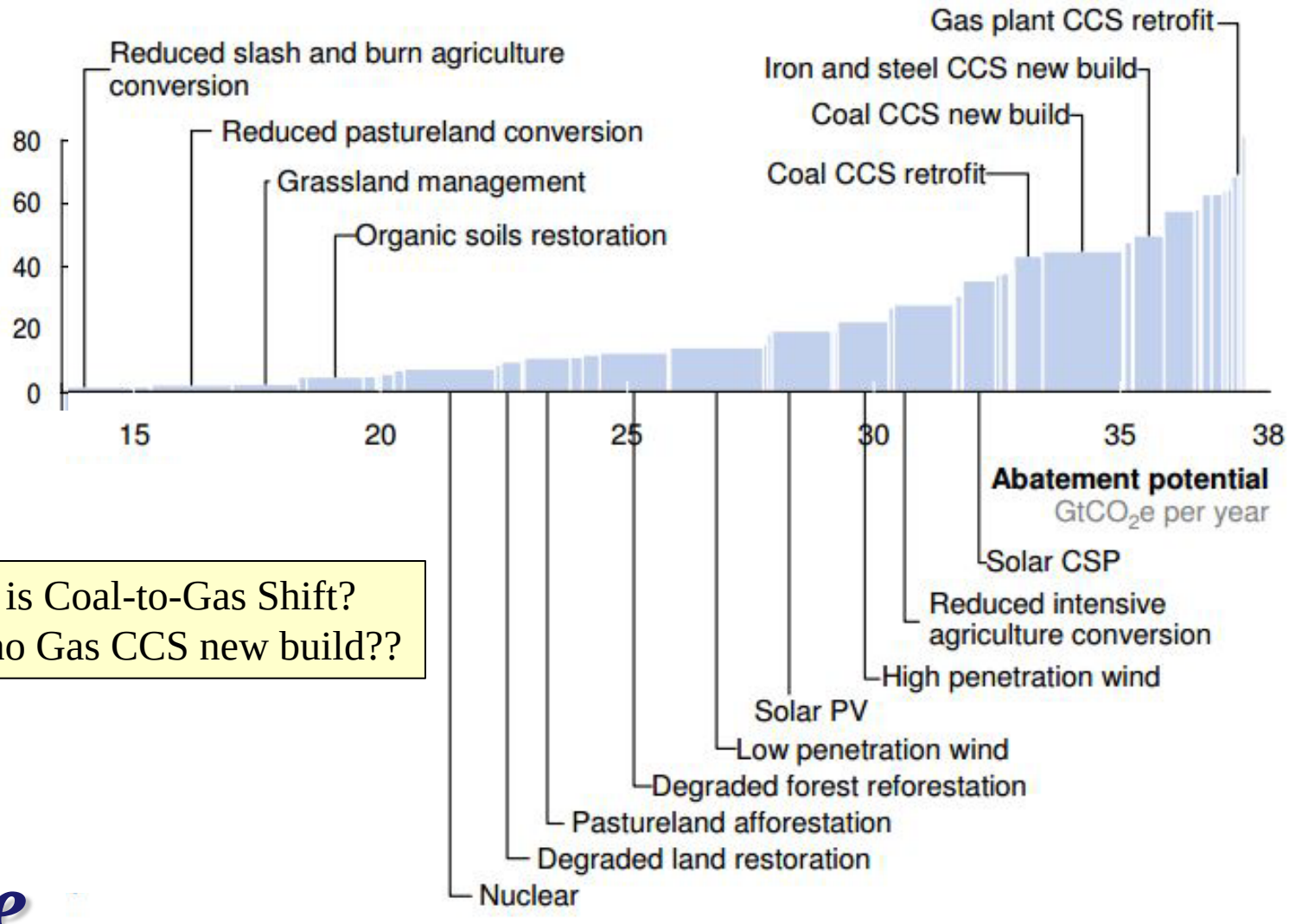
Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.1

Efficiency Improvements - 13 Gt CO2

Cost Savings

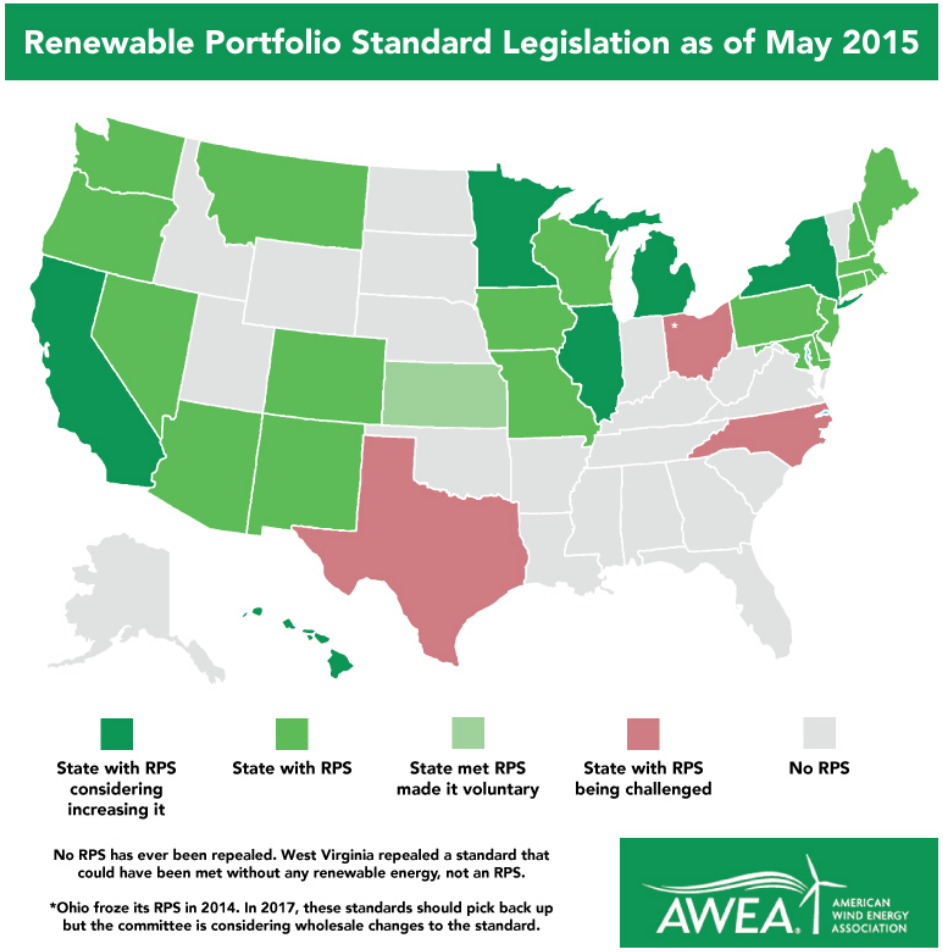


Beyond Efficiency Improvements – 24Gt



Where is Coal-to-Gas Shift?
There is no Gas CCS new build??

Renewable Portfolio Standards

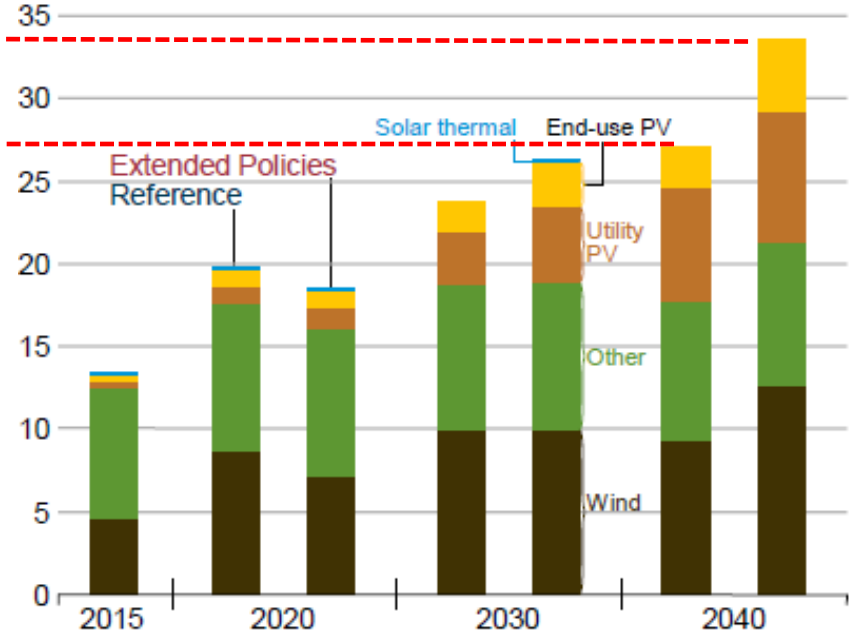


- Seven states—Hawaii, California, Nevada, Colorado, Minnesota, Connecticut, and Oregon—have effective RPS requirements of 25 percent or greater.
- Six states – CA, MI, NY, MN, IL and VT – are seriously debating an increase in their RPS this year.
- Ohio: With the signing of Senate Bill 310 in 2014, Ohio became the only state to "freeze" its RPS, effectively halting the state's mandates for efficiency and renewables until 2017.
- Legislators in four states (CO, MT, CT, and NH) have voted down proposals to diminish or repeal RPS policies this year.

Source: American Wind Energy Association (AWEA)

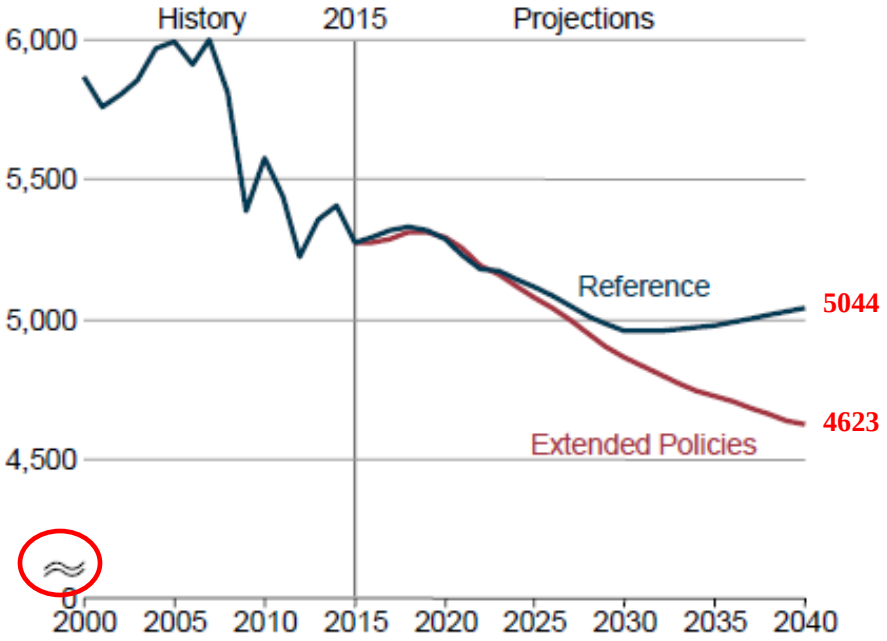
AEO2016 Renewable Energy Forecast

Figure IF3-7. Renewable electricity generation by energy source in two cases, 2015, 2020, 2030, and 2040 (percent of total)



Note: "Other" includes generation from hydroelectric, geothermal, and biomass sources.

Figure IF3-8. Energy-related carbon dioxide emissions in two cases, 2000–2040 (million metric tons)



4.6Gt in 2040 ~ 5°C Trajectory
(See Carbon Conundrum)

Well-to-Wheels Comparison Electric vs. Gasoline

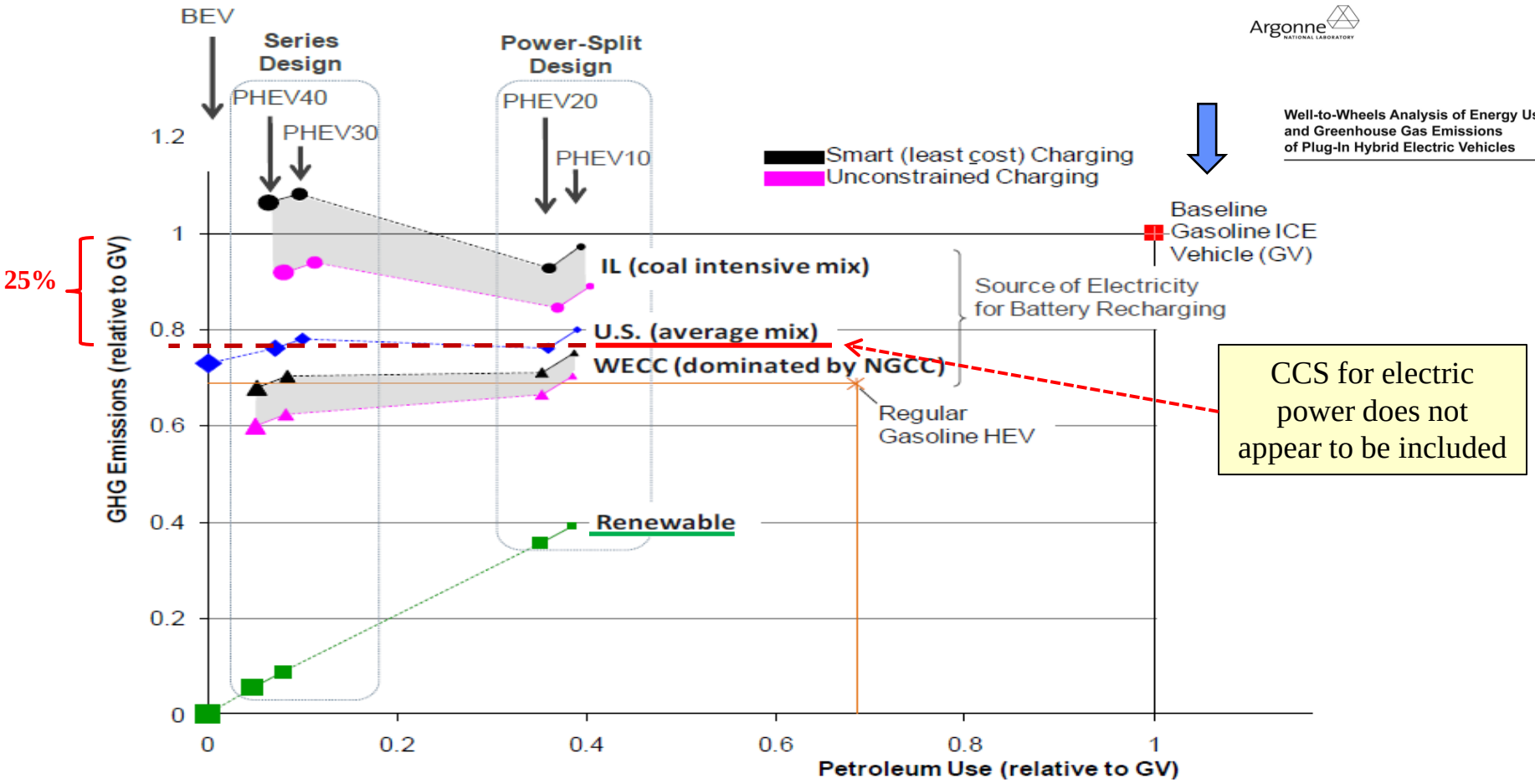


FIGURE ES.1 WTW Petroleum Use and GHG Emissions for CD Operation of Gasoline PHEVs and BEVs Compared with Baseline Gasoline ICEVs and Regular Gasoline HEVs

Renewable Fuels Standards

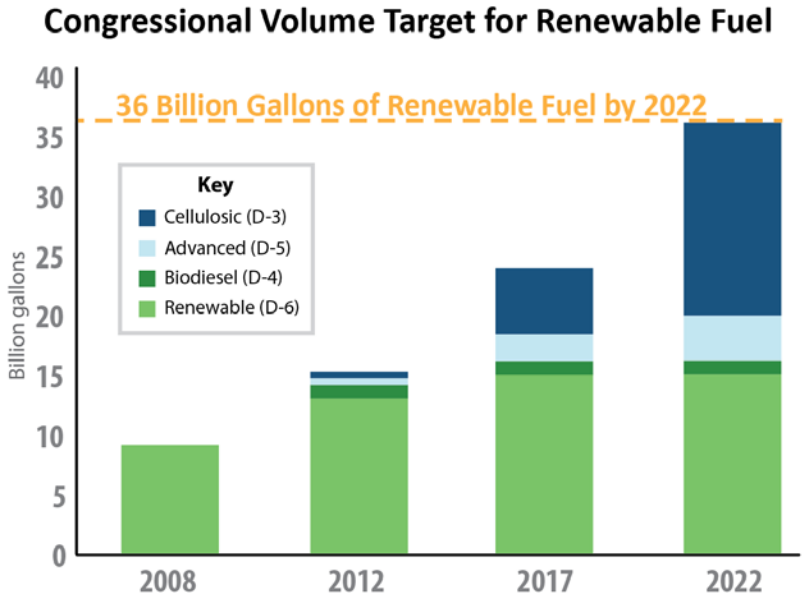
- **The Renewable Fuel Standard (RFS)** is a USA federal program that requires transportation fuel sold in the U.S. to contain a minimum volume of renewable fuels.
- The RFS originated with the **Energy Policy Act of 2005**
- Expanded and extended by the **Energy Independence and Security Act of 2007 (EISA).**
- Requires renewable fuel to be blended into transportation fuel in increasing amounts each year, escalating to **36 billion gallons by 2022**.
- Each renewable fuel category in the RFS program must emit lower levels of greenhouse gases relative to the petroleum fuel it replaces.

This is an ethanol subsidy….

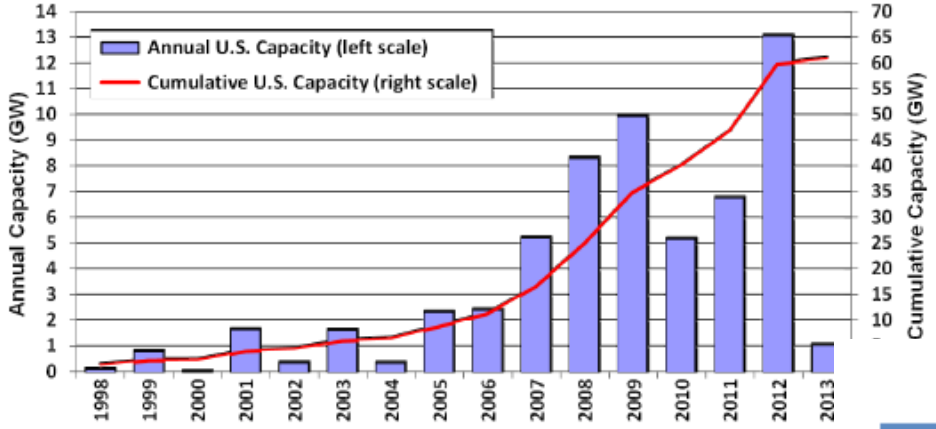
Energy balance [1]

Country	Type	Energy balance
United States	Corn ethanol	1.3
Brazil	Sugarcane ethanol	8.0
Germany	Biodiesel	2.5
United States	Cellulosic ethanol	†2–36

† depending on production method Wikipedia



Wind Generating Capacity



Source: AWEA project database

Figure 1. Annual and cumulative growth in U.S. wind power capacity

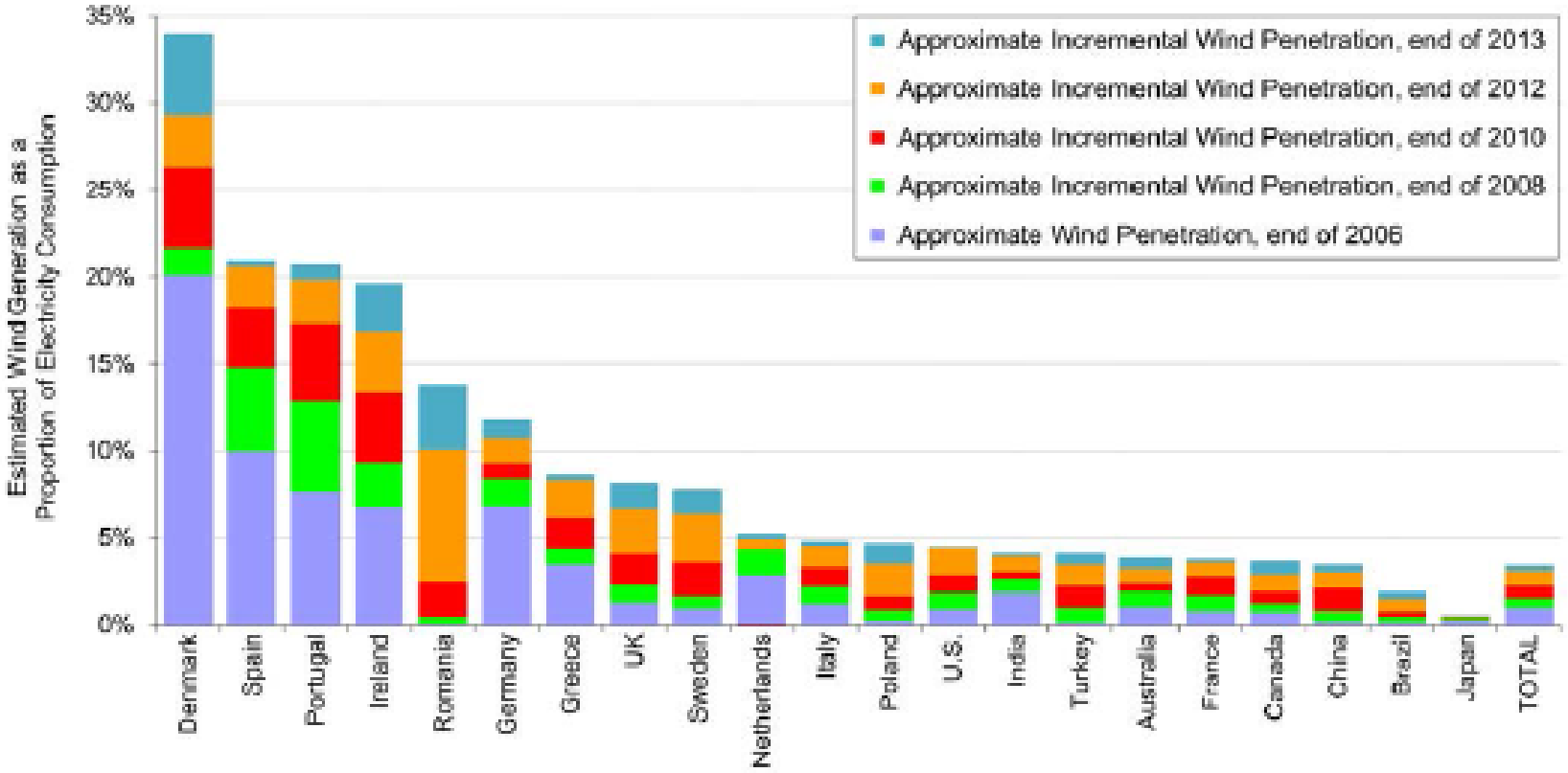
U.S. Total 1063GW
Wind 61GW (5.7%)

Table 1. International rankings of wind power capacity

Annual Capacity (2013, MW)		Cumulative Capacity (end of 2013, MW)	
China	16,088	China	91,460
Germany	3,237	United States	61,110
India	1,987	Germany	34,468
United Kingdom	1,833	Spain	22,637
Canada	1,599	India	20,589
United States	1,087	United Kingdom	10,946
Brazil	948	Italy	8,448
Poland	894	France	8,128
Sweden	724	Canada	7,813
Romania	695	Denmark	4,747
Rest of World	7,045	*Rest of World*	51,031
TOTAL	36,137	TOTAL	321,377

Source: Navigant; AWEA project database for U.S. capacity

Wind Energy Penetration



Source: Berkeley Lab estimates based on data from Navigant, EIA, and elsewhere

Figure 4. Approximate wind energy penetration in the countries with the greatest installed wind power capacity

Wind Installed Capacity & Load Factors (2012)

Top windpower electricity producing countries in 2012 (TWh)

Country	Windpower Production	% of World Total	Nameplate GW	Nameplate TWh	Load Factor
United States	140.9	26.40%	60.0	526	26.8%
China	118.1	22.10%	75.3	660	17.9%
Spain	49.1	9.20%	22.8	200	24.6%
Germany	46.0	8.60%	31.3	274	16.8%
India	30.0	5.60%	18.4	161	18.6%
United Kingdom	19.6	3.70%	8.4	74	26.6%
France	14.9	2.80%	7.6	67	22.4%
Italy	13.4	2.00%	8.1	71	18.9%
Canada	11.8	2.20%	6.2	54	21.7%
Denmark	10.3	1.90%	4.2	36	28.3%
Rest of World	80.2	15.00%	40.9	358	22.4%
World Total	534.3	100.00%	283.1	2480	21.5%

2.3%

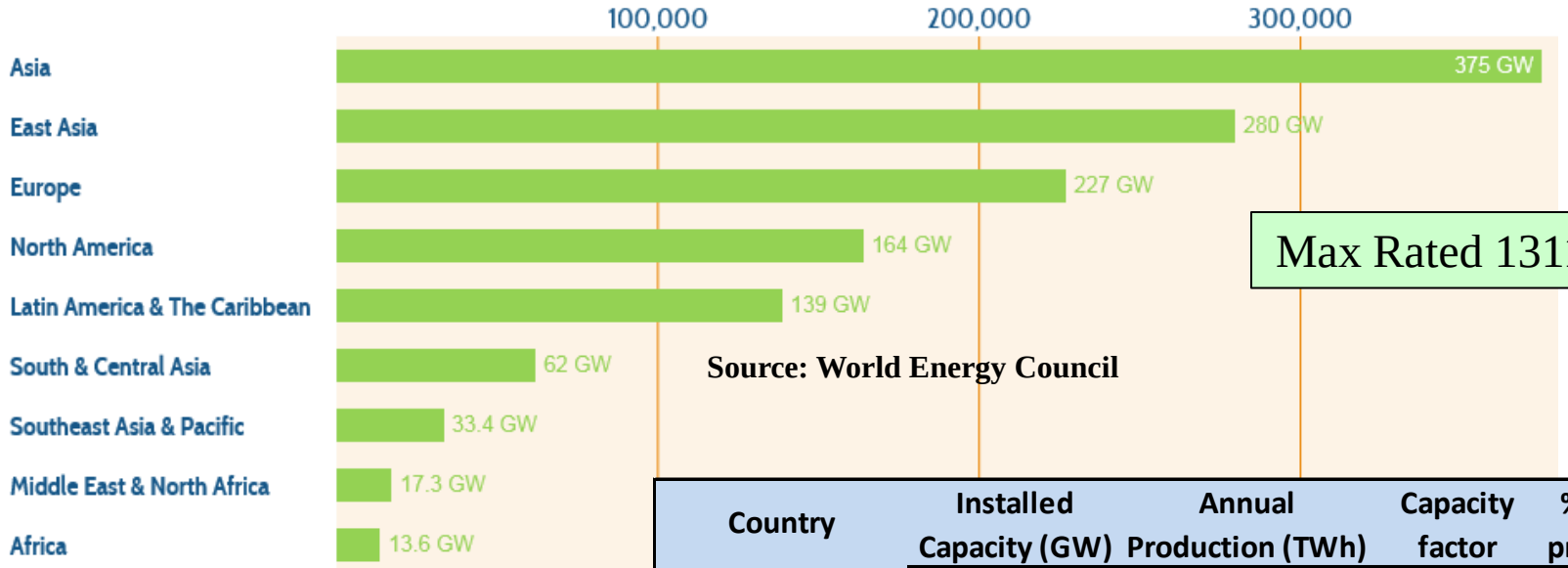
2014 World Electricity Production = 23,537 TWh

Source: Global Wind Report – Annual Market Update 2014, GWEC

Average Load Factor is 21.5%

- High 28.3% - Denmark
  26.8% - USA
  17.9% - China
- Low 16.8% - Germany

World Hydroelectric Capacity – 936 GW



Source: World Energy Council

Max Rated 1311

Country	Installed Capacity (GW)	Annual Production (TWh)	Capacity factor	% of total production
China	196.8	652.1	0.37	22.3
Canada	89.0	369.5	0.59	61.1
Brazil	69.1	363.8	0.56	85.6
United States	79.5	250.6	0.42	5.7
Russia	45.0	167.0	0.42	17.6
Norway	27.5	140.5	0.49	98.3
India	33.6	115.6	0.43	15.8
Venezuela	14.6	86.0	0.67	69.2
Japan	27.2	69.2	0.37	7.2
Sweden	16.2	65.5	0.46	44.3
Total	598.5	2279.7	0.435	

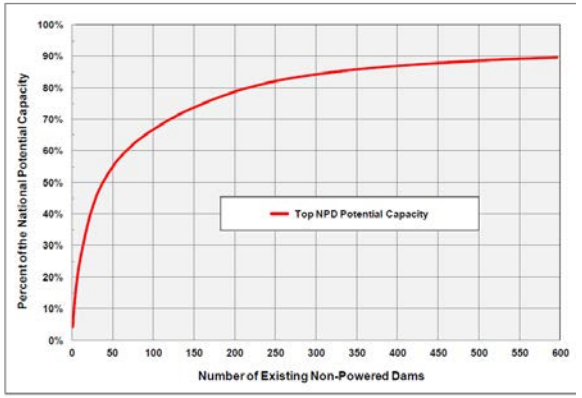
China Three Gorges – 18GW

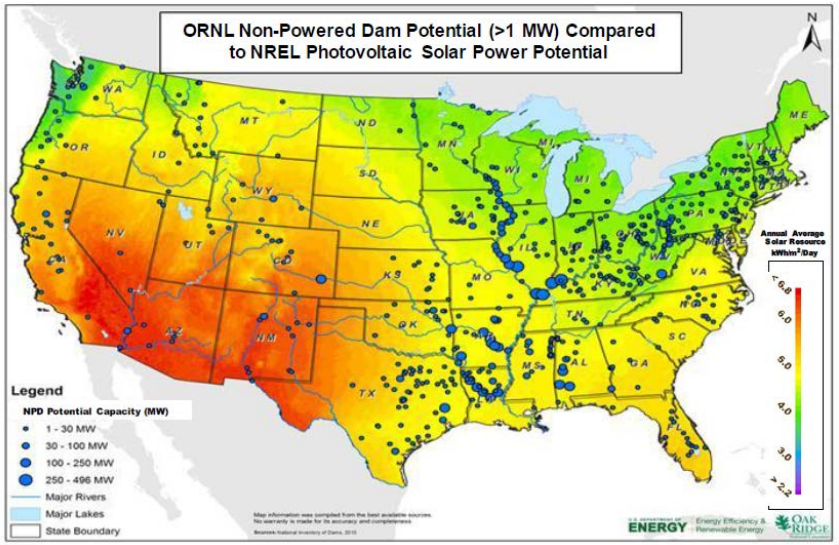
World Total Hydro 3884.6 TWh = 16.5%

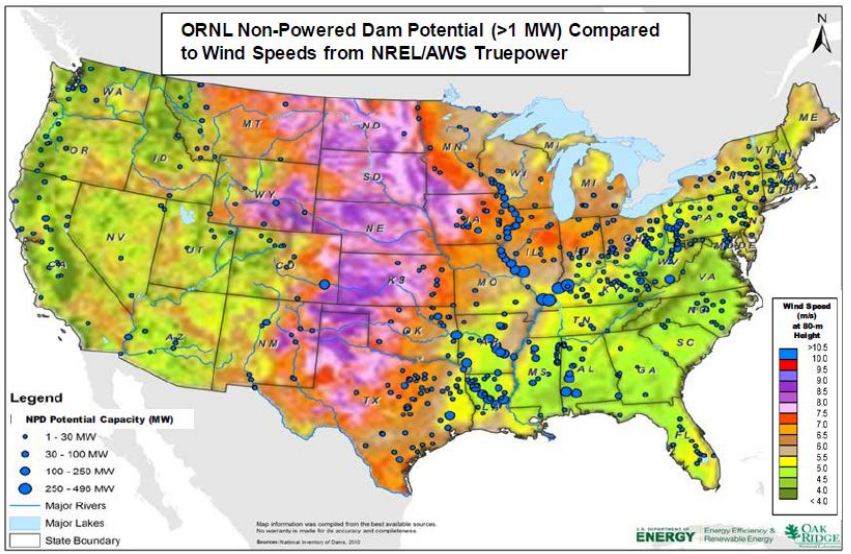
2014 World Electricity Production = 23,537 TWh

12GW Complimentary Non-Power Dams (NPD)

Hydrologic Regions (HUC02)	Potential Capacity (MW)	Potential Generation (TWh/yr)	Hydrologic Regions (HUC02)	Potential Capacity (MW)	Potential Generation (MWh/yr)
1 New England	243	1.110	10 Missouri	258	0.865
2 Mid-Atlantic	479	1.997	11 Arkansas-White-Red	1898	5.960
3 South Atlantic-Gulf	1618	3.778	12 Texas-Gulf	608	1.308
4 Great Lakes	156	0.903	13 Rio Grande	98	0.241
5 Ohio	3236	13.603	14 Upper Colorado	53	0.145
6 Tennessee	53	0.197	15 Lower Colorado	124	0.370
7 Upper Mississippi	2027	9.943	16 Great Basin	29	0.080
8 Lower Mississippi	743	2.802	17 Pacific Northwest	225	0.871
9 Souris-Red-Rainy	58	0.239	18 California	156	0.586







base e

"Practical Strategies for Emerging Energy Technologies"

Cumulative Geothermal Installed Capacity – 12.6GW

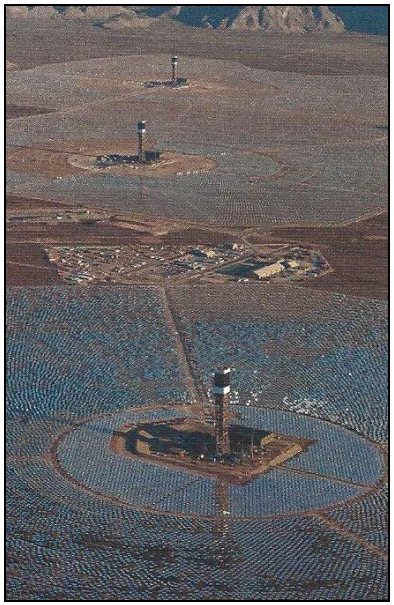
Cumulative installed geothermal power capacity*

Megawatts	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	**2014**	Change 2014 over 2013	2014 share of total
China	28	28	28	28	24	24	24	24	24	27	**27**	0.0%	0.2%
Costa Rica	163	163	163	163	163	166	166	208	208	208	**208**	0.0%	1.7%
El Salvador	151	151	195	195	204	204	204	204	204	204	**204**	0.0%	1.6%
Iceland	202	202	312	485	576	576	575	665	665	665	**665**	0.0%	5.3%
Indonesia	807	850	850	980	1052	1189	1193	1209	1339	1339	**1401**	4.6%	11.1%
Italy	791	791	811	811	811	843	883	883	875	876	**916**	4.6%	7.3%
Japan	535	534	534	532	532	500	502	502	502	503	**539**	7.2%	4.3%
Kenya	167	167	167	170	174	174	209	212	217	253	**590**	133.7%	4.7%
Mexico	960	960	960	960	965	965	965	887	812	834	**834**	0.0%	6.6%
New Zealand	370	425	425	443	585	625	723	723	723	971	**971**	0.0%	7.7%
Philippines	1932	1978	1978	1958	1958	1953	1966	1783	1848	1868	**1917**	2.6%	15.2%
Russia (Kamchatka)	79	79	79	82	82	82	82	82	82	82	**82**	0.0%	0.7%
Turkey	20	20	28	28	35	82	94	114	114	226	**368**	62.6%	2.9%
US	2866	2893	2940	3037	3163	3289	3308	3318	3450	3524	**3525**	0.0%	28.0%
Total World	**9225**	**9396**	**9655**	**10121**	**10575**	**10928**	**11152**	**11071**	**11397**	**11917**	**12594**	**5.7%**	**100.0%**

Sources: International Geothermal Association, ThinkGeoEnergy, and national sources

Concentrating “Big Solar”

Parameter	Ivanpah
Output	392 MW (gross), 377 MW (net)
Boiler inlet temp	368F
Steam temp	1,013F
Steam pressure	2,479 psi
Heliostats	173,500 (each holds two mirrors)
Heliostat solar-field aperture area	2,600,000 m^3
Tower height	459 ft
Net generation (first 100 days)	116,000 MWh
Gross efficiency	28.72%

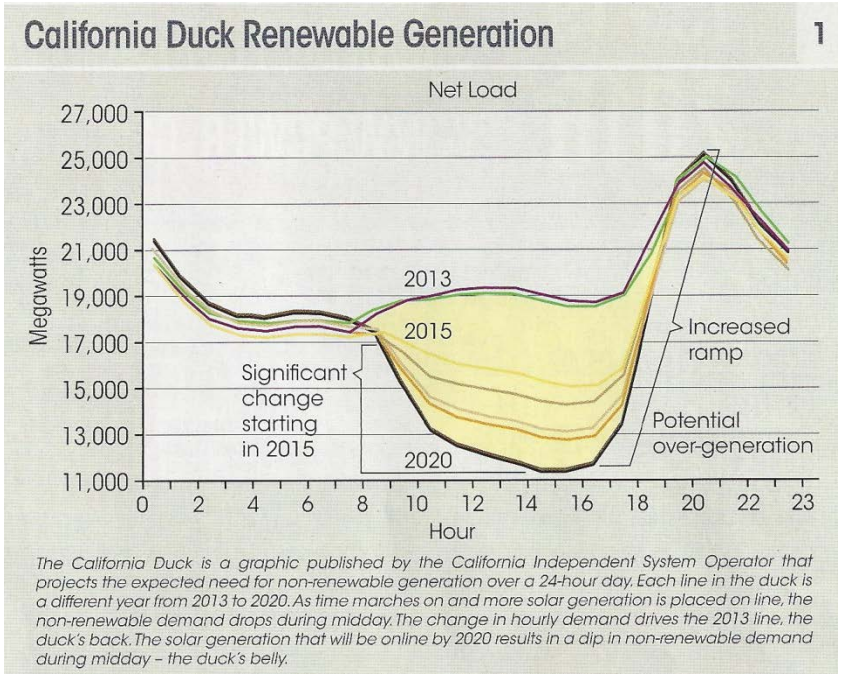


- Three self-contained units
- 3500 acres
- 5 miles end-to-end
- 4 types of heliostats depending on distance
- Air-cooled condensers

- Project Partners
- Bright Source Energy
- NRG Energy (NRG Renew)
- Google
- Bechtel

Source: Power Magazine August 2104

Dealing with the Duck



The California Duck is a graphic published by the California Independent System Operator that projects the expected need for non-renewable generation over a 24-hour day. Each line in the duck is a different year from 2013 to 2020. As time marches on and more solar generation is placed on line, the non-renewable demand drops during midday. The change in hourly demand drives the 2013 line, the duck's back. The solar generation that will be online by 2020 results in a dip in non-renewable demand during midday – the duck's belly.

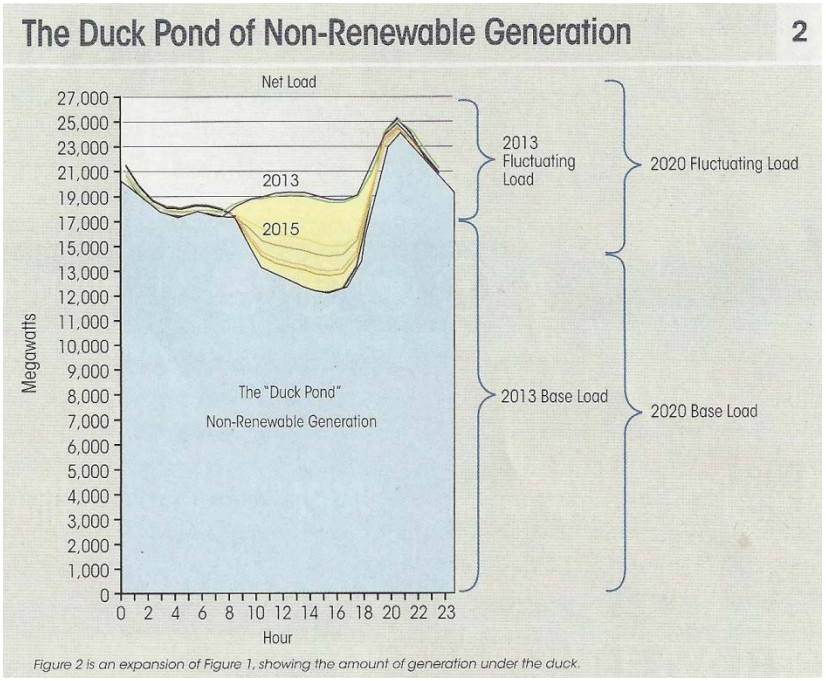


Figure 2 is an expansion of Figure 1, showing the amount of generation under the duck.

Source: Bonnie Marini – Siemens Energy
Through Power Engineering

Economic Merit Order Dispatch (Utility Cost Curve)

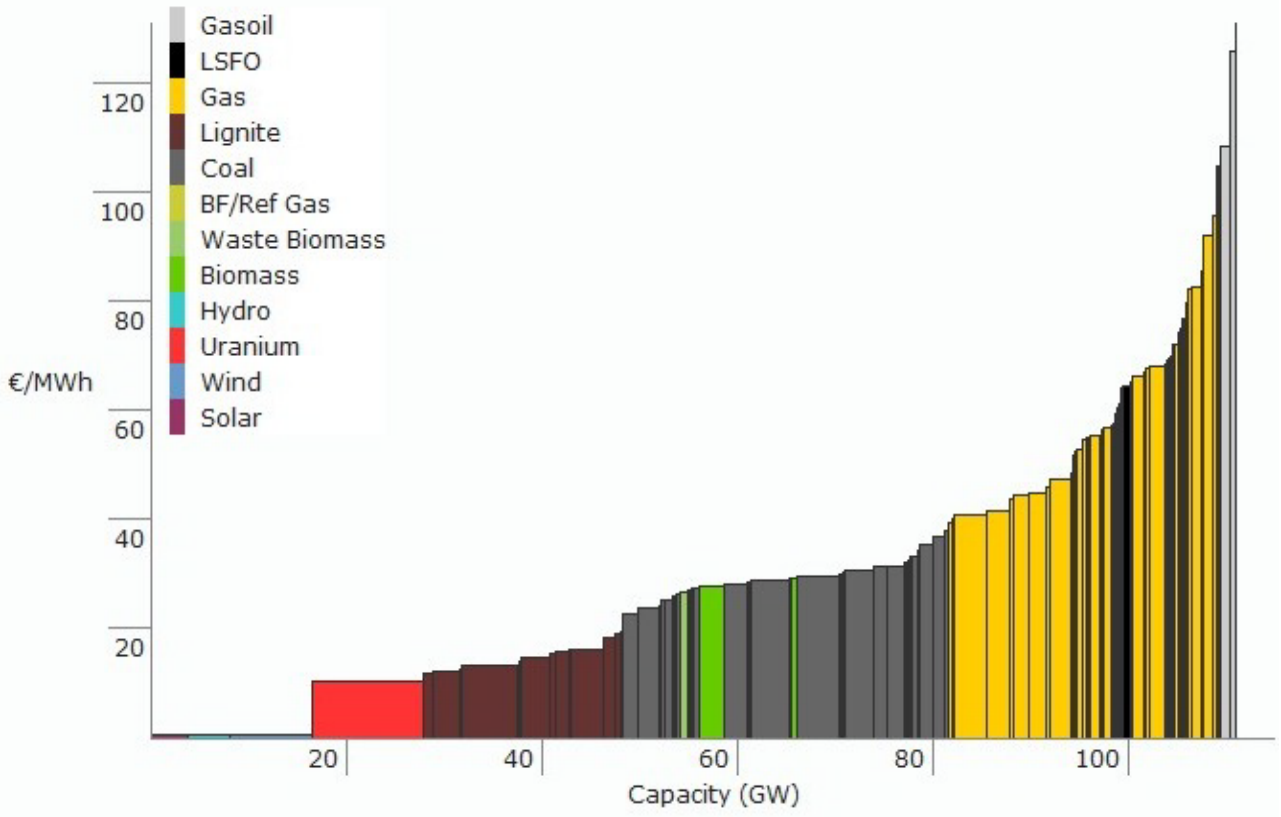
Include plant:
☑ Operational

Fuel	Price	Units	Rating
Gasoil	406.7	$/tonne	100 %
LSFO	258.7	$/tonne	100 %
Gas	19.15	€/MWh	100 %
Lignite	10.28	€/tonne	100 %
Coal	58.10	$/tonne	100 %
BF/Ref Gas	4.73	€/GJ	50 %
Waste Biomass	2.40	€/GJ	50 %
Biomass	2.80	€/GJ	100 %
Hydro	0.00	€/MWh(e)	40 %
Uranium	5.00	€/MWh(e)	100 %
Wind	0.00	€/MWh(e)	25 %
Solar	0.00	€/MWh(e)	10 %
CO2 price	7.16	Euro/t	
Dollars per Euro	1.16	$/Euro	

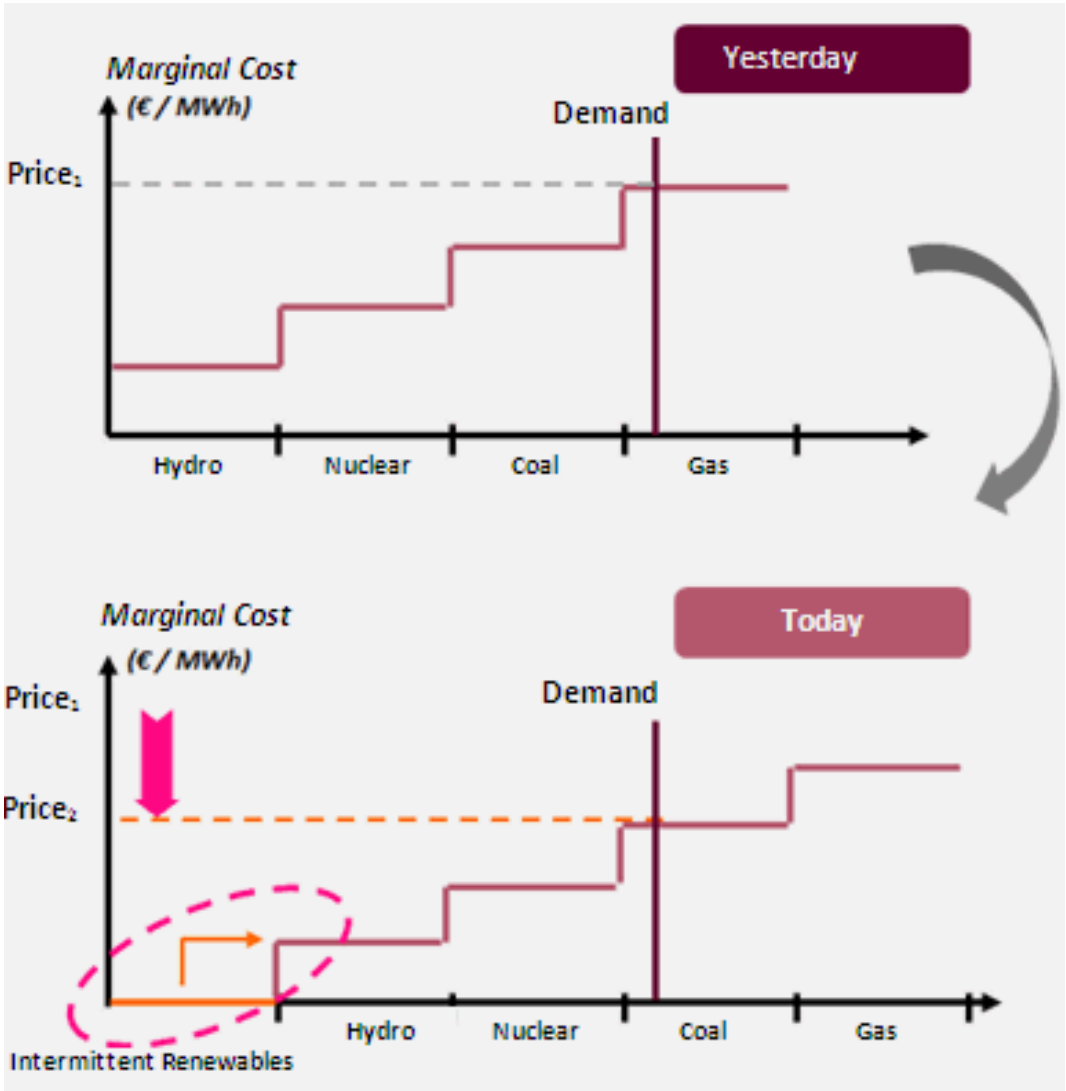
Group similar fuels ☐

Create chart by fuel

Total charted capacity: 182 GW | To download: 21-01-2015 Daily

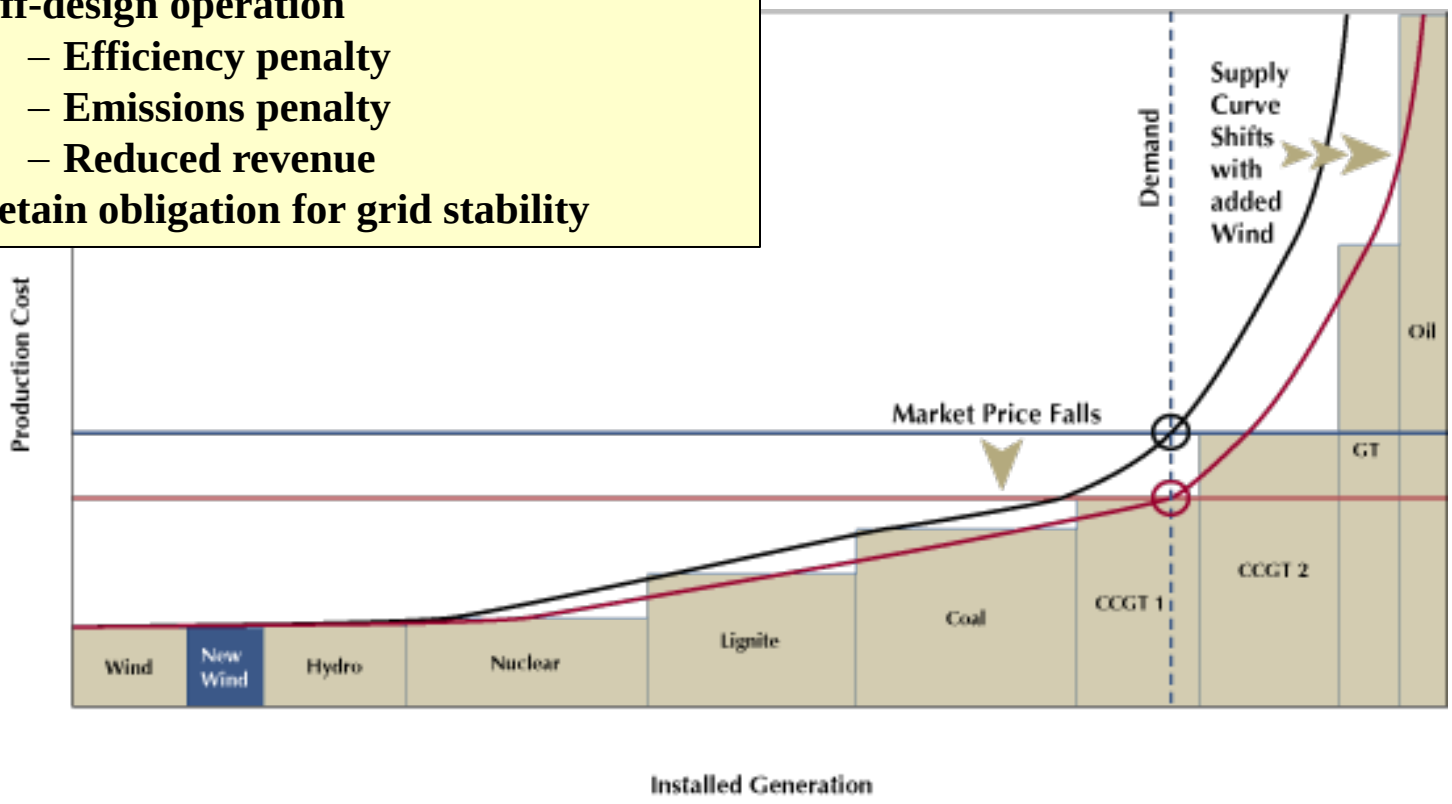


Impact of Intermittent Renewables on Merit Order



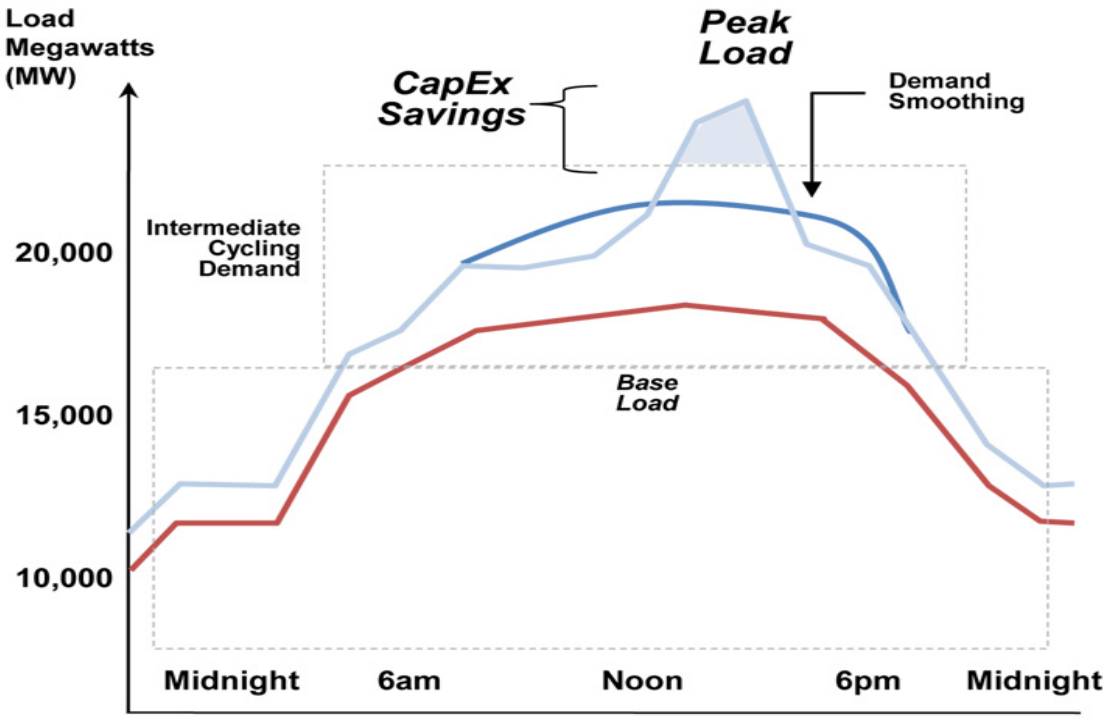
Shift in Supply Cost Curve with Renewables

Fossil Assets Pushed Back In Merit Order
- **Reduced load factor 85% to 65%**
- **Rapid ramp rates and start/stop operation**
- **Off-design operation**
  - **Efficiency penalty**
  - **Emissions penalty**
  - **Reduced revenue**
- **Retain obligation for grid stability**



Demand Response

- DR as changes (usually reductions) in electricity **usage by end-use customers from their normal** consumption patterns.
- In response to **changes in the price of electricity or to direct incentives**, typically at times of high wholesale market prices or when system reliability is jeopardized.
- An important distinction for DR is that it must be **dispatchable by a utility or system operator** or be initiated by a customer in response to a non-fixed price signal.



Demand Response is an important component of "Smart Grid"

Time of Day Rates Encourage Customer DR

Summer

	On-Peak	Mid-Peak	Off-Peak	Total
Annual Operating Hours	650	975	2015	3640
Electric Demand Charge - $/kW/month	16.50	2.45	3.30	5.43
Electric Rate - $/kWh	0.1445	0.0680	0.0430	0.0678
Demand Charge - $/kWh	0.1269	0.0126	0.0082	0.0306
Average Electric Rate - $/kWh	0.2714	0.0806	0.0512	0.0984

Months of Operation-Summer: 5

Winter

	On-Peak	Mid-Peak	Off-Peak	Total
Annual Operating Hours	0	1972	3124	5096
Electric Demand Charge - $/kW/month	0.00	0.00	3.30	2.02
Electric Rate - $/kWh	0.0000	0.0800	0.0460	0.0592
Demand Charge - $/kWh	0.0000	0.0000	0.0074	0.0045
Average Electric Rate - $/kWh	0.0000	0.0800	0.0534	0.0637

Months of Operation-Winter: 7

Total

	On-Peak	Mid-Peak	Off-Peak	Total
Annual Operating Hours	650	2947	5139	8736
Electric Demand Charge - $/kW/month	16.50	0.81	3.30	3.44
Electric Rate - $/kWh	0.1445	0.0760	0.0448	0.0628
Demand Charge - $/kWh	0.1269	0.0042	0.0077	0.0154
Average Electric Rate - $/kWh	0.2714	0.0802	0.0525	0.0781

Months of Operation-Total: 12

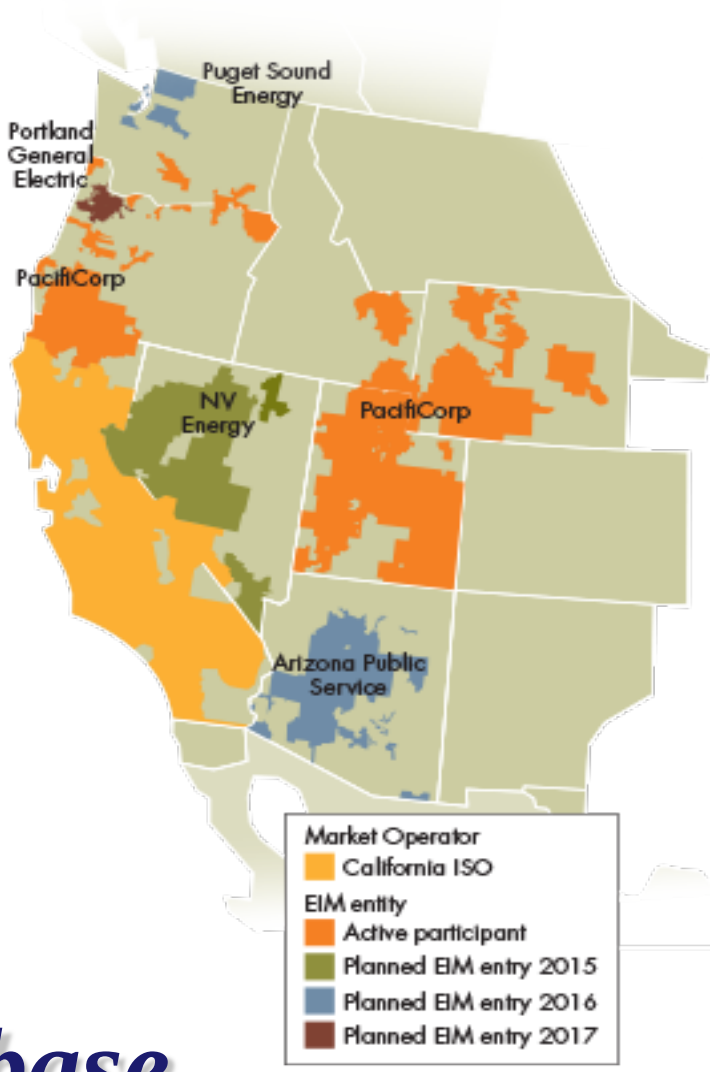
Net Metering

- Net Metering is a service to an electric consumer under which electric energy generated by that electric consumer from an eligible on-site generating facility and delivered to the local distribution facilities may be used to offset electric energy provided by the electric utility to the electric consumer during the applicable billing period.
- Net metering policies can vary significantly by country and by state or province
- Net metering can be implemented solely as an accounting procedure, and requires no special metering, or even any prior arrangement or notification
- **Unlike a feed-in-tariff (FIT), which requires two meters, net metering uses a single, bi-directional meter and can measure current flowing in two directions.**

–With one meter (net metering), the user/generator receives retail price for any electricity generated

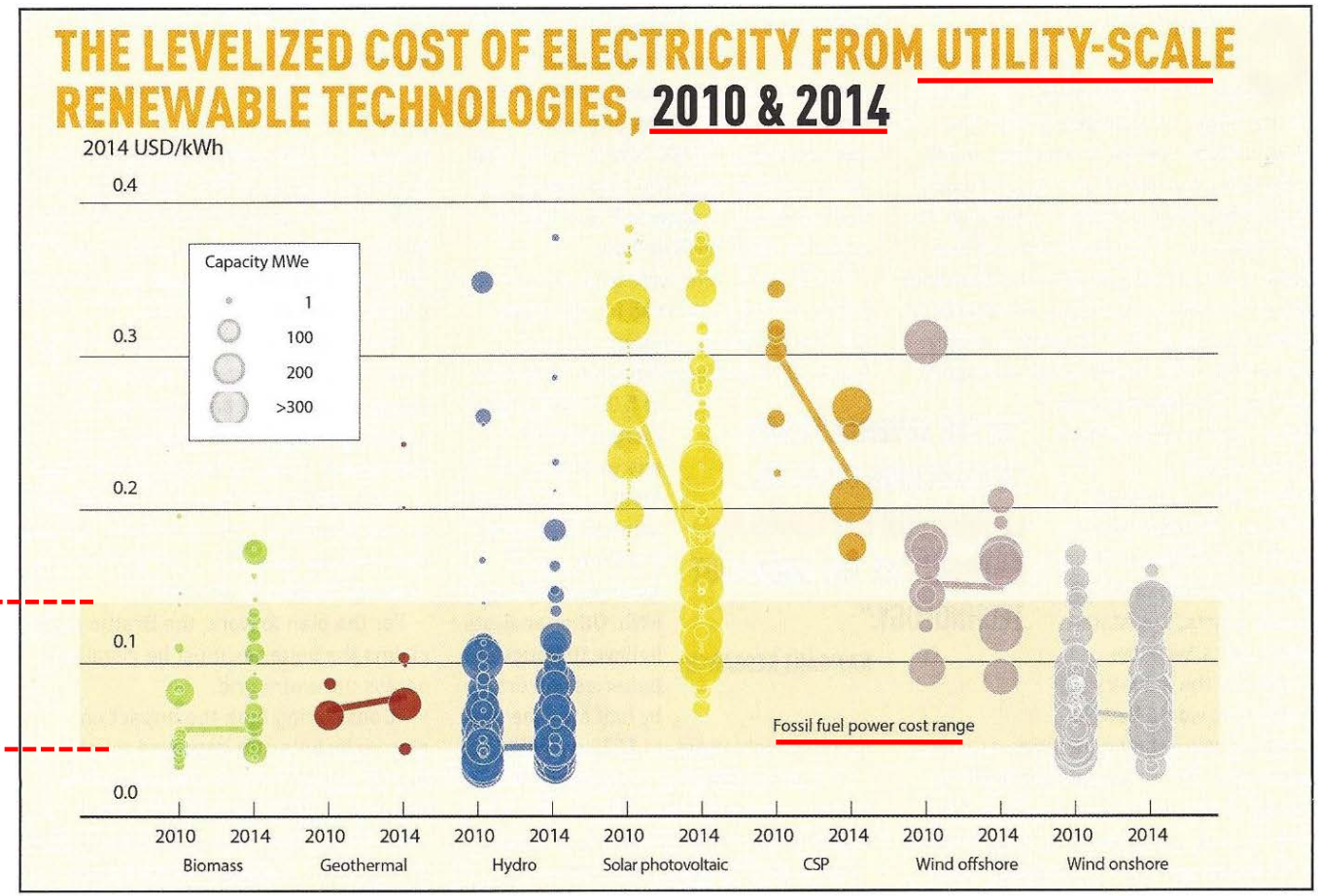
–With two meters (FIT), the user/generator receives wholesale price for any electricity generated

Energy Imbalance Market - EIM



- ISO advanced market systems automatically balance supply and demand for electricity every 15-minutes, dispatching the least-cost resources every 5-minutes.
- Voluntary energy imbalance market service became available in November 2014 as a way to share reserves and integrate renewable resources across a larger geographic region--reliably and efficiently.
- A wider portfolio of resources to maintain system balance could reduce the costs of energy and capacity
- Improved situational awareness and real-time visibility of transmission constraints to avoid congestion issues.
- Captures the benefits of geographical diversity of load and resources

Renewables Levelized Cost 2010 & 2014



$0.14/kWh --------

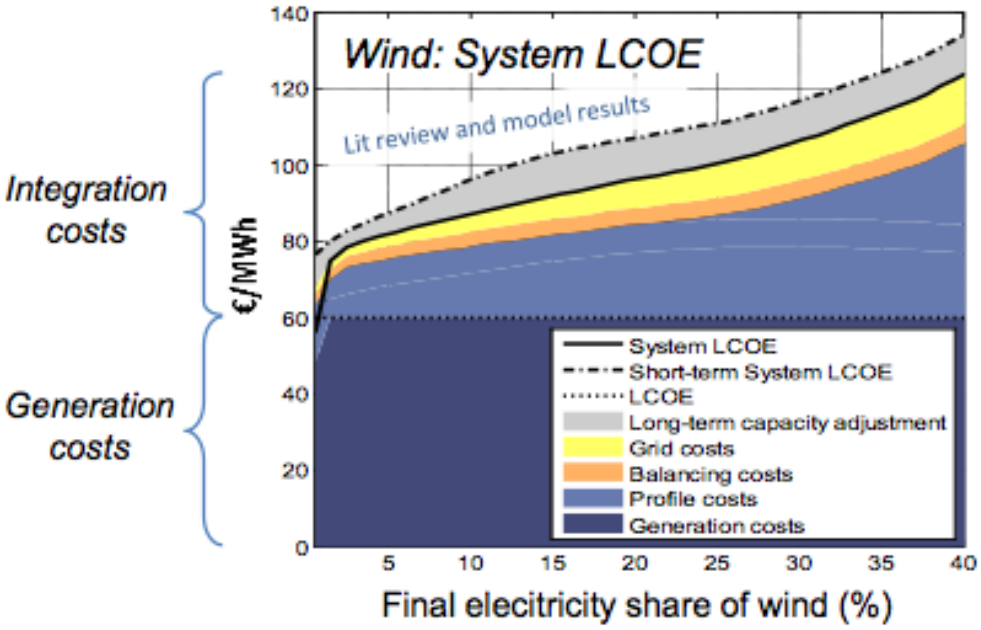
$0.05/kWh ---------

Source: IRENA Renewable Cost Database.
Note: Size of the diameter of the circle represents the size of the project. The centre of each circle is the value for the cost of each project on the Y axis. Real weighted average cost of capital is 7.5% in OECD countries and China; 10% in the rest of the world.

Wind Integration Costs

- Integration includes:
  - Fluctuating output profile costs
  - Output uncertainties balancing costs
  - Grid costs

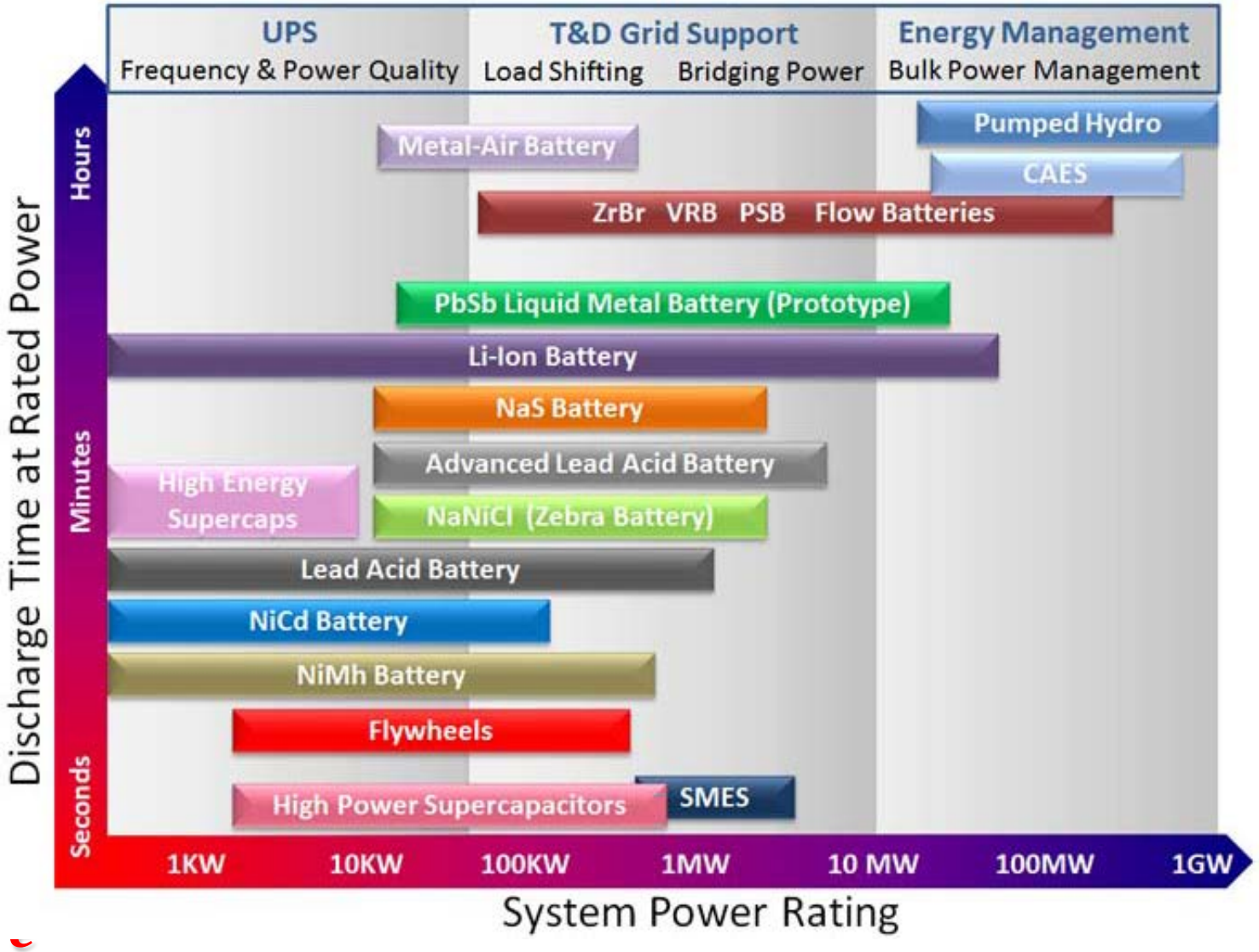
At higher penetration, integration costs for wind exceed generation costs.



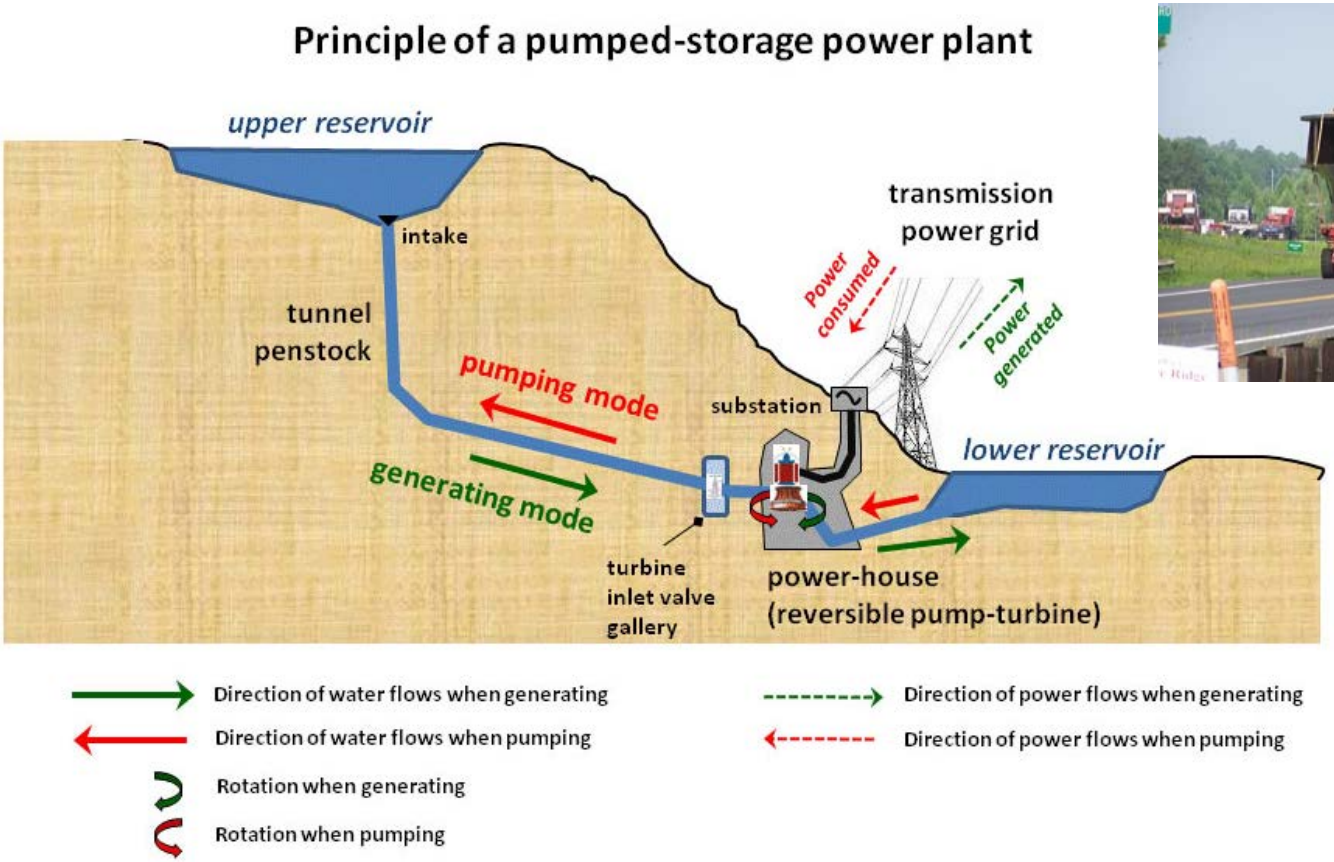
Source: System LCOE: What are the costs of variable renewables? Falko Ueckerdt, Lion Hirth, Gunnar Luderer, Ottmar Edenhofer Paris, June 20, 2013 32th International Energy Workshop

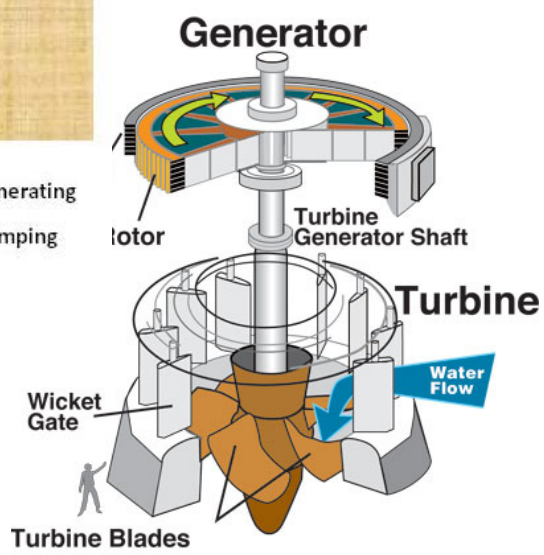
As presented by John Thompson Clean Air Task Force CCS – Pittsburgh 2104

Energy Storage Technologies

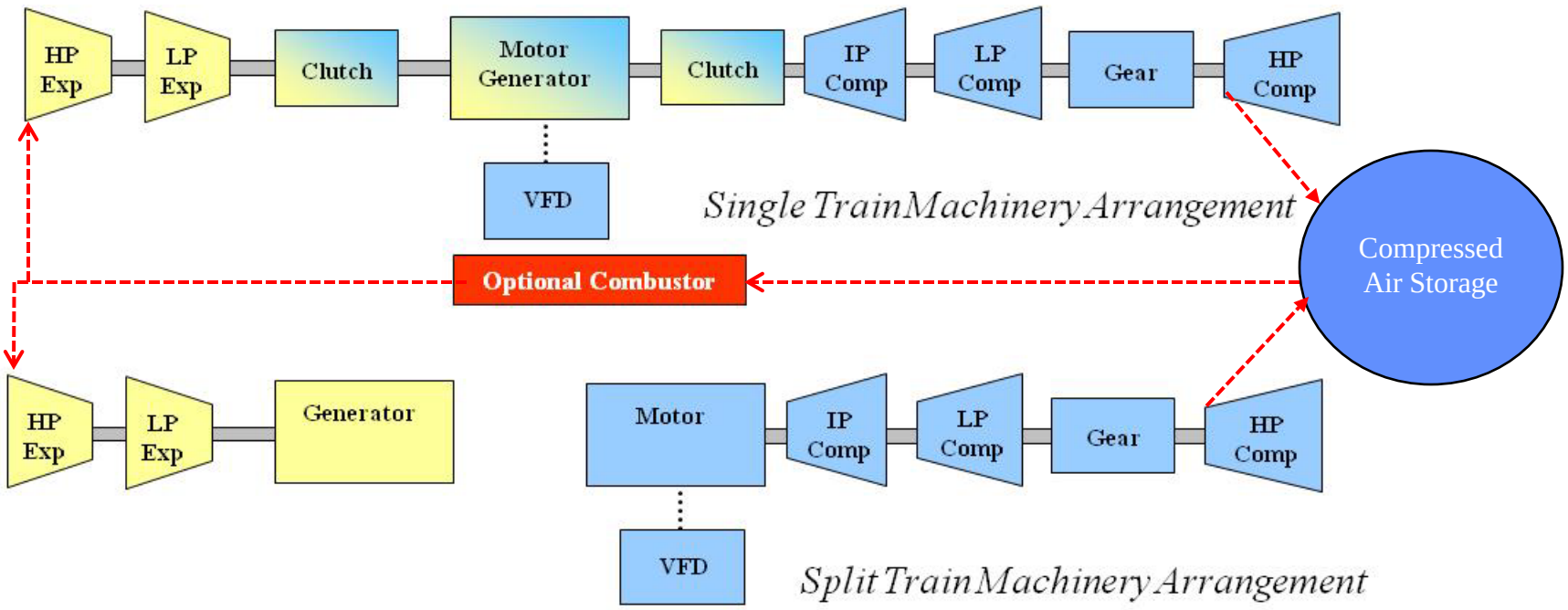


Pumped Hydro Storage





Compressed Air Energy Storage (CAES)



Split the two components of a gas turbine

1. **Compressor**
2. **Turbine (Expander)**

So they can operate at different time(s) of day

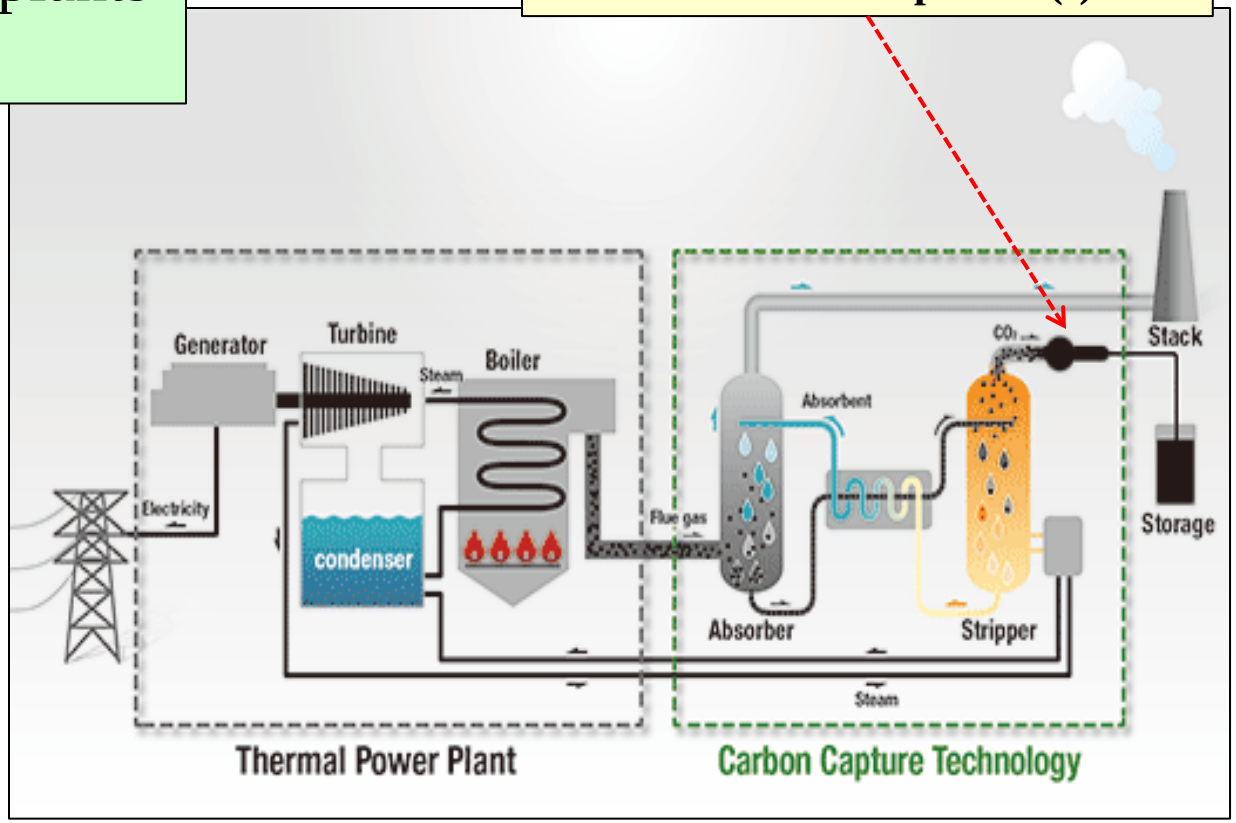
Turbine may be "fired" or "un-fired"

Source: Dresser-Rand

Fossil Fuel Power Plant – CC&S

All fossil fuel power plants produce CO2

This is the compressor(s)



CO2 Compressor Power

- **Advanced pulverize coal – 8-12%**
  - **600MW ⇨70MW ⇨93,000 hp**
- **IGCC - 5%**
  - **600MW ⇨30MW ⇨40,000 hp**
- **NGCC – 8%**
  - **400MW ⇨32MW ⇨43,000 hp**

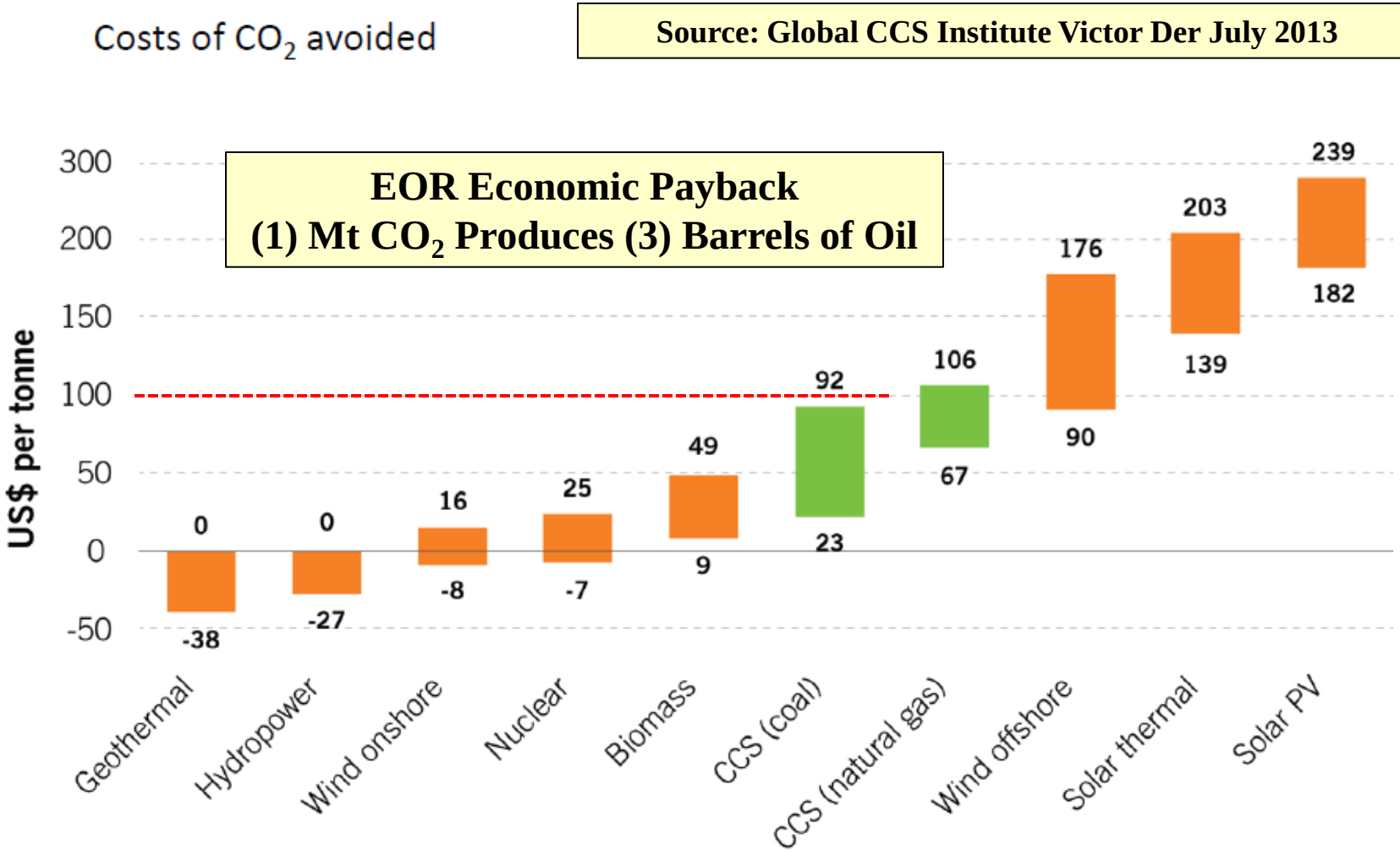
Compression Costs are 36% of Total Cost/Mt of CO2

This is what 6000 hp Compressor Really Looks Like

Pr 200:1
1.70 Pr per stage
10-stage
6000 hp
$8.0 million
$1350/hp

Costs of CO_2 Avoided

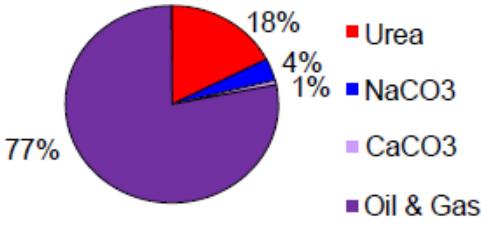
Source: Global CCS Institute Victor Der July 2013



Annual U.S. CO_2 Utilization vs. Emissions

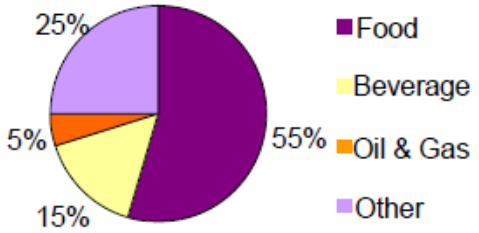
Gaseous Consumption

Mainly enhanced oil recovery



Liquid/Solid Consumption

Mainly Food



Total Utilization ~ 100 Mt

Sources: SRI Consulting, MIT, UT Austin

5 Largest CO_2 Emitters in 2009

	Plant	Location	CO_2, Mt/yr	GWe
1	Scherer	Juliette, GA	25.0	3.56
2	Bowen	Cartersville, GA	20.8	3.50
3	Miller	Quinton, AL	23.3	2.82
4	Martin Lake	Tatum, TX	26.0	2.38
5	Gibson	Owensville, IN	22.2	3.34
		Total	**117.3**	**15.6**

U.S. Utilization = 100 Mt
= Emissions 5 large plants

U.S. Emissions = 2400 Mt from utility
= 6000 Mt total

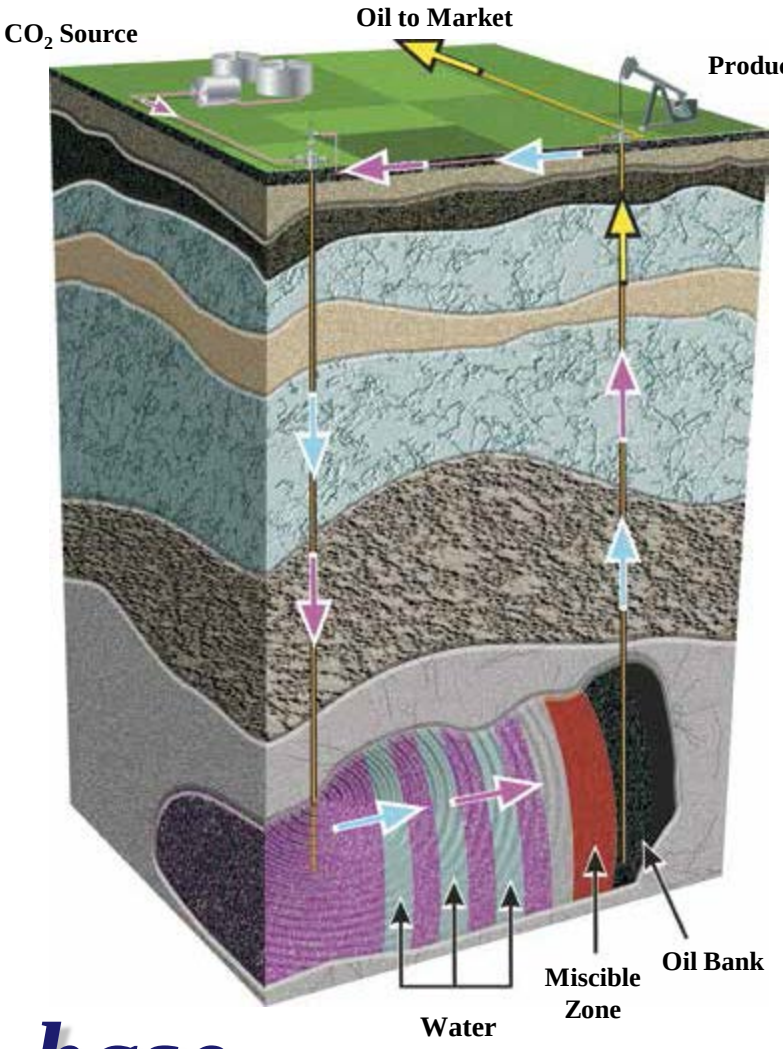
Sources: EPA, IEA

DOE estimates ~25% of coal power CO_2 emissions could be used for EOR, if ~$30/t

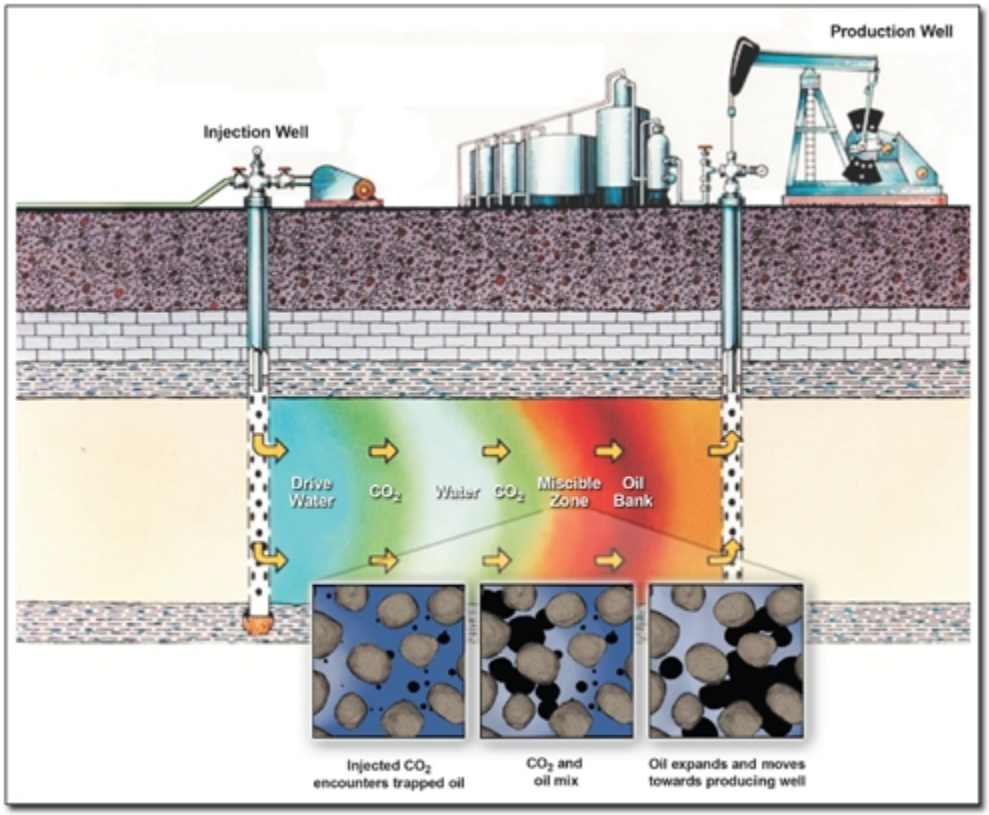
EPRI ELECTRIC POWER RESEARCH INSTITUTE

We do not grasp the scale of the problem

Enhanced Oil Recovery



EOR Economic Payback
(1) Mt CO_2 Produces (3) Barrels of Oil



NETL U.S. Carbon Storage Atlas V

Estimates of CO_2 Stationary Source Emissions and Estimates of CO_2 Storage Resources for Geologic Storage Sites

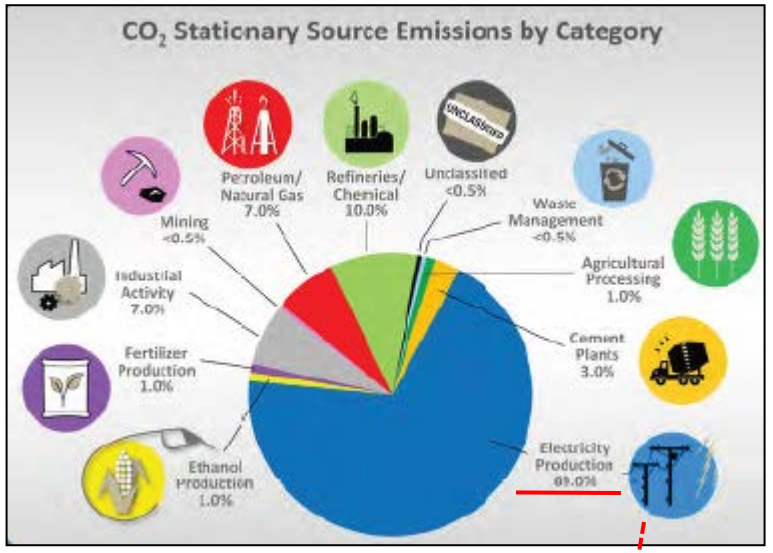
RCSP or Geographic Region	CO_2 Stationary Sources		CO_2 Storage Resource Estimates (billion metric tons of CO_2)								
			Saline Formations			Oil and Gas Reservoirs			Unmineable Coal Areas		
	CO_2 Emissions (million metric tons per year)	Number of Sources	Low	Med***	High	Low	Med***	High	Low	Med***	High
BSCSP	115	301	211	805	2,152	<1	<1	1	<1	<1	<1
MGSC	267	380	41	163	421	<1	<1	<1	2	3	3
MRCSP	604	1,308	108	122	143	9	14	26	<1	<1	<1
PCOR*	522	946	305	583	1,012	2	4	9	7	7	7
SECARB	1,022	1,857	1,376	5,257	14,089	27	34	41	33	51	75
SWP	326	779	256	1,000	2,693	144	147	148	<1	1	2
WESTCARB*	162	555	82	398	1,124	4	5	7	11	17	25
Non-RCSP**	53	232	--	--	--	--	--	--	--	--	--
Total	3,071	6,358	2,379	8,328	21,633	186	205	232	54	80	113

Source: U.S. Carbon Storage Atlas – Fifth Edition (Atlas V); data current as of November 2014

* Totals include Canadian sources identified by the RCSP

** As of November 2014, "U.S. Non-RCSP" includes Connecticut, Delaware, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, and Puerto Rico

*** Medium = p50



Sources >25,000 tonnes

Electricity Production 69%

2005 = 2416 Mt

2012 = 0.69 x 3,071 = 2,119 Mt

U.S. Totals

2011 = 5601 (37.6%)

2015 = 5680 (37.3%)

http://www.netl.doe.gov/research/coal/carbon-storage/natcarb-atlas

Appendix

Basic Comparisons

	China	USA	India	Japan	Germany	Russia
Population - July 2015 est	1,367,485,388	321,368,864	1,251,695,584	126,919,659	80,854,408	142,423,773
Population Growth Rate	0.45%	0.78%	1.22%	-0.16%	-0.17%	-0.04%
Area - km^2	9,596,960	9,826,675	3,287,263	377,915	357,022	17,098,242
GDP - Purchasing Power Parity ($trillion)	19.4	17.6	8.0	4.8	3.8	3.7
Installed Generating Capacity GW	1,505	1,063	255	293	177	242
% of World at 5,291 GW	28%	20%	5%	6%	3%	5%
Electric Production TWh	5,650	4,048	1,052	966	585	1,064
Electric Consumption TWh	5,523	3,832	865	921	540	1,065
Aggregate Load Factor	42.9%	43.5%	47.1%	37.6%	37.7%	50.2%
Natural Gas Production - BCM	121.5	782.2	31.7	4.7	10.1	578.7
Natural Gas Consumption - BCM	180.4	759.4	50.6	134.3	77.5	409.2
Refined Petroleum Products Production - mmbbl/d	9.9	19.1	4.4	3.3	2.2	6.1
Refined Petroleum Products Consumption - mmbbl/d	10.5	19.0	3.7	4.3	2.4	2.8
Coal Production - Million Tonnes Oil Equivalent	1827.0	455.2	283.9	0.7	42.9	184.5
Coal Consumption - Million Tonnes Oil Equivalent	1920.4	396.3	407.2	119.4	78.3	88.7

Source: CIA World Factbook

World Total Installed Electrical Generating Capacity 5,291 GW

Ps…….Total Value of Outstanding Student Loans - $1.3 trillion
U.S. health care cost 2014 - 3.0 trillion

World Energy Consumption Mtoe

13,147.3 Mtoe = 521.3Quads

Million tonnes oil equivalent	Oil	Natural Gas	Coal	Nuclear Energy	Hydro electric	Renew-ables	Total	Percent of 2015 Total
US	851.6	713.6	396.3	189.9	57.4	71.7	**2280.6**	17.3%
Canada	100.3	92.2	19.8	23.6	86.7	7.3	**329.9**	2.5%
Mexico	84.3	74.9	12.8	2.6	6.8	3.5	**185.0**	1.4%
Total North America	**1036.3**	**880.7**	**429.0**	**216.1**	**150.9**	**82.6**	**2795.5**	21.3%
Brazil	137.3	36.8	17.4	3.3	81.7	16.3	**292.8**	2.2%
Total S. & Cent. America	**322.7**	**157.3**	**37.1**	**5.0**	**152.9**	**24.2**	**699.3**	5.3%
								0.0%
France	76.1	35.1	8.7	99.0	12.2	7.9	**239.0**	1.8%
Germany	110.2	67.2	78.3	20.7	4.4	40.0	**320.6**	2.4%
Italy	59.3	55.3	12.4	-	9.9	14.7	**151.7**	1.2%
Russian Federation	143.0	352.3	88.7	44.2	38.5	0.1	**666.8**	5.1%
Spain	60.5	24.8	14.4	12.9	6.3	15.4	**134.4**	1.0%
Turkey	38.8	39.2	34.4	-	15.1	3.8	**131.3**	1.0%
Ukraine	8.4	25.9	29.2	19.8	1.4	0.3	**85.1**	0.6%
United Kingdom	71.6	61.4	23.4	15.9	1.4	17.4	**191.2**	1.5%
Total Europe & Eurasia	**862.2**	**903.1**	**467.9**	**264.0**	**194.4**	**142.8**	**2834.4**	21.6%
Iran	88.9	172.1	1.2	0.8	4.1	0.1	**267.2**	2.0%
Saudi Arabia	168.1	95.8	0.1	-	-	^	**264.0**	2.0%
Other Middle East	83.3	45.4	0.8	-	1.8	0.1	**131.4**	1.0%
Total Middle East	**425.7**	**441.2**	**10.5**	**0.8**	**5.9**	**0.5**	**884.7**	6.7%
South Africa	31.1	4.5	85.0	2.4	0.2	1.0	**124.2**	0.9%
Other Africa	93.5	39.2	11.0	-	23.8	2.4	**169.9**	1.3%
Total Africa	**183.0**	**121.9**	**96.9**	**2.4**	**27.0**	**3.8**	**435.0**	3.3%
Australia	46.2	30.9	46.6	-	3.1	4.5	**131.4**	1.0%
China	559.7	177.6	1920.4	38.6	254.9	62.7	**3014.0**	22.9%
India	195.5	45.5	407.2	8.6	28.1	15.5	**700.5**	5.3%
Indonesia	73.5	35.8	80.3	-	3.6	2.4	**195.6**	1.5%
Japan	189.6	102.1	119.4	1.0	21.9	14.5	**448.5**	3.4%
South Korea	113.7	39.2	84.5	37.3	0.7	1.6	**276.9**	2.1%
Total Asia Pacific	**1501.4**	**631.0**	**2798.5**	**94.9**	**361.9**	**110.9**	**5498.5**	41.8%
Total World	**4331.3**	**3135.2**	**3839.9**	**583.1**	**892.9**	**364.9**	**13147.3**	100.0%
	32.9%	23.8%	29.2%	4.4%	6.8%	2.8%	100.0%	

U.S.
– 3.0% Renewables
– 2.5% Hydro

Renewables
– Germany 12.5%
– Spain 11.5%

Nuclear
– France 41.4%

Asia Pacific Represents 72.9% of Coal Consumption

base®e

"Practical Strategies for Emerging Energy Technologies"

53.0% Gas & Coal ⟷ **2.8% Renewables**

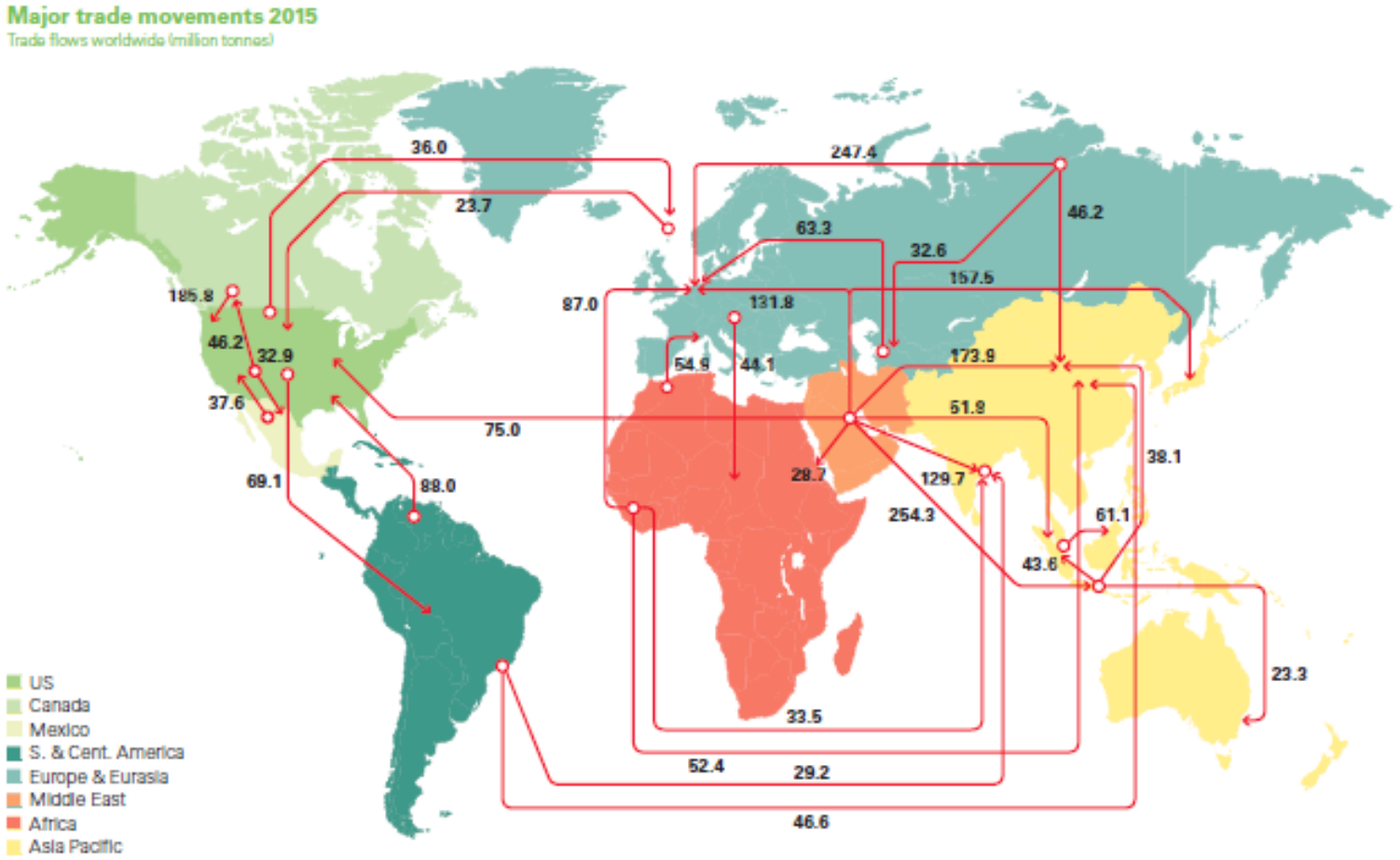
Crude Oil Production – 91.7 MMbbl/d

Oil: Production*

Thousand barrels daily	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**2015**	Change 2015 over 2014	2015 share of total
US	6900	6826	6860	6785	7264	7550	7853	8883	10059	11723	**12704**	8.5%	13.0%
Canada	3041	3208	3290	3207	3202	3332	3515	3740	4000	4278	**4385**	2.8%	4.9%
Mexico	3767	3692	3481	3167	2980	2961	2942	2912	2876	2785	**2588**	-7.0%	2.9%
Total North America	**13708**	**13726**	**13631**	**13159**	**13447**	**13843**	**14310**	**15535**	**16934**	**18786**	**19676**	**4.7%**	**20.9%**
Brazil	1713	1809	1833	1899	2029	2137	2193	2149	2114	2346	**2527**	7.9%	3.0%
Colombia	526	529	531	588	671	786	915	944	1004	990	**1008**	1.7%	1.2%
Venezuela	3308	3336	3230	3222	3033	2838	2758	2701	2678	2685	**2626**	-2.1%	3.1%
Total S. & Cent. America	**7328**	**7463**	**7295**	**7376**	**7322**	**7348**	**7401**	**7322**	**7344**	**7605**	**7712**	**1.5%**	**9.1%**
Azerbaijan	445	646	856	895	1014	1023	919	872	877	849	**841**	-1.0%	1.0%
Kazakhstan	1294	1368	1413	1483	1609	1676	1684	1662	1720	1701	**1669**	-1.9%	1.8%
Norway	2961	2772	2551	2466	2349	2136	2040	1917	1838	1889	**1948**	3.2%	2.0%
Russian Federation	9597	9818	10043	9950	10139	10366	10518	10639	10779	10838	**10980**	1.2%	12.4%
United Kingdom	1843	1666	1659	1555	1477	1361	1116	949	867	855	**965**	13.4%	1.0%
Total Europe & Eurasia	**17523**	**17587**	**17800**	**17577**	**17760**	**17699**	**17390**	**17124**	**17166**	**17206**	**17463**	**1.4%**	**19.4%**
Iran	4216	4290	4333	4361	4250	4420	4466	3814	3611	3736	**3920**	4.5%	4.2%
Iraq	1833	1999	2143	2428	2452	2490	2801	3116	3141	3285	**4031**	22.9%	4.5%
Kuwait	2668	2737	2661	2786	2500	2561	2915	3171	3134	3120	**3096**	-1.1%	3.4%
Oman	777	738	710	757	813	865	885	918	942	943	**952**	0.8%	1.1%
Qatar	1151	1241	1267	1438	1421	1638	1834	1931	1903	1893	**1898**	-0.4%	1.8%
Saudi Arabia	10931	10671	10268	10663	9663	10075	11144	11635	11393	11505	**12014**	4.6%	13.0%
United Arab Emirates	2919	3098	3002	3027	2725	2895	3320	3403	3640	3685	**3902**	5.3%	4.0%
Total Middle East	**25549**	**25764**	**25322**	**26372**	**24723**	**25827**	**28160**	**28532**	**28181**	**28557**	**30098**	**5.4%**	**32.4%**
Algeria	1990	1979	1992	1969	1775	1689	1642	1537	1485	1589	**1586**	-0.4%	1.6%
Angola	1282	1432	1699	1916	1804	1863	1726	1784	1799	1712	**1826**	6.8%	2.0%
Egypt	672	679	698	715	730	725	714	715	710	714	**723**	1.4%	0.8%
Nigeria	2527	2433	2314	2134	2234	2535	2476	2430	2321	2389	**2352**	-1.5%	2.6%
Total Africa	**9811**	**10011**	**10269**	**10246**	**9890**	**10142**	**8548**	**9327**	**8711**	**8371**	**8375**	**0.1%**	**9.1%**
China	3642	3711	3742	3814	3805	4077	4074	4155	4216	4246	**4309**	1.5%	4.9%
India	737	760	768	803	816	882	916	906	906	887	**876**	-1.1%	0.9%
Indonesia	1096	1018	972	1006	994	1003	952	918	882	852	**825**	-3.0%	0.9%
Total Asia Pacific	**7978**	**7937**	**7961**	**8088**	**8039**	**8424**	**8287**	**8378**	**8254**	**8310**	**8346**	**0.5%**	**9.1%**
Total World	**81896**	**82487**	**82277**	**82818**	**81182**	**83283**	**84097**	**86218**	**86591**	**88834**	**91670**	**3.2%**	**100.0%**

Source: BP Statistical Review of World Energy 2016

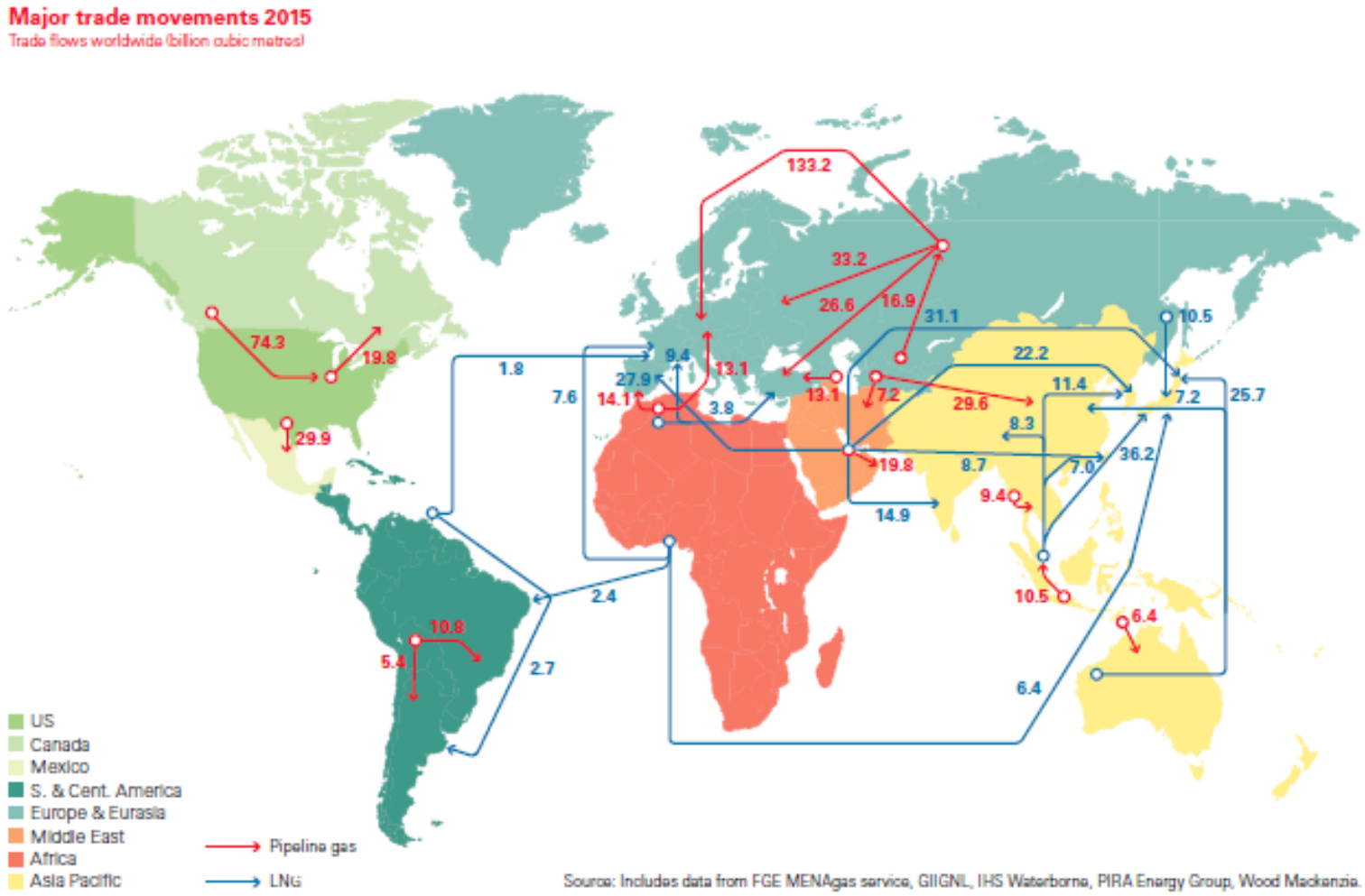
Crude Oil Trade Movements -2015



Total Trade 61.2 MMbbl/d is approximately 2/3rd of consumption

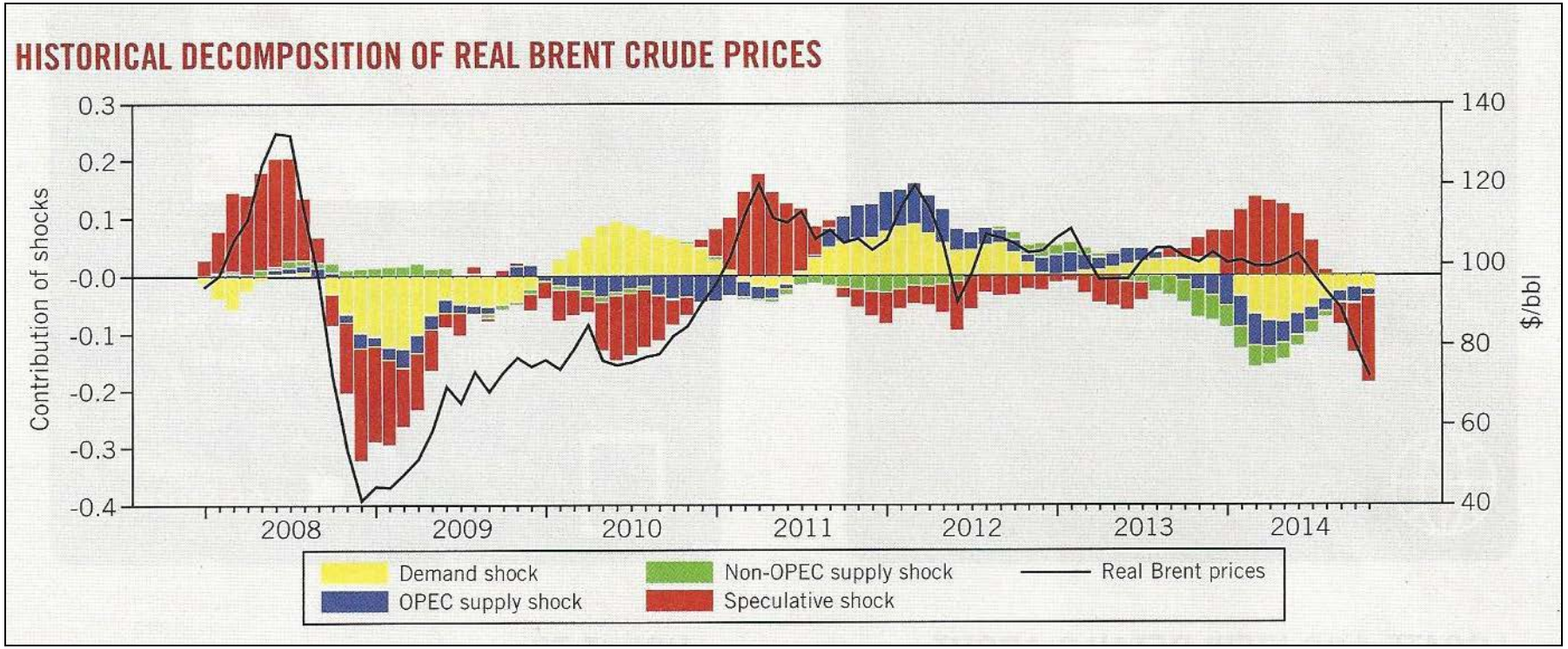
Source: BP Statistical Review of World Energy 2015

Major Natural Gas Trade Movements BCM - 2015



Source: BP Statistical Review of World Energy 2016

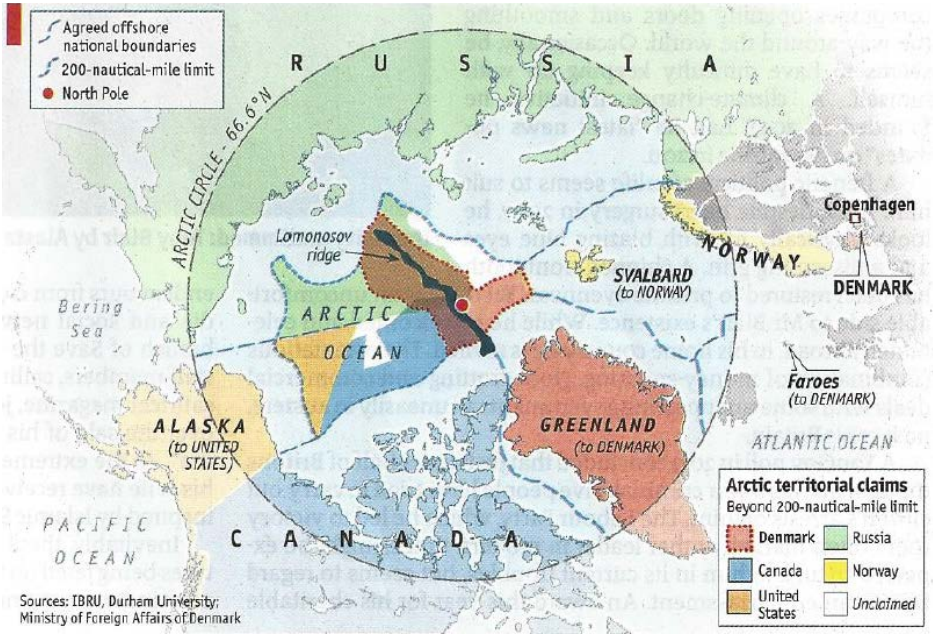
O&G Journal – Conglin Xu



Source: O& G Journal Jan 2015

Arctic Oil & Gas

- Estimated 13% (90 billion barrels) of the world's undiscovered conventional oil
- 30% of its undiscovered conventional natural gas
- Costs to develop reserves in the region can be 50-100% more than similar projects undertaken in Texas.
- Profitable development challenging due to the following factors:
  - Equipment needs to be specially designed to withstand the frigid temperatures.
  - On Arctic lands, poor soil conditions
  - Long supply lines
  - Natural gas hydrates can pose operational problems
  - Natural gas development could be impeded by the low market value of natural gas relative to that of oil. and higher transportation costs
  - Environmental issues include the preservation of animal and plant species unique to the Arctic
  - The adequacy of existing technology to manage offshore oil spills in an arctic environment



The Economist 2014

- Overlapping and disputed claims of economic sovereignty.
  - Exclusive Economic Zone (EEZ)- countries have exclusive rights to seabed resources up to 200 miles
  - Beyond the EEZ, assessments of "natural prolongation" of the continental shelf may influence countries' seabed boundaries.