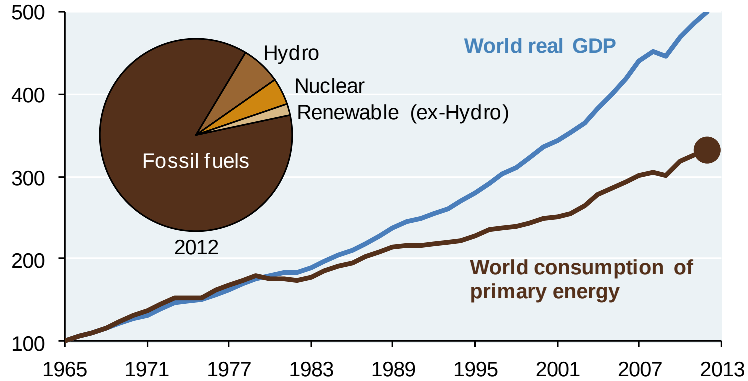
Our annual energy update: a reality check **October 28, 2013**

While the world has become more energy efficient, it still uses a lot of energy to grow (twice as much as in the 1970s), and most of it based on fossil fuels. Perhaps even more than fiscal policy, energy issues create a lot of debate. Some developed countries have been restricting coal, while others have curtailed either nuclear and/or offshore petroleum drilling. At 300 universities in the United States, students have taken to petitioning their respective endowments to divest from the roughly 2% they have invested in fossil fuel stocks (how that would actually translate into greater renewable energy production and consumption escapes me). At the same time, the developing world has been subsidizing fuel and electricity consumption by $450 billion per year according to the IMF, providing over 90% of such subsidies worldwide.

A more efficient but still energy-intensive world
Index (1965 = 100), with inset 2012 energy consumption breakdown



Source: BP Statistical Review of World Energy, OECD. June 2013.

For the last few years, we have prepared an annual paper on the 5 most interesting energy trends of the year, working closely with Vaclav Smil from the University of Manitoba (see biography below; according to Bill Gates, there is no author whose books he looks forward to more). This year's version is a **Reality Check,** focusing on how the world is doing in its attempt to migrate away from carbon-intensive and nuclear energy, as well as on efforts by the United States to attain energy independence and find offshore buyers for its natural gas.

Here are the topics for 2013; they are followed by some concluding thoughts.

1. An update on US energy independence and why it is unlikely to be accompanied by much lower oil prices
2. A growing cottage industry: estimating the system-wide costs of renewable energy as its share of generation increases
3. Is there too much optimism regarding the development of US liquified natural gas (LNG) exports?
4. Coal, which is at its highest level as a share of global primary energy consumption since 1970
5. Japan's reconsideration of nuclear generation in the face of rising gas prices, despite a worsening situation at Fukushima

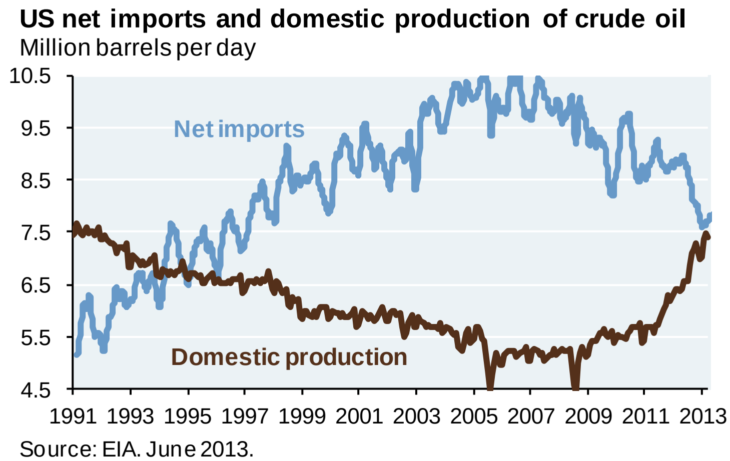
One common denominator: the US is likely to maintain its current advantage of lower electricity prices for households and businesses (50% of European levels and 55% of China's), and is gradually moving towards greater energy independence. After a decade of limited wage increases and a weak dollar, the US is in a position to benefit from an increase in foreign direct investment and the repatriation of certain high-wage manufacturing jobs.

Michael Cembalest
J.P. Morgan Asset Management

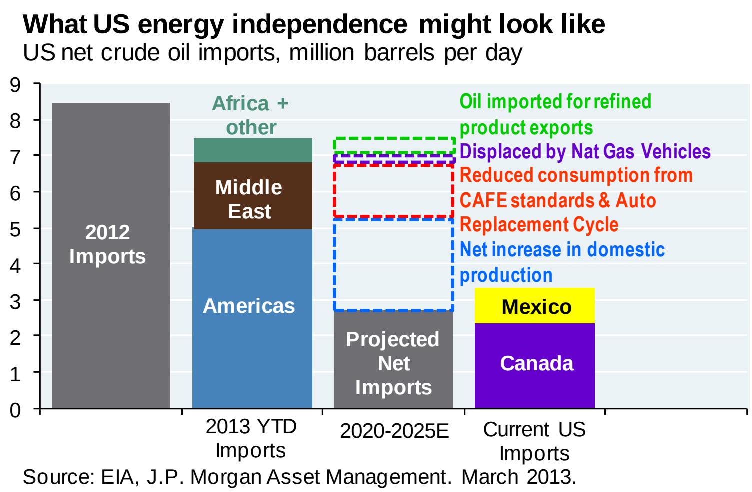
Biography
Vaclav Smil is a Distinguished Professor Emeritus in the Faculty of Environment at the University of Manitoba in Winnipeg and a Fellow of the Royal Society of Canada. His interdisciplinary research has included the studies of energy systems (resources, conversions, and impacts), environmental change (particularly global biogeochemical cycles), and the history of technical advances and interactions among energy, environment, food, economy, and population. He is the author of 35 books and more than four hundred papers on these subjects and has lectured widely in North America, Europe, and Asia. In 2010 *Foreign Policy* magazine listed him among the 100 most influential global thinkers.

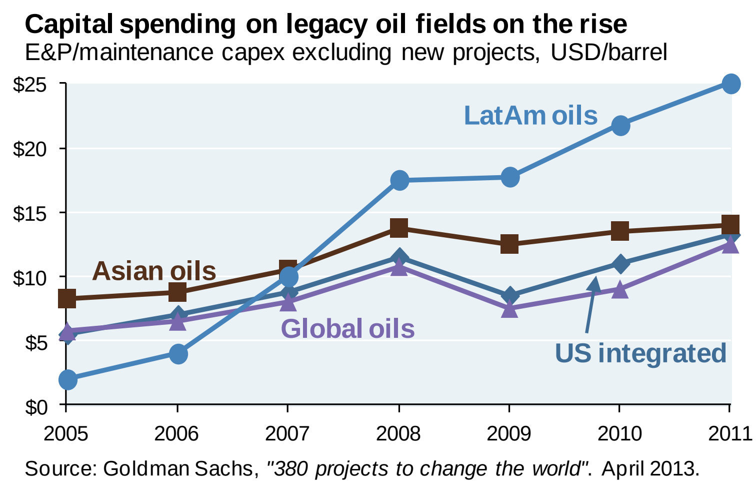
1. An update on US energy independence and why it is unlikely to be accompanied by much lower oil prices

The goal of "US energy independence" is within reach, depending on how you define it. As shown in the first chart, crude oil imports have been falling and domestic production has been rising. Estimates for domestic oil production in 2020 range from 8 million to 11 million barrels per day[1].



The chart below shows what US energy independence might look like. The second bar plots today, with a breakdown of 2013 imports by region. The 3rd bar shows what US energy independence might look like in 2020-2025. US crude oil imports are projected to decline to less than 3 million bpd, a by-product of continued increases in US domestic oil production, reduced oil import needs resulting from rising CAFE standards applied to new automobile purchases[2], some displacement by compressed natural gas fleets, and after accounting for oil imported for purposes of refined product exports. At these levels, imports from Mexico and Canada alone could meet US crude oil import needs (although the private sector really determines where the US imports oil from, based on transportation and refining costs, crude grades, etc.).





The economic benefits of such an outcome could be substantial and include 3 million jobs created by 2020 (estimated by IHS/CERA and which include direct, indirect and induced jobs), and a stronger dollar. However, the US oil boom is unlikely to be accompanied by much lower oil *prices*. The reasons why can be explained as follows:

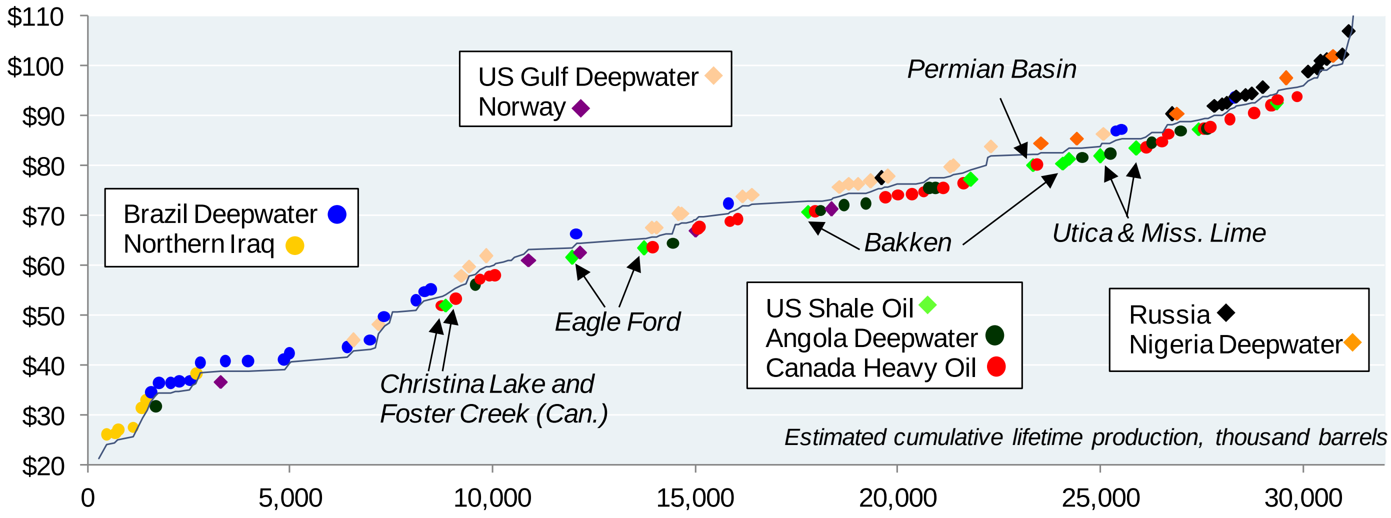
- ***Decline rates and rising capital costs of legacy fields***. The decline rates of existing fields are a well-known challenge, and range on an annualized basis from 3%-6% across the US, Europe and Latin America. Legacy fields become more capital intensive and require more investment as they age. As shown in the chart above, maintenance capex per barrel has been rising around the world for these legacy fields, raising the marginal cost of oil. For this reason, most global oil companies reportedly need prices of $100-$125 per barrel to be cash flow-neutral after capex and dividends.

[1] One of the higher forecasts is 10.4 mm bpd in 2017 from Leonardo Magueri of Harvard's Belfer Center (and formerly SVP at Italian energy giant ENI) in his June 2013 update. Magueri projects an increase in tight/shale oil production from 1.5 mm bpd in 2012 to 5 mm by 2017.

[2] The Union for Concerned Scientists estimated the benefit of CAFE at 3 million bpd by 2030, while the Administration's estimate is 2.2 mm by 2025; our estimate is more conservative, at 1.5 million. According to the University of Michigan Transportation Research Institute, the average fuel-economy value of new vehicles sold in the U.S. in May 2013 was 24.8 mpg, up by 4.7 mpg since October 2007.

- ***Rising cost of US shale oil production outside Eagle Ford***. While breakeven costs of $60 per barrel at Eagle Ford are comparable to conventional production, other shale location production costs are higher. Bakken costs have been rising, a function of a 15% decline in average well productivity since its peak, and infrastructure bottlenecks requiring rail transport instead of cheaper pipelines. Anadarko, Utica and Mississippi Lime cost estimates range from $70 to $90 per barrel.
- ***High cost of other marginal new supplies.*** Goldman Sachs tracks all new global oil E&P projects (recently producing, under development or pre-sanction) with more than 300 mm barrels in estimated lifetime production. As shown below, some have attractive costs: Iraq, many Brazil and US deepwater sites, Norway and 2 Canadian heavy oil sites (Christina Lake and Foster Creek). However, over the last 2 years, no new projects added to the list have breakeven costs below $70, and most have costs in the $80-$100 per barrel range, including the majority of Canadian heavy oil sites. Global oil consumption of ~90 mm bpd cannot be met just from lower cost sites, meaning that the marginal barrel of oil is often sourced from higher cost locations. Note: Russian breakeven costs shown are high primarily due to heavy taxation.
- ***The long term impact of the Arab Spring***. It will take time to sort out the consequences, but an early read on the Arab Spring shows that factionalism and tribal differences have the capacity to disrupt production and/or exports (~two-thirds of Libyan production is offline). In OPEC countries seeking to maintain the status quo, domestic spending is often high to garner popular support. OPEC countries need $100 per barrel to balance their budgets in 2015, up from $20 just a decade ago (above $100: Iran, Iraq, Russia and Algeria). The link between OPEC domestic spending and oil prices is not a direct one, but suggests that OPEC may be increasingly tempted to opt for the highest prices that the global economy can sustain.

Cost curve for new projects (recently producing, under development or pre-sanction)
USD per barrel



Source: Goldman Sachs, *"380 projects to change the world"*. April 2013.

2. A growing cottage industry: measuring the total costs of renewable energy at higher penetration levels

The pie chart on page 1 makes renewable energy (ex-hydro) seem like a rounding error in the scheme of things, but it's growing. Global solar photovoltaic and wind power capacity have risen by 60% and 25% p.a. since 2007, and in 2012, wind was the largest source of US capacity additions[3]. Falling capital costs, minimum renewable targets and generous subsidies are part of the reason. The US Energy Information Agency estimates that the all-in "levelized" cost[4] (LCoE) of new wind capacity in 2018 will be cheaper per MWh than coal, and only 20%-30% more expensive than natural gas (all numbers excluding subsidies). Some cost estimates you will find for renewable energy are even lower than the EIA's.

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[3] We will have to watch future renewable energy capacity additions closely: global renewable *investment* fell in 2012 vs. 2011 and in 2013 vs. 2012, in part a reflection of declining European subsidies.

[4] **Levelized cost of electricity** measures the all-in cost of generating a MWh of electricity, and incorporates upfront capital costs, financing costs, ongoing operating & maintenance and fuel costs, and each technology's capacity factor (actual output vs. potential output).

Unfortunately, there's a Rashomon effect in play: different analysts see the levelized cost picture very differently. **And to complicate matters further, these levelized costs don't even capture the entire cost structure of renewable energy.** In the table below, we show estimates of levelized cost (excluding subsidies) from the EIA alongside wind and solar estimates from Lazard, which are considerably lower. The variances reflect different sample universes (with Lazard focusing on more optimal locations and EIA focusing on national averages), and different assumptions regarding continued productivity advances. We also show estimates from the Lawrence Berkeley National Laboratory (LBNL) for cross-checking purposes. LBNL costs for solar PV are higher than Lazard's, but reflect projects that were *completed* in 2012 and *contracted and paid for* 2-3 years earlier when capital costs were higher. According to the Solar Energy Industries Association capital costs have fallen by 45% since Q2 2011 (mostly due to the collapse in solar PV panel prices from $2 to 70 cents). Another observation: Investors in utility-scale PV plants now describe projects for delivery in 2015-16 as having upfront costs in the $2,000 per KW range, which is more consistent with Lazard's estimates than EIA's. As for operating and maintenance costs, Lazard's are considerably lower; more time will be needed to assess steady-state O&M costs of utility-scale wind and solar. **Bottom line: on a stand-alone basis in the best locations, renewable energy costs are declining and probably cheaper than EIA estimates.**

The Rashomon effect: different views of renewable energy's levelized costs

	LCoE EIA	Capital costs, $ / KW	Operat/ Maint, $ / KW	Capacity factor %	LCoE Lazard	Capital costs, $ / KW	Operat/ Maint, $ / KW	Capacity factor %	LCoE LBNL	Capital costs, $ / KW	Operat/ Maint, $ / KW	Capacity factor %
Combined Cycle Nat Gas	$ 67											
Onshore Wind	$ 87	$ 2,175	$ 38.9	34%	$45 - $95	$1,500 - $2,000	$ 30.0	30% - 52%	$62 - $72	$ 1,940	$ 57.0	25% - 45%
Geothermal	$ 90											
Hydropower	$ 90											
Conventional Coal	$ 100											
Biomass	$ 111											
Solar Photovoltaic	$ 144	$ 3,805	$ 21.4	25%	$89 - $99	$1,750 - $2,000	$13 - $20	21% - 28%		$ 3,500	$ 28.0	25%
Concentr. Thermal Solar	$ 262											

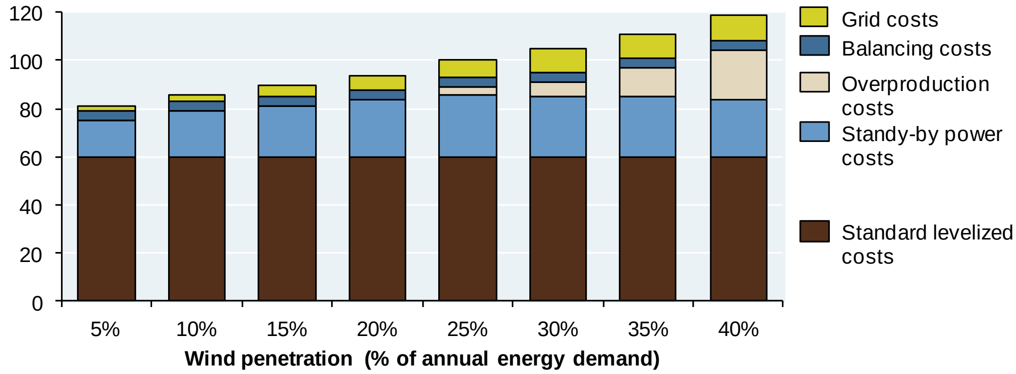
Sources: EIA - January 2013. Lazard's Levelized Cost of Energy Analysis 7.0 - August 2013. Lawrence Berkeley National Laboratory - September 2013. Excludes subsidies.

These three entities do agree on one thing: levelized cost estimates do not incorporate all of the costs that occur when significant alternative energy installations are added. A typical electricity system might rely on coal and nuclear for baseload power, on hydro/natural gas for peaking needs, and then add solar/wind capacity. When large amounts of solar/wind are introduced into the grid, there are additional costs which LCoE does not capture. Recent studies categorize them as follows:

- *Stand-by power costs*: when renewable energy is first added, the grid can sustain similar capacity reductions in conventional "dispatchable" power (natural gas, hydro, coal, etc.). When renewable penetration rates rise, further possible reductions in dispatchable power decline given intermittency of solar/wind and the need for adequate generation to meet peak demand. **While fossil fuel *usage* would decline with more renewable capacity, the costs to build/maintain dispatchable capacity decline at a much slower pace.**
- *Over-production costs*: when wind/solar penetration is high, plants at times over-produce relative to demand, given the inability for baseload power to make further reductions below operational minimums (coal, hydro and nuclear). This over-production may (as is the case in Germany) strain existing grids and require construction of more expensive HVDC links.
- *Balancing costs*: the costs of turning peaking facilities on/off or ramping on-line generators up and down.
- *Grid transmission*: every technology entails transmission costs, but high-quality wind and solar installations are generally situated further from the grid than thermal power.

Here's an example: authors from the Potsdam Institute for Climate Impact Research estimated system-wide costs of wind in Germany. As shown in the chart on the next page, if wind's share of electricity reached 20%, **its system-wide costs could be 50% higher than traditional LCoE estimates**. The practical implications of all of this can be seen in many recent assessments of Germany's electricity supply. While the country's large industrial consumers are exempt from paying higher, subsidized, renewable electricity prices (although they still pay far more than their US counterparts), rapidly rising higher costs are passed to increasingly struggling households, a situation that is becoming politically untenable. This has led to a recent decline in government subsidies and tax benefits for renewable energy in Germany, and in Greece and Spain as well.

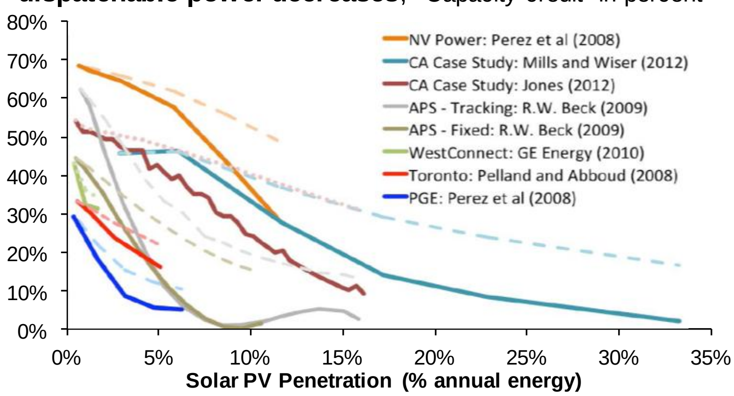
Total system costs of wind in Germany
System costs at increasing wind shares, EUR per MWh



Source: Potsdam Institute for Climate Impact Research. January 2013.

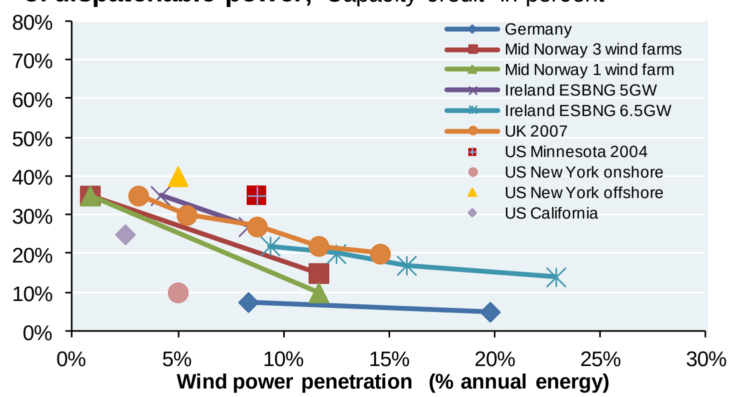
In a similar vein to the Potsdam analysis, Berkeley National Laboratory compiled various estimates of conventional power capacity declines that can be sustained as solar/wind rise, referred to as "capacity credits". As per the below, the first 100 MW of solar PV added to the grid allows for reductions of 40-70 MW in dispatchable capacity. However, as solar penetration reaches just 10%, sustainable reductions in dispatchable capacity shrink and may be as little as 20-40 MW. Capacity credit estimates for wind are similar, as shown in the second chart. Capacity credits for wind are typically lower than solar since solar power tends (in most places) to coincide with peak energy demand. **Simply put, declining capacity credits reflect possible diminishing returns as renewable energy use rises as it relates to the cost of building/maintaining dispatchable power.**

As solar capacity increases, its replacement potential of dispatchable power decreases, "Capacity credit" in percent



Source: A.Mills and R.Wiser, Berkeley National Laboratory. December 2012.

Same for wind, and with lower possible displacement of dispatchable power, "Capacity credit" in percent



Source: A.Mills, Berkeley National Laboratory. IEA Wind Task 25. 2009.

All authors point out that they are not including any assessment of the benefit of lower CO_2, SO_2 and NO_X emissions. Juxtaposing this section with the one on coal (#4) leads to the following conclusion: for environmental reasons, the world should ideally reduce reliance on coal, or at least stop its rate of growth. However, if solutions rely on large contributions from wind and solar power, there are system-wide costs and return on capital issues which need to be taken into account, and which are not captured by traditional LCoE data. Here are a few approaches that could mitigate these incremental renewable energy costs:

- Invention/adoption of utility-scale electricity storage (over 95% is currently done through pumped hydro storage[5])
- Load shifting, which requires commercial and retail customers to use electricity at different times (e.g., at night)
- Greater regional integration of transmission grids; feasible but expensive, and complicated given eminent domain issues

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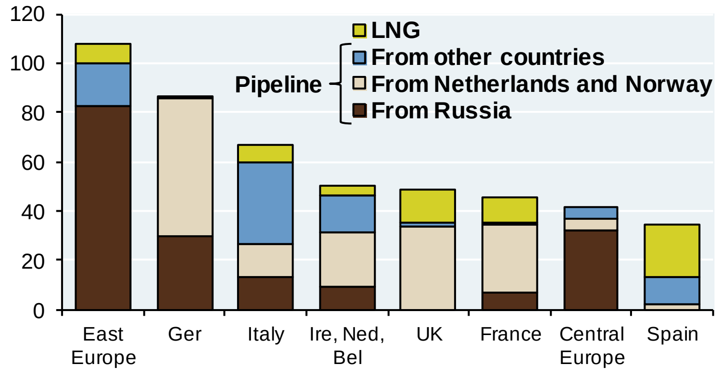
[5] **There are 22 GW of pumped storage in the US with permits for an additional 50 GW**. This works out to ~ 1.75% of US electricity generating capacity. From a *flow* perspective, pumped storage is a net *consumer* of electricity since more electricity is used to pump water uphill than is generated by flowing water downhill through a turbine. However, since daytime demand can be 1.6x higher than at night, pumped storage can create *economic* value, depending on its capital cost. Not much progress has been made to-date on utility-scale battery storage; both lithium ion and sodium sulfur batteries store 2-10x the amount of energy required to build them, while the pumped storage ratio is more than 200x.

3. Is there too much optimism regarding future US liquefied natural gas exports?

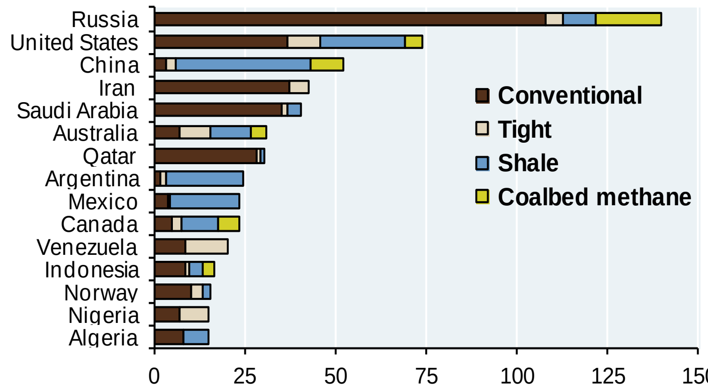
There are more than 20 proposed liquified natural gas export facilities in the United States, with requests to export 40% of the US gas supply or ~30 billion cu ft per day. The earliest expected completion dates are in 2017/2018. Who are the projects' owners planning to sell the gas to, and at what prices? A discussion of LNG export competition should start with Russia and its enormous resources of gas shown in the first chart. Over time, its recoverable reserves may exceed 2011 estimates by the IEA.

Crowded marketplace for natural gas imports into Europe, billion cubic meters



Source: BP Statistical Review of World Energy. June 2013.

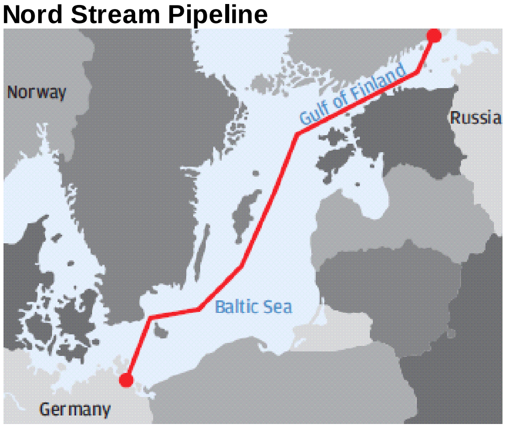
Russia dominates estimates of recoverable gas resources
Trillion cubic meters



Source: IEA. October 2011.

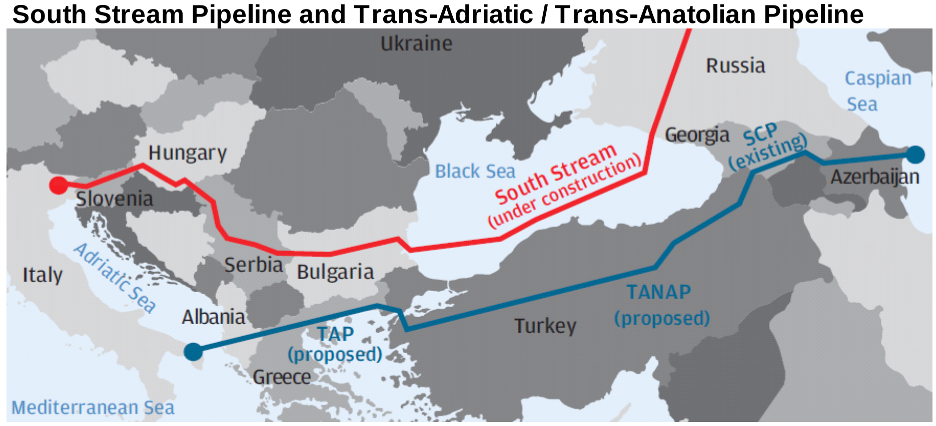
Let's look at potential European LNG customers for US exporters. As shown above, Russia appears to have Eastern and Central Europe locked down. The largest European gas user is Germany, which has developed a close relationship with Russia based on the Nord Stream pipeline, completed in 2012. Nord Stream is owned 51% by Gazprom; German gas companies own another 31%. Another indication of the partnership: former German chancellor Gerhard Schröder is the Chairman of the Nord Stream Shareholders' Committee. Germany's remaining gas imports come from the Netherlands and Norway.

Nord Stream Pipeline



Source: JPMAM, Nord Stream project official website.

South Stream Pipeline and Trans-Adriatic / Trans-Anatolian Pipeline



Source: JPMAM. South Caucasus, South Stream, Trans-Adriatic and Trans-Anatolian official websites.

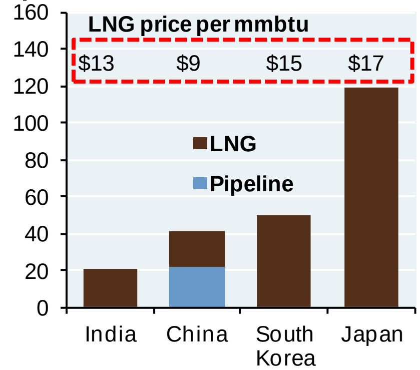
To further cement its penetration of Eastern and Southern Europe, Russia is building another pipeline, South Stream. Its construction began late last year, with commercial deliveries expected in 2015/2016. For a host of geopolitical reasons, South Stream bypasses Ukraine and traverses Turkish territorial waters instead. South Stream will compete with the proposed Trans-Adriatic/Trans-Anatolian Pipeline (TAP/TANAP), a project that would bring natural gas from Azerbaijan through the existing South Caucasus pipeline across Turkey to Central Europe[6]. **Should South Stream and TAP be built, they would further increase the supply of natural gas transported to Europe from the East without the cost and complexity associated with US LNG imports**.

[6] Nabucco, a project supported by Europe and the United States to reduce European reliance on Russian gas, has apparently been scrapped. The President of Romania has reportedly asked for compensation from the EU for having supported the project instead of South Stream.

Now let's take a look at Western Europe. According to BP data for 2012, the UK and Spain do not import Russian gas, and France, Italy and Belgium only import modest amounts. However, all of these countries already import LNG, nearly 60 bn cubic meters per year out of a total of 330 bn cubic meters of LNG imported worldwide in 2012, mostly through long term contracts with Qatar and Algeria. In terms of cost, the IEA estimated in 2009 that LNG shipping costs from the Caribbean were twice the pipeline costs from Algeria to Spain. As a result, part of any US cost advantage could be eroded through higher shipping costs.

Instead, US LNG exporters are targeting large LNG importers in Asia where prices are high. South Korean, Indian, Japanese and European companies have signed offtake agreements with several US Gulf Coast and East Coast projects. As for China, it plans to develop its own shale gas, but the country's basins are less easily accessed than those in the US, more difficult to develop and in water-short regions. Consequently, China will probably need to *import* gas to make headway in reducing coal consumption. Regarding US East Coast and Gulf Coast exports to Asia: the expanded Panama Canal (2014) will make the trip shorter, but require higher usage tolls for LNG tankers. While Asia is promising, Russia comes back into the picture as well. Gazprom has proposed 60 bn cubic meters of gas capacity from Western Siberia to North-Western China. This project is on hold given disagreements about pricing, but may re-emerge once incentives are aligned.

Asia importing a lot of LNG at high prices, billion cubic meters

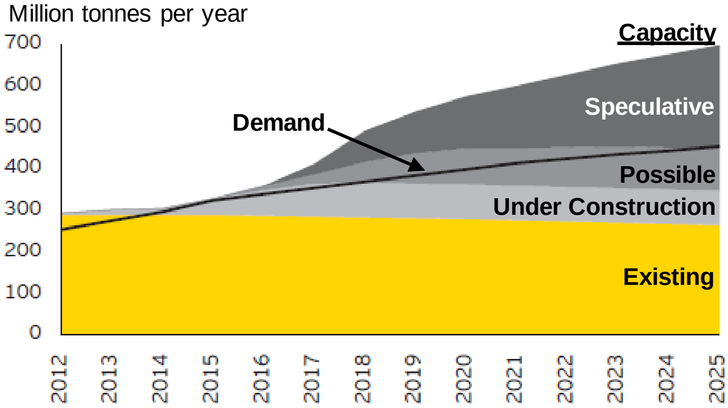


Source: Bloomberg, BP, FERC. June 2013.

The challenge for LNG exporters is that supply will grow with demand. If all proposed LNG export projects were developed, capacity could double by 2025, resulting in price competition and upward pressure on development costs. Australian operators are pursuing projects equal to 25% of global LNG demand. Good news for some US exporters: their "brownfield" sites (existing infrastructure built when the US was expected to be an LNG *importer*) have a 30%-40% cost advantage over newer sites, and even larger advantages vs. Australian projects sponsored by Chevron and Inpex (Japan). In Australia, the rising costs of steel/labor and a strong currency have resulted in 20%-30% project cost increases since 2009. Western Canada will be interesting to watch: even though many of its sites are new, its incremental capital costs are offset by lower shipping and raw materials costs. Furthermore, the gas is less critical to Canadian electricity generation.

In theory, importers of US LNG would have to pay around $10-$11 per mm btu, assuming a spot natural gas price in the US of $4. The import cost includes expenses associated with shipping, liquefaction and capacity charges[7]. Natural gas prices in Asia are above this level now, but this is partly a consequence of Fukushima whose impact may be partially resolved through a resumption of nuclear power, and future gas exploration/production in Russia.

Some estimates of future LNG capacity exceed demand
Million tonnes per year



Source: Ernst & Young. March 2013.

Based on Sabine Pass, US LNG exports are cheaper than Asian imports, USD per mmbtu

Henry Hub	$3.00	$4.00	$5.00
Liquefaction	0.45	0.60	0.75
Capacity charge	3.00	3.00	3.00
Shipping	2.51	2.51	2.51
Total indicated cost	$8.96	$10.11	$11.26

Source: Deutsche Bank, Cheniere Energy Inc. September 2012.

[7] The capacity charge in the table is the amount paid by the LNG importer to the exporter irrespective of actual usage, and is the amount the LNG exporter receives to cover capital costs on a multi-billion dollar facility, interest costs and a return on capital.

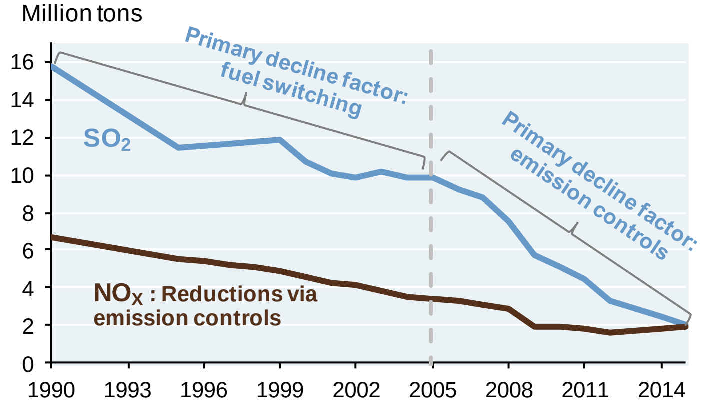
The question for US LNG companies looking to export 30 bn cu ft per day: how deep is the pool of actual buyers? Sabine Pass, Freeport, Dominion Cove and Lake Charles have found LNG counterparties and have been approved by the DoE (even with non-Free Trade counterparties signing on). These projects represent ~6.4 bn cu ft per day. There are two other projects (Cameron and Freeport Expansion) with another 3.1 bn cu ft in the near-term approval pipeline. However, these volumes and other proposed projects may overstate the US LNG that will actually be exported in the future. Contracts have only been signed on 25-30% of proposed projects, since there may be a limit to demand for US "lean" gas (which has more methane and ethane in it) compared to richer gas elsewhere. In addition, some contract signers are intermediaries and can cancel if they can't find end-buyers, and others may be hedging their bets by over-committing without the intention of signing a final investment decision, and are simply waiting to see who can get the necessary financing. **This is perhaps why energy research and consulting firm Wood Mackenzie only expects 20-25% of proposed US LNG projects to make it through governmental, environmental and financing stages and actually export LNG.** Another factor: US natural gas production has been a beneficiary of cheap capital for drilling. If the supply of capital constricts, the effect on production could be noticeable, given the steep decline rates of shale gas production.

4. Don't look now, but coal usage is actually rising, despite its environmental and health impacts

Here are some environmental consequences from coal in the US, courtesy of the Union of Concerned Scientists, Harvard's Public School of Health and the Clean Air Task Force:

- Coal-fired power plants are a top source of **carbon dioxide**, **smog, acid rain** and **heavy metals** emissions. Sulfur dioxide (SO_2) and nitrogen oxides (NO_X) are two of the worst: in the atmosphere, they are converted into sulfates and nitrates, acidic particles that penetrate into human lungs and can be absorbed into the bloodstream. Since the 2005 Clean Air Interstate Rule, coal plant SO_2 and NO_X emissions have fallen sharply[8]. However, a coal plant with emissions controls can still emit several thousand tons of SO_2 and NO_X per year, as controls are only 70%-85% effective. The industry-wide projection by the EPA of a combined 4 million tons per year in 2014 still creates substantial and widespread health and environmental damage.

US declines in coal-fired SO_2 and NO_X emissions
Million tons



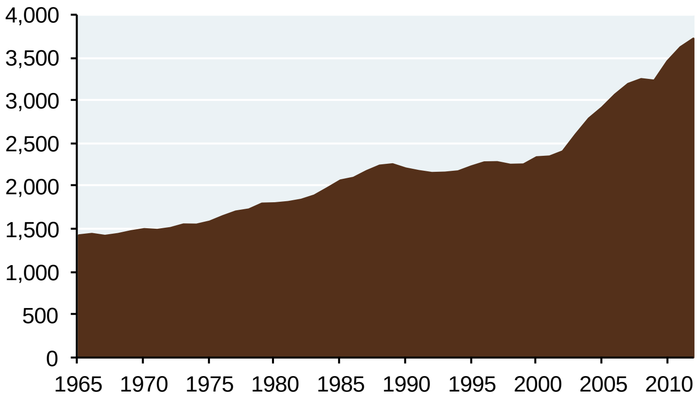
Source: US Environmental Protection Agency. December 2012.

- Coal plants also create more than half of anthropogenic emissions of **mercury**, which causes brain damage and heart problems, particularly in children exposed in utero from fish consumed by their mothers. Over 40 states have consumption advisories on fish due to mercury poisoning. Activated carbon injection technology can reduce mercury emissions by up to 90% when combined with baghouse filters and controls like sulfur scrubbers. The Mercury Air Toxics Standards rule was promulgated by the EPA in 2010, but utilities have until 2015 to comply, and the rule is currently under court challenge by the coal industry and some US states.
- **Mountain top removal**: 500 Appalachian summits have been removed, impacting 1.4 million acres. Over 2,000 miles of streams have been buried, and there are 2,500 miles of polluted streams in Kentucky alone. The deforestation and landscape changes associated with mountain top removal also impact carbon storage and water cycles.
- **Sludge, slurry and "fly ash" ponds**: Thousands of sludge and slurry ponds lie near coal mines and processing plants. Roughly 1,300 impoundments adjacent to coal-fired power plants store fly ash captured from combustion gases, and receive 130 million tons of waste annually which is known to contain radioactive elements and toxins. There are waste heaps near abandoned coal mines and persistent underground fires in some coal seams.

[8] SO_2 emissions were first reduced in the 1990's through fuel switching to lower-sulfur coal, and then by fuel switching and emissions control technology. The 1990 Acid Rain law capped SO_2 emissions and resulted in the use of flue gas desulfurization ("scrubbers"), and controls for all but carbon dioxide emissions are mandatory through federal and state regulations.

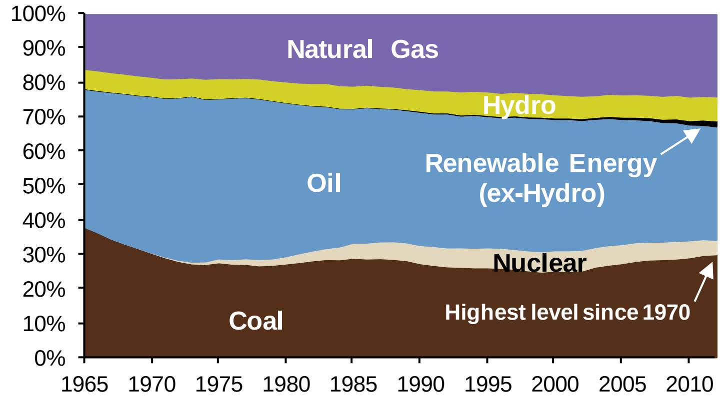
Coal's impact is likely similar or worse in other countries (and is worth keeping in mind when thinking about environmental costs and benefits of natural gas and nuclear). **You might think that given what's known about coal, its usage would be in decline.** Not so; as shown below, 2012 marked the greatest amount of global coal usage on record, and amazingly, its largest share of global primary energy consumption since 1970. According to the BP Statistical Review of World Energy, coal is the fastest-growing fossil fuel, and the IEA predicts coal use will increase 50% by 2035.

World consumption of coal on the rise
Million tonnes oil equivalent



Source: BP Statistical Review of World Energy. June 2013.

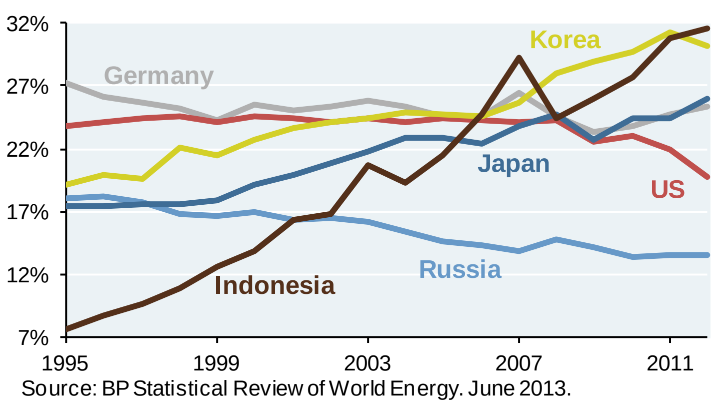
World consumption of primary energy still dominated by fossil fuels, percent



Source: BP Statistical Review of World Energy. June 2013.

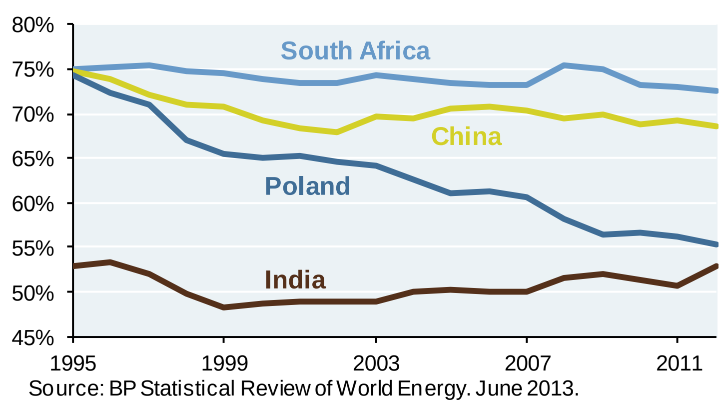
Let's look at the details. Ten countries account for 85% of all coal usage worldwide. We divide them below into countries with diversified energy sources (coal at less than a third of energy consumption), and countries with higher, concentrated reliance on coal. **In the first group, US coal reductions are notable (20% capacity shutdowns are expected from 2011-2018), but this may be a consequence of collapsing gas prices, a trend which has run its course.** In countries like Germany and Japan, coal use has been *rising*. In Germany, which is the paragon of a hard shift toward renewable energy (*die Energiewende*), coal consumption rose by 10% between 2009 and 2012! Amazing but true: as the US switched from coal to natural gas-powered electricity, US carbon emissions hit their lowest level since 1994. As a result, **the US has overtaken most European countries in meeting the goals of the Kyoto protocol**, despite never ratifying the climate change agreement.

World's biggest coal consumers: diversified
Coal as a percentage of total primary energy consumption



Source: BP Statistical Review of World Energy. June 2013.

World's biggest coal consumers: concentrated
Coal as a percentage of total primary energy consumption



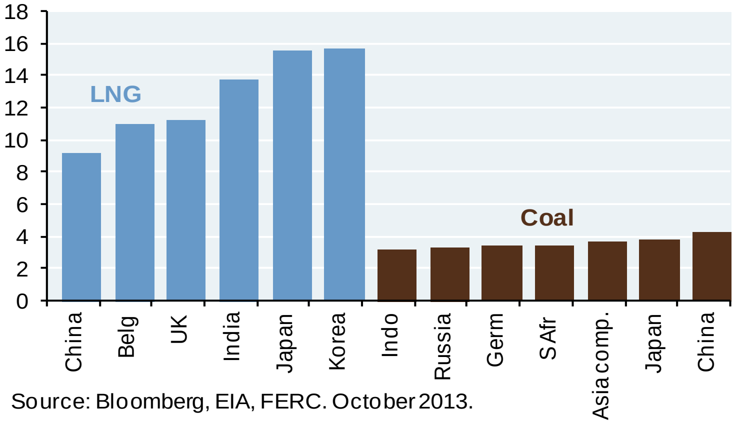
Source: BP Statistical Review of World Energy. June 2013.

Among countries that have more concentrated reliance on coal, their coal usage is flat, with the exception of Poland's substantial decline. In coal *volume* terms, given rising energy consumption, India and China have seen enormous growth in coal consumption. Between 2000 and 2012, India's coal consumption doubled and China's rose 2.7 times. China's rapid expansion of renewable electricity (hydro, wind and solar) is impressive; its wind power production rose by more than coal power for the first time in 2012, and China now generates more electricity from wind than nuclear. However, China's electricity generation is only anticipated to reduce its coal share of primary energy use by 5% by 2017.

Why does coal consumption remain so high?

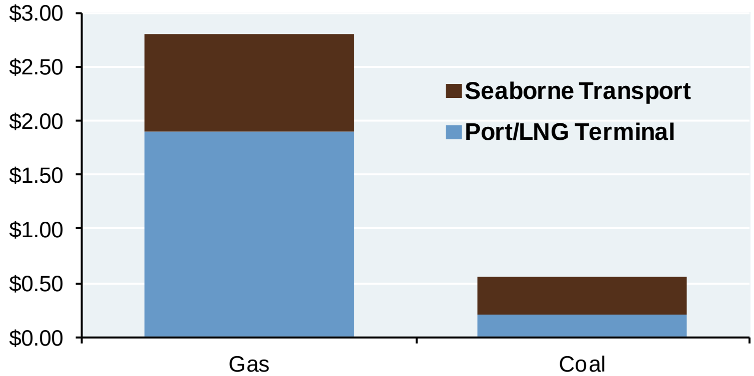
- For countries without sufficient domestic natural gas reserves, coal can be much cheaper to use than imported natural gas (first chart below)
- Operating & maintenance ("O&M") costs are often higher for coal than natural gas. However, according to IEA estimates, fuel costs are much higher than O&M costs, such that the benefit of cheaper raw material prices for coal end up dwarfing their higher operating costs. For coal, fuel costs are 5x O&M costs, and for natural gas, 12x. In addition, shipping costs for LNG are 4x-6x higher than for coal (second chart).

Global LNG and coal prices
USD per mmbtu



Source: Bloomberg, EIA, FERC. October 2013.

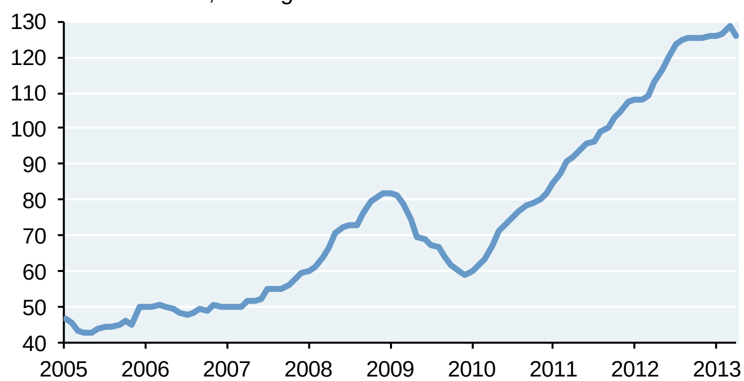
Typical cost breakdown for 5,000 km transport
USD per gigajoule



Source: IEA. December 2012.

Since coal's many externalities are not included in its price, even in countries with a carbon tax, it often remains a cheaper option. One example: according to 2010 IEA analysis, combined O&M and fuel costs of natural gas in Germany were 2.5x higher than coal. Even after a carbon tax of $30 per tone which penalized the more carbon-intensive consequences of coal production, natural gas was still 1.5x more expensive than coal. While some countries are taking steps to reduce reliance on coal, its low cost (assuming sunk capital costs on plant construction) make it an addiction that's hard to shake. Unless coal prices were to incorporate more of the previously noted externalities, we cannot expect major reductions in global coal consumption. Just the opposite has been happening: as shown, US coal exports to the rest of the world have been rising.

US total coal exports
Million short tons, trailing 12-months

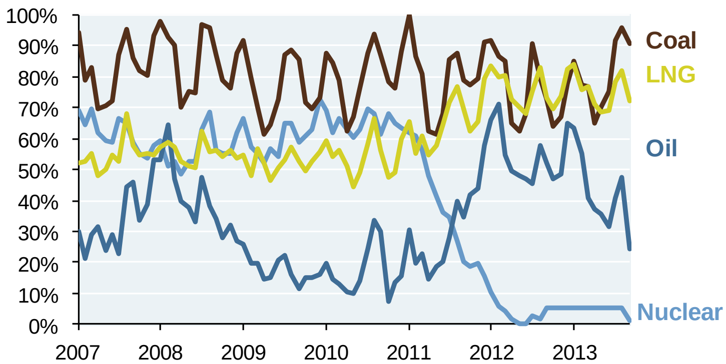


Source: EIA. April 2013.

5. Japan's second thoughts: a likely rebirth of its nuclear energy industry, even as the Fukushima disaster worsens

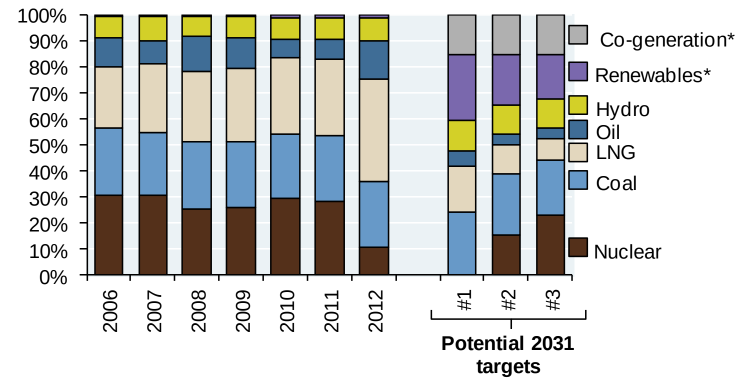
In the wake of the March 2011 Fukushima Dai-ichi disaster, Japan shuttered nearly all of its nuclear generating capacity, idling 52 of 54 reactors. Nuclear plants were operating at close to 70% capacity in early 2011, and are now at less than 5%. In 2012, Japan released a long-term plan designed to dramatically alter the source of its electricity by 2030. Each iteration of the plan relies on less crude oil and LNG and more on both renewable energy and contributions from waste-heat co-generation. This is quite an ambitious plan, since both renewable energy and co-gen are currently negligible. The second chart shows a history of Japanese power generation, and 2030 plan iterations.

Japan's power plant capacity utilization by fuel type
Percent



Source: Federation of Electric Power Companies of Japan, J.P. Morgan Commodities Research. September 2013.

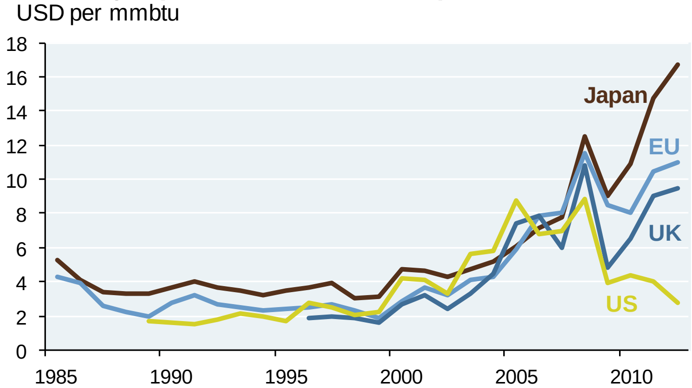
Current / 2031 targets for Japanese power generation
Percent



Source: Federation of Electric Power Companies of Japan, METI Advisory Committee. August 2012. * = Current contribution is negligible.

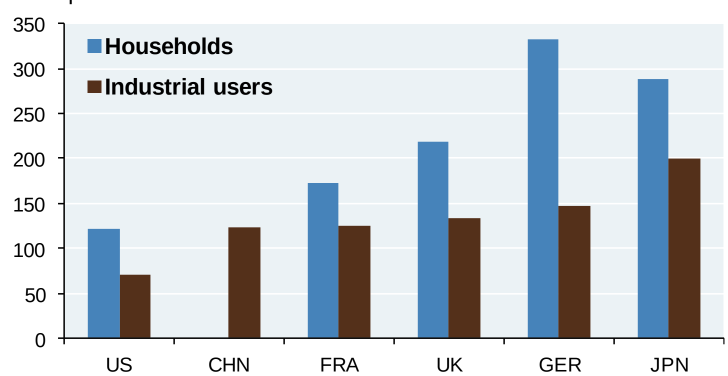
More than two years after Fukushima, Japan may be considering a re-embrace of nuclear energy. The reasons are simple: natural gas prices are extremely high in Japan relative to the rest of the world (causing the country's import tab for LNG to rise sharply), and so are its electricity prices. In 2013, Japanese electricity prices went up 12-18% for commercial users, and 8-12% for households. Since Japan imports 84% of its total energy requirements, the former Japanese director general of the IEA is concerned that Japan could be headed for trouble if events in the Middle East push up the price of its oil and gas imports further.

Natural gas prices: the Fukushima premium
USD per mmbtu



Source: BP Statistical Review of World Energy. June 2013.

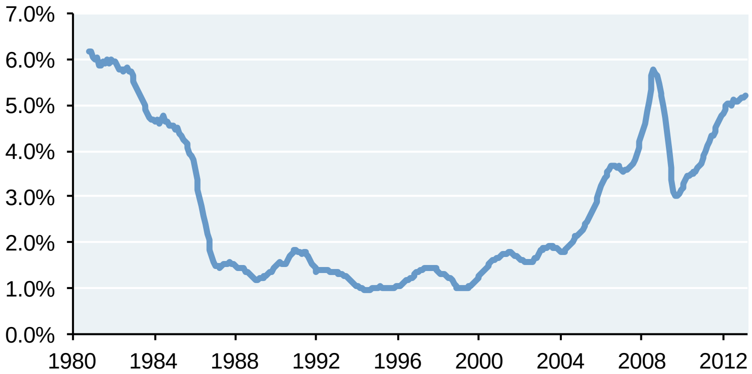
Electricity prices by region
USD per MWh



Source: IEA, National Development and Reform Commission. Q2 2012.

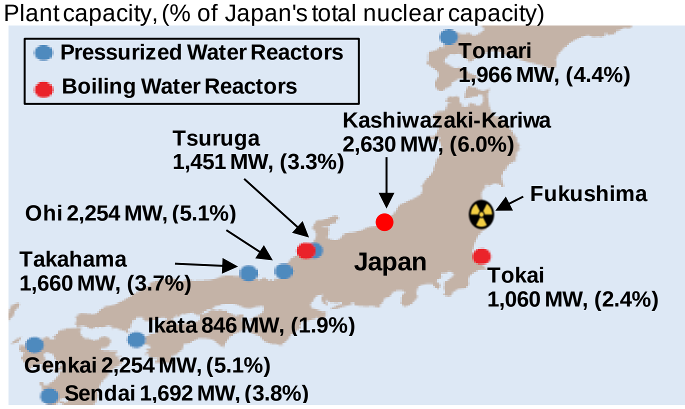
Our annual energy update: a reality check **October 28, 2013**

Japan's rising cost of mineral fuel imports
Percent of GDP



Source: Cabinet Office of Japan, Japan Ministry of Finance. April 2013.

One-third of nuclear capacity applying for reactivation
Plant capacity, (% of Japan's total nuclear capacity)



Source: World Nuclear Organization, Nuclear Regulation Authority of Japan, JPMAM. September 26, 2013.

According to the Japanese Institute of Energy Economics, turning back on all of the shut-down nuclear reactors would reduce Japan's energy import bill by 30%, with a possible 3% reduction in its trade deficit. However, the announced plan is more modest: Japan is reportedly considering the re-engagement of 17 reactors at the nine plants shown in the map. Notice that all but three of these plants employ more modern (and inherently more safe) pressurized water reactors, rather than the boiling water reactors used in Fukushima. In total, the reactors considered for reactivation account for 36% of Japan's nuclear capacity. **While Japan appears to be serious about its renewable energy goals, the pressing realities of affordable electricity for a highly electrified nation that is also a major industrial exporter like Japan may take precedence. That may explain why the ruling Liberal Democratic Party government now plans to clarify its long-term policy and possibly keep nuclear energy in the nation's energy mix as long as it is deemed to be safe and secure.**

A concerning Fukushima update: Water that is used to cool the crippled nuclear reactors has been stored on site in hundreds of hastily built storage tanks whose number has been steadily increasing. Several tanks have been leaking and in late August, radiation in their vicinity reached dangerous levels, nearly 40x allowed occupational exposure. In addition, at least 300 tons of groundwater flowing through contaminated tunnels and pits are leaking into the sea every day. This water contains not only fast-decaying cesium-137, but also increasingly higher levels of more dangerous strontium-90. That is why in early September, the government stepped in and allocated half a billion dollars to create a giant underground wall of frozen earth to prevent further contamination of groundwater. But since so much radioactive water has already reached the sea, any hopes for an early restart of ocean fishing in nearby waters are fading. The International Atomic Energy Agency team expects 30-40 years as a minimum timetable for complete clean-up.

Concluding thoughts for 2013. 150 years after the oil age began, the global economy is inextricably dependent on oil and natural gas, and actually *increasing* its dependence on coal. It takes less fossil fuel to generate a unit of growth than it did 30 years ago, but this is more a reflection of the increased efficiency of energy conversions than of increased reliance on renewable energy. In my discussions with Vaclav, he extols the benefits of renewable energy, applauds its successes and hopes for the best outcomes in terms of productivity advances. Vaclav even refers to renewable energy as the "**fourth great energy transition**" (the first three: mastery of fire; a shift from foraging to agriculture and domesticated animals; and a shift from biomass fuels and human/animal labor to economies based on the combustion of fossil fuels). But he also cautions that its limitations, costs and complexities are often woefully underestimated, and may obscure behavioral and further engineering changes that could result in meaningful declines in fossil fuel usage as this fourth transition, over many decades, unfolds.

See you next year.

Abbreviations

BPD	barrels per day	BTU	British thermal unit
CAFE	corporate average fuel economy	CERA	Cambridge Energy Research Associates
EIA	Energy Information Agency	EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission	FTA	Free Trade Agreement
HVDC	high voltage direct current	IEA	International Energy Agency
IHS	Information Handling Services	IPCC	Intergovernmental Panel on Climate Change
LCoE	Levelized cost of electricity	LNG	Liquefied natural gas
MW	megawatt	MWh	megawatt-hour
Tepco	Tokyo Electric Power Company	TJ	terajoule
TWh	terawatt-hour		

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