

## Energy in 2011 – Disruption and Continuity

By Christof Rühl and Joseph Giljum\*

### A Year of Disruptions

2011 was a year of political upheaval and natural disasters that translated into huge and unpredictable disruptions to the global energy system. While individual fuel markets each have a unique tale to tell, the main theme of this review is about fuel substitution and changes in trade patterns in response to the disruptions of 2011, how global energy markets coped, and what lessons can be drawn from the adjustment. The following is a summary of the findings of the 2012 Statistical Review of World Energy, a rigorous and objective review of last year's energy data. This paper addresses the major theme of last year – disruption and continuity – and how the global energy system coped by examining individual fuel markets.

Political unrest and violence caused outages in oil and gas production in parts of the Arab world. The cessation of Libyan oil exports alone removed 1.2 Mb/d of crude for the year. Adding in outages of natural gas and losses in other countries shows a total decline in excess of 72 mtoe compared to 2010 production – equivalent to more than 11% of the European Union's oil consumption.

The shut-down of nuclear reactors at Fukushima and earthquake-related damage to Japanese coal-fired power stations, plus the subsequent closure of additional reactors in Japan and Europe led to losses of 43 mtoe for the year – equivalent to almost a third of Asia's, or 7% of global nuclear power consumption in 2010.

And yet - nothing in the aggregate data indicates anything out of the ordinary. In fact, both GDP and energy consumption growth last year landed right at their long term average with GDP at 3.7% growing slightly faster than primary energy consumption at 2.5%. Furthermore, other major long term trends, such as the shift of the world's center of gravity toward the non-

OECD economies, continued unabated as well. So how did the energy system cope?

Price changes give a first indication that major adjustments took place underneath the smooth aggregate surface. 2011 saw big price increases: average annual Brent prices increased by 40% to reach \$111 per barrel, the highest annual nominal oil price ever; for a higher price in inflation adjusted terms one has to go all the way back to 1864. A simple average of international coal prices increased by 24%, with the biggest increase in Europe. While U.S. gas prices continued their decline following the shale gas revolution, oil indexed gas prices outside the U.S. increased, pulled up by the rising price of crude while spot prices followed suit.

With disruptions one plausible cause for rising energy prices, the other usual suspect is economic growth.

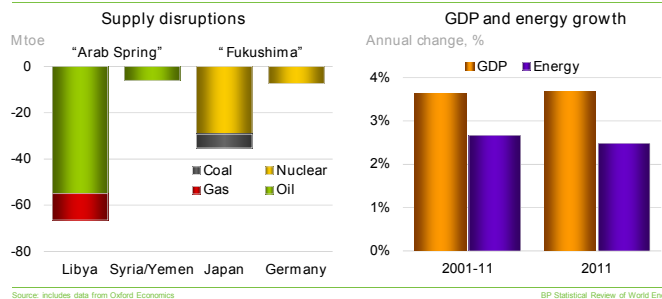
### Energy and the Economy

To be upfront, there is not much in the economic data to indicate abnormal pressure on energy demand or prices. As has become customary, non-OECD economies outpaced the OECD, contributing almost three quarters of global growth. Adding in primary energy growth confirms that for once, given the upheavals of the last few years, there was no extraordinary impact from the economy on energy demand. An interesting deviation from trend emerges only if one distinguishes OECD from non-OECD energy growth.

Non-OECD energy consumption growth of 5.3% stayed firmly on trend last year, with China growing at 8.8% – that is, adding more than total annual UK energy consumption – similar to last year. OECD energy consumption, in contrast, fell by 0.8%, despite average GDP growth. While OECD GDP finally returned to pre-crisis levels, energy consumption remains 3.3% below its 2007 peak; it has declined in three out of the last four years. Why last year?

There are broadly three reasons: first, the impact of high oil prices everywhere, and of high coal and gas prices outside the U.S. Energy prices in the OECD are least sheltered by subsidies, and so the price impact is most direct. The second reason for the decline was the impact of Fukushima: energy consumption in Japan, the world's third largest economy, declined by 5%; and switching off

### Energy in 2011 – disruptions and continuity



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nuclear power had knock-on effects on another large economy, Germany. Finally, Europe experienced an exceptional swing to warmer weather compared to 2010, the key reason behind a 3.1% decline in EU energy consumption.

The energy dislocations in the OECD give another indication of how markets coped with the disruptions that characterized 2011. Fuel substitution, supply and demand responses and trading patterns all played their role. In a nutshell, three major adjustments took place: an increase in oil supplies, most notably from Saudi Arabia, together with flexibility in trading and in the global refining system, allowed heavier Saudi crudes to replace lighter Libyan oil in Europe; a diversion of natural gas from Europe to Asia allowed the substitution of lost nuclear energy in Japan without harming the energy needs of other economies in this fast growing region; and finally, the release of coal from the Americas, facilitated by the availability of unconventional gas in the U.S., helped to replace gas in Europe.

To trace these developments in more detail, it's best to look at them fuel by fuel.

## Fuel by Fuel

### Crude Oil

Like energy markets at large, oil markets experienced significant turbulence in 2011. Oil prices rose substantially in 2011. Prices began the year slightly above \$90 and rose sharply following the loss of Libyan supplies in February. They peaked just below \$127 in mid-April and moderated thereafter as the economy weakened, OECD nations released 35 Mbbls of oil from strategic storage in July and August, and other OPEC producers began to increase output.

The main factor driving prices up last year was the sustained loss of supplies caused by upheavals in the Arab world, primarily in Libya, and the slow pace of other OPEC members in filling the void. Libyan output last year fell by 1.2 Mb/d or 71% – the largest decline in a country's oil production since the aftermath of the Soviet collapse 20 years ago.

However, these losses are not visible in the annual data: global oil production increased last year by 1.1 Mb/d. Moreover, virtually all of that increase was from OPEC countries – a group that includes Libya. The reason is a massive increase in oil production among OPEC members in the Arabian Peninsula and Iraq, who collectively increased output by 2.5 Mb/d, in the event meeting not only the loss of Libyan supply but also the growth in global oil demand. Saudi Arabia alone increased output by 1.2 Mb/d, with production reaching a record 11.2 Mb/d. Outside OPEC, production was essentially flat, with growth in

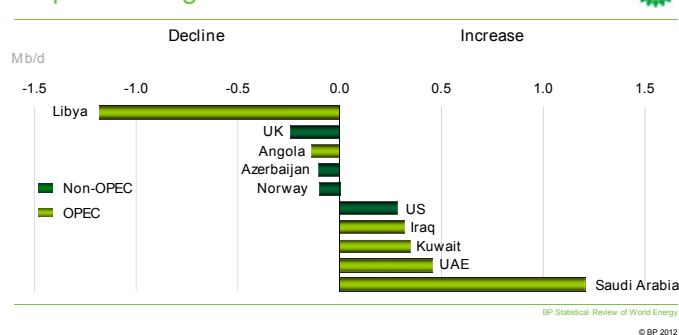
the U.S., Canada, Russia and Colombia offsetting continued declines in mature provinces such as the North Sea, extended outages in a number of countries such as Azerbaijan, and flat biofuels output due to weather related disruptions in Brazil.

Consumption growth, meanwhile, was weak. Global oil demand rose by just 0.7% or 600 Kb/d in 2011, a little over half the ten year average – despite global GDP staying at trend. Non-OECD consumption grew by 1.2 Mb/d or 2.8%. China once again saw the world's largest increase, at 500 Kb/d, accounting for 42% of the net increment, with significant gains also seen in Russia (160 Kb/d), India (140 Kb/d) and Saudi Arabia (110 Kb/d). Consumption declined in North Africa and growth was below average in the Middle-East – yet another

glimpse of the political upheaval in these regions, but also reflecting subsidy cuts in Iran. OECD demand continued its long term decline and fell by 600 Kb/d, reaching its lowest level since 1995, with the U.S. (350 Kb/d) and Germany (80 Kb/d) accounting for the largest contractions.

The consumption data confirm another important development. Demand responses to high prices are still disproportionately concentrated in OECD economies, where subsidies of oil products are absent. However, emerging economies are becoming more price sensitive because subsidization in this segment has decreased. Only about 20% of the world's oil consumption was in countries with subsidies last year, down from nearly 40% in 2008, the last year of record high oil prices. Because subsidies are expensive and because of the realization that energy efficiency matters in international competition, the cycle of rising oil prices resulting in rising subsidies appears to have been broken: we estimate that non-OECD countries passed roughly 70% of last year's oil price increase on to consumers, up from about 25% in 2008.

### Oil production growth in 2011



These global developments in production and consumption explain nicely the trajectory of prices in 2011. As 2011 began, oil consumption was outpacing production and that gap widened significantly after the loss of Libyan supplies in February. Even with the large increase in output from Saudi Arabia and other Gulf states described earlier, overall OPEC output did not surpass pre-disruption levels – and global production did not exceed consumption – until late in 2011. This timing left inventories well below average despite the SPR release and in this way supported crude prices throughout the second half of 2011.

### Refining

The global refining environment continues to be characterized by excess capacity and slow throughput growth. Net global refining capacity grew by 1.4 Mb/d in 2011, led by growth of 730 Kb/d in Asia Pacific, mainly in China. In contrast, global crude runs grew by just 380 Kb/d, slightly below liquids consumption growth because of new NGL supplies. Therefore, global unused capacity increased by 1 Mb/d and is now more than 5 Mb/d higher than it was in 2005 while refinery utilisation fell to 81.2%, the second lowest since 1994. There is too much refining capacity – but not everyone is suffering to the same extent. Flexible sites with world class operations can be successful and in 2011, some had the opportunity to prove it.

The disruption of Libyan supplies meant that Europe lost around 800 Kb/d of good quality crude oil. Other African exporters made good about half of these losses by re-optimizing trade. The Former Soviet Union is Europe's largest crude oil supplier by far but its oil production grew only marginally last year. That created an opportunity for Middle East exporters to regain market share and, led by Saudi Arabia, they increased medium and heavy sour crude exports to Europe by more than 250 Kb/d. With flexible sites and excess capacity in Europe, the lost Libyan barrels were, therefore, easily replaced.

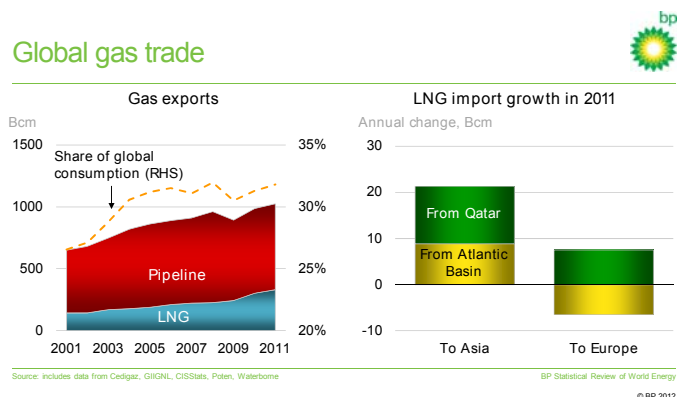
### Natural Gas

Natural gas has produced some of the biggest changes in energy markets over the last few years: there is the rapid increase in trade, especially of LNG, that connects hitherto segmented regions in an increasingly flexible manner and the development of unconventional resources in the U.S. Both of these developments shaped 2011; and as it happens played a key role in the response to last year's disruptions.

Overall, natural gas production and consumption growth moderated, compared to last year's exceptional increases. Global production was up 3.1% (98 Bcm) with growth originating from the Middle East (11.4%, 54 Bcm), North America (5.5%, 45 Bcm) and the Former Soviet Union (4.6%, 34 Bcm). Consumption rose by 2.2% (70 Bcm) led by Asia Pacific (5.9%, 33 Bcm), North America (3.2%, 28 Bcm) and the Middle East (6.9%, 26 Bcm). European consumption, in contrast, suffered an unprecedented 7.8% (42 Bcm) decline.

There is no global price for natural gas. Regional price changes, therefore, provide a first glimpse of the underlying forces of demand and supply. Annual average spot prices for LNG in Asia rose by 82% to \$14/Mmbtu in 2011, driven by a combination of higher oil prices pushing up oil-indexed contract prices, and strong additional demand for LNG from Japan, to displace losses in nuclear power. At the other end of the spectrum, U.S. prices slipped by 8% to an average of \$4/Mmbtu in 2011. European spot and contract prices hovered between the U.S. and Asian extremes, with UK spot prices averaging \$9/Mmbtu in 2011, up 37% on the previous year.

International trade continued to outpace consumption, rising by 4% (39 Bcm). LNG grew by more than 10%. 32% of all natural gas is now traded across international borders; and 32% of all traded gas is LNG, meaning that LNG accounts for 10% of all natural gas consumed globally. Trading patterns in 2011 show a large shift of LNG toward Asia, driven by the continued need to fuel rapid demand growth, especially from China, as well as the necessity to replace nuclear power in Japan. Asian net LNG imports increased by 34% (27.6 Bcm), compared to just 3% (2.1 Bcm) in Europe and Asia's share of LNG deliveries rose to 63% of the global total, whereas Europe's market share fell to 27%. By coincidence also last year, Qatar finalized the final phase of expansion of its LNG export capacity. Thus Japanese demand could tap into a combination of short-term deals for new Qatari supply and spot



purchases from various suppliers, especially Atlantic Basin producers such as Nigeria and Equatorial Guinea.

With Asia absorbing most of the growth in LNG supplies, there was little left for Europe. European markets also had to deal with the loss of Libyan supplies (7 Bcm) and large production declines in the North Sea (23 Bcm). The situation was mitigated, however, by increased pipeline imports from Russia, falling demand, and substitution by additional coal consumption. Gas consumption was sharply lower across most European markets due to the combination of weak economic growth, an exceptionally mild winter compared to 2010, and substitution by coal in power generation. In fact, the European Union's gas demand dropped by 10% which was the largest on record.

So while Asian markets were looking for supplies to meet surging demand, and Europe coped with declining production, the North American gas market faced a very different challenge. The continued momentum in the growth of unconventional gas supplies saw U.S. gas production increase by a record 47 Bcm, accounting for 48% of the growth of world gas production in 2011, and taking U.S. gas production to a new all-time high, above the previous peak in 1973. Demand could not keep up (2.4%, 17 Bcm), despite a reduction of net imports and gas prices low enough versus coal to encourage substantial substitution in power generation, leading to significant gains in inventories and downward pressure on prices.

Overall, the growth of LNG and the production of unconventional supplies continue to transform the world of natural gas. In 2011, they combined to give gas markets the flexibility to accommodate additional Japanese LNG demand, without disruption in other parts of the system. To see how, one needs to look at coal.

### Coal

Coal was the fastest growing fossil fuel last year, in production as well as consumption. The coal story is a one of production and trade patterns able to adjust to market conditions. In this way, coal was buttressing global supply security.

Coal production increased by 6.1% (229 mtoe) globally, easily exceeding the ten year average (4.9%). Growth last year, as in many previous years, came from China (8.8%, 158 mtoe) which provided the largest volumetric increment, raising its share in global production to 50%. It did not come from India, where a prolonged monsoon caused production growth of 2.3% (5 mtoe) to lag consumption growth by an even wider margin than usual. EU production also grew by 2.6% (4.2 mtoe), the first increase since 1995.

Only a small share of coal is traded, but this share is growing – in size and reach. In 2011, and outside China, coal exporters, benefiting from growing import needs in Asia and Europe, have been the largest contributors to production growth with Indonesia recording the largest production increment (18.1%, 30.6 mtoe) by far. The world's biggest exporter, Australia, was an exception; it recorded a production decline (2.2%, 5.3 mtoe) because of floods.

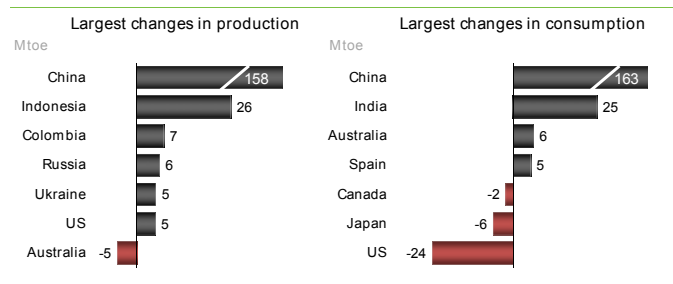
Strong demand was driven by the non-OECD, in particular by China at 9.7% (163 mtoe) and India at 9.2% (25 mtoe) who together accounted for 98% of net consumption growth. Over the last decade, the OECD share in global coal demand has declined from 47% to 29%. Last year, OECD consumption declined by 1.1% (12 mtoe), five times the average rate. Yet this was not your typical coal-equals-emerging-markets year.

The OECD decline in 2011 was particularly pronounced in the US (-4.6%, 24 mtoe) where shale gas eroded coal's role in power generation; and in Japan (-4.8%, 6 mtoe), where coal-fired electricity production had to be reduced after the earthquake.

These declines were partially offset by growth in the EU (3.6%, 9.8 mtoe), where coal was winning against gas in power generation because of lower prices, and also because of regulatory incentives: carbon prices remained extremely weak and explicit quotas protected coal from competition in Spain.

Steam coal prices in Asia remained at a premium, with Chinese import demand driving up prices throughout the region - including in Japan, the world's second largest coal importer. European import prices rose more rapidly (31.4% y-o-y, compared to 26.1% in China), albeit from a lower level – and just enough to attract addi-

### Coal growth in 2011



tional imports from across the Atlantic. A clear pattern emerges: Asian suppliers and Russia provided the bulk of additional coal for Asia; American suppliers and Russia did the same for Europe – in the course of events also replacing European Union imports from Indian Ocean suppliers that had been redirected to Asia.

In this way, markets balanced. European markets compensated for LNG bypassing the old continent for Asia in part by picking up abundant U.S. and Colombian coal supplies. Higher Asian prices directed previous exports from Indian Ocean suppliers back into Asia, while attracting new supplies from Russia and Indonesia. And coal from the U.S. was available at a price advantage against gas because at home, it had been backed out by natural gas.

This, then, completes the puzzle of how markets coped with the large scale disruptions dominating the headlines in 2011. Production increases, demand changes and even the weather all helped. In essence, however, this is a story of fuel substitution and shifts in trade flows, triggered by price adjustments.

#### *Non-Fossil Fuels*

Nuclear was of course at the heart of one of the major disruptions in 2011. Global nuclear generation fell by 4.3% (119 TWh), the largest decline on record, bringing it back roughly to the level of 2001. Nuclear's share of global energy (4.9%) was at the lowest level since 1986. But beyond the closure of Japanese and German nuclear plants, the global impact on energy markets of the Fukushima incident has actually been relatively mild as nuclear output grew in 22 countries in 2011.

Renewable power generation grew 18%, the ninth successive year of double-digit growth. This was the largest ever volume increment (29.3 mtoe), contributing 10% of the overall increase in world energy consumption. The U.S. (16.4%), China (48.4%) and Germany (22.9%), together accounted for more than half (56%) of renewable power growth in 2011. Overall, renewable energy, including biofuels, accounted for 2% of primary energy consumption in 2011, of which 1.6% was from fuels for power generation.

#### **Conclusion**

There are a few takeaways to be had from this year of disruptions, with seemingly normal growth and in line with long-term structural changes. These evolve around the flexibility of markets – the ability to increase production, to substitute across fuels, and to change trading patterns has been crucial to the ease with which the system has adapted. For this to work, prices must be allowed their role as signals to guide the reallocation of energy flows.

There is a second, related, conclusion here. It has become fashionable to advocate energy independence as a path to security. However, an objective look at the data shows that it is precisely the interdependence of the world's energy system that is its real strength. Just imagine if Japan would have been truly self-sufficient, and not integrated into the global energy system at all – the adjustments we have seen would have been impossible.

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Both Vance and Frondel are affiliated with the Rheinisch-Westfälisches Institute (RWI) in Germany.

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The committee also noted that the overall quality of the papers was excellent and would like to thank all of the authors for their submissions.

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