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Costs and challenges of energy transition

In estimating the costs involved in global energy transition, difficulties are encountered in integrating a myriad of decisions to be made at all levels, from final users though to government, concerning energy saving versus energy supply substitution by renewable and low carbon energy. However, under any hypothesis, large energy savings or demand-side management will be necessary to mitigate the effects of climate change. This paper indicates that a minimum of US$750 billion to US$1000 billion per year of investment and spending will need to be mobilised to enable global energy transition away from fossil fuels.

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DEPENDING ON TARGETS AND TIMELINES, the estimated costs of global energy transition away from fossil fuels can vary significantly. Key factors affecting these different cost scenarios include the quantity and rate of commercial fossil fuel substitution by low carbon alternative energy, the amount of current commercial energy demand that is eliminated by energy conservation and restructuring of the energy economy, general economic conditions and society's expectations.

Also greatly affecting these cost ranges are the various hypotheses or scenarios in relation to technological, industrial, institutional, economic, financial, legislative, normative or regulatory, and other factors. These considerations will affect the targets to be set for energy transition nationally, regionally or multilaterally. Over time, there can be major changes in policy and public appreciation of the urgency, or not, of energy transition that will have an impact on the pace of change.

Most cost scenarios compare existing energy supply systems and infrastructures, on the upstream, with downstream economic and social energy needs and uses, notably using the yardstick of energy consumption per unit of GDP. Due to these parameters being far from fixed or rigorous, scenarios for both the future energy targets, and the overall balance of 'energy saving or energy substitution' over the next 15 to 25 years are necessarily approximate and need to be interpreted carefully.

The approach used here is to focus on one key driver of energy transition, viz. oil and gas energy substitution needed *due to geological depletion of reserves* during the next 15 to 25 years. Using many different data sources (e.g. the International Energy Agency (IEA), Association for the Study of Peak Oil and Gas (ASPO), Total Oil SA and the OPEC Secretariat) we find strong convergence of views on this subject, enabling us to advance an oil-only substitution target of 25 mbd (million barrels per day) as the likely minimum possible target for energy transition to 2025.

This excludes natural gas reserve depletion to 2025, and the somewhat anguished question of coal. Some climate change experts[1] claim that coal must be 'eliminated from the energy mix' within 20 years unless completely functional CCS (clean coal and carbon sequestration) technology and systems can be developed and retrofitted to all coal-fired power plants worldwide. These plants currently supply over one-half of the world's entire electricity. The estimated costs of retrofitting all coal power plants with CCS are very high.

This paper is based on the assumption that world coal burning will probably continue at around current rates (about 6 billion tons per year), while simply due to depletion, natural gas burning (about 2.7 billion tons oil equivalent/year) will necessarily fall. This,

therefore, takes into account the potential for significant energy saving identified by many studies (e.g. by McKinsey & Co for the European Commission)[2] including in gas, rather than fossil fuel supply substitution. However, at this time, the total costs, timelines, policy and industrial contexts for massive energy saving instead of supply substitution are all subject to wide forecasting margins.

On this basis and with these caveats, this paper provides approximate energy transition costs in 2009 US dollar terms starting at around US$750 billion per year for a minimum program investment and spending need, also expressed in 2009 US$ terms, of around *US$11,000 billion* for *25 mbd oil substitution by 2025*. Current investment levels are a small fraction of this requirement.

Major considerations for energy transition

Energy intensity (average demand per capita)

Arguably, due to their very high present oil and gas intensity, the main goal of energy transition for the OECD countries should be to reduce the fossil energy intensity of the economy and society. This would require a 'twin strategy' of energy saving and development of all feasible sources of renewable, non-fossil and low carbon energy. The 27-nation European Union regional grouping of states has already decided (December 2008) to target a 20% reduction of fossil energy consumption by 2020, and the development of renewable and low carbon alternate energy supply able to cover 20% of total EU energy demand by 2020. At this stage, cost estimates for this program are widely variable.

GHG (Greenhouse Gas) emissions reduction

Various national, regional and international targets and proposed targets exist for eliminating or reducing CO2 and other greenhouse gases (GHG) produced by current fossil fuel burning, and increasing national energy security for fossil energy import-dependent states, notably the OECD group.[3] The European Union 'climate-energy package' of December 2008 also targets a 20% reduction in GHG emissions by 2020.[4] Electricity is the major focus of current national and regional GHG reduction targets. Reduction of coal burning is 'controversial' due to the absence of economically viable CCS, but increased dependence on coal and lignite is probably certain due not only to their lower cost but also their larger remaining world reserves relative to oil and gas. At present, about 28.5% of world commercial energy is supplied by coal and lignite, and about 55% of world electricity is coal based. Only about 11% of world electricity or 6% to 7% of world commercial energy is renewable hydropower (based on US Energy Information Administration 2007 data). Electricity accounts for about 20% to 40% of final commercial energy demand, depending on country and economic structure.

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Climate change and fossil fuels

CO2 and other GHG emissions from fossil fuel burning probably total about 28 billion tons annually, or 30 billion tons annually including release of unburnt methane (natural gas) and coal loss. These emissions are vastly higher than all natural volcanic, tectonic, seismic and geological sources of GHG, which likely total less than 0.5 billion tons annually. At least 10% of world nameplate natural gas capacity is vented, flared, or lost in transmission. Equally intense in climate change impact, coal production and transport losses worldwide total around 90 to 125 million tons annually, much of it lost through underground fires in abandoned mines. While having less impact on the world's climate, but massively polluting the world's oceans, and some land areas, at least 1.4 million barrels per day (mbd) of oil is lost 'from well to wheel'. This loss rate is increasing much faster than production, notably due to extreme depth offshore production and tertiary production from tar sands and oil sands.

Electricity demand

Due to extremely high growth rates for electricity consumption in many countries, particularly the emerging economies (often close to or above 10% per year until the present recession), renewable hydroelectricity and wind power penetration, or their share of global electricity and commercial energy demand, has tended to stagnate or decline in 2005–09. According to the OECD's IEA, in 2008, other renewable and low carbon energy, including the 'new renewables' such as emerging solar thermal and photovoltaic, wavepower, geothermal, biomass fuel and electricity, and low carbon landfill methane and coal bed methane accounted for only another 1% to 1.25% of world total commercial energy.

Energy demand and economic structure

One major problem that arises in attempting to substitute the approximately 55% of world electricity presently supplied by coal burning (more than 75% of Chinese electricity in 2008) with non-coal or non-fossil primary energy sources is the linkage of power demand growth with GDP growth. Oil and natural gas demand are less

closely linked, that is, the growth in electricity demand per unit of GDP growth under the current economic structure is above unity (1) in most countries, but is often much lower for oil and gas. In recession, oil and gas demand can fall while GDP can grow weakly for a few quarters, but this is rare for electricity. The steady and long-term shift to higher electricity intensity of the economy on a worldwide basis therefore presents as many problems as solutions, for example, the claimed advantage of most 'new renewables' in only delivering electricity as their final form of commercial energy.

Economic recession impacts

Only during recession is oil intensity seriously reduced. During the most powerful economic recession before the present (1979–83), global oil demand contracted about 9.6%. Conversely, due to price adjustments, world gas demand did not contract in the same period. It should be noted that the timeframes considered in this paper cover at least two and maybe more economic cycles. Recessions provide only short-term respite from the ever-growing demand for energy.

Quantities of fossil fuels to be substituted:

Of the fossil fuels of oil, coal and natural gas, coal and lignite have the highest 'carbon footprint' and the highest current demand growth profiles. This is almost exclusively due to coal being cheap. Also, due to cost differences – natural gas is 'historically' cheaper than oil – world natural gas demand has grown much faster than oil. Gas demand more than tripled through 1969–2008, but oil demand 'only' doubled in the same period. Obviously, the question of energy prices and energy taxation (including carbon tax) will determine which fossil fuels are most easily substituted or eliminated.

Reliance on free market mechanisms

Reports such as the 2006 report by Lord Stern (UK)[5] present various economic methodologies and costings for not avoiding or mitigating climate change. One of Lord Stern's scenarios suggests that economic losses due to insufficient climate change mitigation could reach around US$50,000 billion per year (2006 US$ value) by about year 2040. This is approximately equivalent to current world total GNP. However, the Stern report, like others, gives prominence to the present European ETS (emissions trading scheme) free market-based process for supposedly 'reducing or limiting' GHG emissions. Apart from being very small relative to other markets (such as equities, currencies, government paper, energies and non-energy commodities), this scheme is remarkable in terms of its opacity and volatility. Operating since 2005, the European ETS has so far had zero impact on fossil energy consumption in Europe, with several EU ratifying countries 'robustly' increasing their oil, gas and coal burn through the 2005–07 period of fast economic growth and only trimming their fossil energy demand once their economies moved into recession in 2008.

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Dimensions of the problem

Substituting oil, then natural gas, and preferably coal and lignite, presents huge challenges. These include massive and long-term financing and global efforts to achieve energy transition without catastrophic economic impacts, or further geopolitical conflict, particularly in the Middle East, central Asia and Africa. The immense challenges of energy transition are very clear, including both the pressing need to quickly develop and deploy CCS ('clean coal') to reduce impacts from coal and lignite burning worldwide, and the problems for raising biofuels production while also increasing world food supply.

Various data sources, including both the IEA and ASPO, suggest that global oil depletion may reach about 27 mbd of capacity loss from conventional sources in the 2007–2015 period alone. Using IEA estimates, projected requirements of 'new, replacement or additional' oil and gas supply capacity needed through the period to about 2030–35 total some 63 mbd oil equivalent. IEA estimates of investment and spending costs to achieve this target are about US$26,000 billion (US$ 2008 value). Other cost estimates for broadly similar targets, notably by Matt Simmons,[6] are as high as US$100,000 billion.

Assuming similar costs for alternate energy, this implies costs of between US$11,000 billion and over US$40,000 billion to substitute 25 mbd of oil supply through the period to about 2025. On a 'straight line' annual basis, in US$ 2009 terms, this would amount to a minimum of around US$750 billion per year. Given that the majority of non-fossil and low carbon energy supply sources and systems are considerably more expensive than oil or natural gas (and much more costly than coal and lignite), it is prudent to raise this cost estimate closer to US$1000 billion per year.

Unfortunately, the current financial mechanisms to achieve this end remain vague, volatile, speculative and very small relative to needs. In early 2009, speculative asset creation and trading, and financial engineering activities including private venture start-ups and asset refinancing of alternate energy companies, M&A activity and LBOs has already led to the collapse of the so-called 'biofuels boom'. Estimates by Clean Edge for 2008 and 2009 ytd (year to date) free market activity in the very

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broadly defined 'alternate and green energy sector' suggest that new investment trends of around *US$75 billion per year in 2008* had fallen considerably by early 2009.[7]

World efforts to develop renewable and low-carbon energy sources and systems are currently concentrated in the OECD countries, despite very large potential natural resources in other countries. As noted above, the 'boom-and-slump' sequences that have already taken place with biofuels, wind-electric power development, particularly in Europe, and probably soon with emerging solar photovoltaic electric power, show that global investment in alternate and renewable energy is hostage to the whims of private market players and their very classic short-term oriented, profit-maximising behavior. This strongly suggests the need for urgent attention to creating at least partly automatic financing frameworks for multilateral energy transition with adequate planning, regulation and control. This would be a truly global and necessarily long-term process, extending well beyond 2025 and taking into account the realities of oil and natural gas depletion, as well as climate change imperatives.

Conclusions

Costing what is a massive energy transition effort, far bigger than any changes in world energy during the past 30 years, encounters the difficulty of integrating a myriad of decisions that will be made. These decisions will be made at all levels from final users to government, concerning energy saving versus energy supply substitution by renewable and low carbon energy.

Under any hypothesis, however, we must assume that large energy savings or demand-side management will be critical to mitigating the effects of climate change. In an economic and social context in which 'only the market will decide', as we have found since late 2008, outright and massive economic recession is the only guaranteed way to obtain real cuts in oil demand and the start of zero growth trends for other fossil energy demand.

The costs of energy transition will be large under any hypothesis. Using a reference target of 25 mbd oil substitution by low carbon energy to 2025, and comparing this with recent performance in the world oil and gas industry, a minimum of *US$750 billion to US$1000 billion per year* of investment and spending will need to be mobilised. This should be compared with the US$75 billion global investment in equity markets alone in 2008.

Notes

1 See open letter from James Hansen to President Obama, 21 Nov 2008 at http://www.carbonpositive.net/viewarticle.aspx?articleID=1358

2 McKinsey & Company 2008, *Capturing the European energy productivity opportunity*, September. See www.mckinsey.com/mgi/publications/capture_europe_energy/index.asp; and McKinsey & Company 2008, *CCS: Assessing the economics*, report prepared for the European Commission, September. See http://europa.eu under Press releases.

3 Baron, Richard, Buchner, Barbara and Ellis, Jane 2009, *Sectoral approaches and the carbon market*, IEA and OECD, June. See www.oecd.org under Environment Directorate; Kim, Joy Aeree, Corfee-Morlot, Jan and de T'Serclaes, Philippine 2009, *Linking mitigation actions with mitigation support in developing countries: a conceptual framework*, OECD and IEA, March; and Ellis, Jane and Moarif, Sara 2009, *GHG mitigation actions: MRV issues and options*, OECD and IEA, March.

4 European Union 2008, *Climate change: Commission welcomes final adoption of Europe's climate and energy package*, 17 December. See http://europa.eu under Press releases.

5 Full details of the Stern Report (2006) available at http://www.occ.gov.uk/activities/stern.htm

6 See Matt Simmons's original statement at http://www.silverbearcafe.com/private/5.08/rebuild.html

7 Clean Edge's estimates for 'cleantech' spending in 2008 and 2009 to date are available at http://www.cleanedge.com/reports/reports-trends2009.php