BALLARD | WHITE PAPER

The Energy System of 2030

Towards an Electron Democracy

Noordin Nanji
Vice President, Strategy and Development

Matthew Klippenstein
Senior Engineer

March 2009

*An abbreviated version of this White Paper has been published by **McKinsey & Company**, management consultants, under the title "Electron-democracy". It is available in McKinsey's What Matters online publication at http://whatmatters.mckinseydigital.com/energy.*

Abstract

In the absence of aggressive public policy, fossil fuels will continue to dominate the energy system in 2030, despite reduced oil production rates. Projecting current growth rates forward, the two major renewable energy sources – wind and solar – will still only contribute a fraction of the energy from present coal production, alone.

A structural shift in the electric grid is expected over the next two decades, strongly favouring the growth of distributed power. The ultimate effect will be to democratize power generation, making it available in smaller increments at the individual and community levels. In the resulting *electron democracy*, centralized power plants will remain, but grid activity may be dominated by innumerable small energy flows to and from these small producers.

This trend is closely compatible with sustained, rapid growth in a variety of renewables and clean technologies, whether they *leapfrog* fossil fuel networks, or *leverage* them. The prominent role of intermittent renewables will drive demand for complementary, on-site and on-demand energy technologies, of which fuel cells are a leading example.

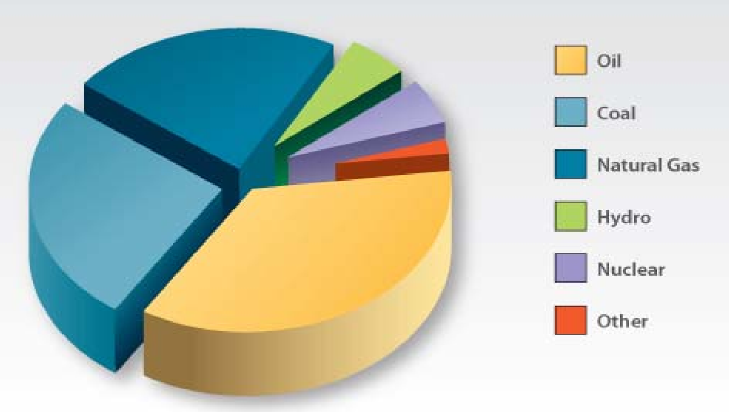
Introduction

This White Paper outlines the energy system we foresee in 2030, a date often used as a milestone by policy groups and thought leaders. A twenty-year timeframe allows emerging technologies to scale up, and reduces the risk that future innovations or events will upend existing trends, as compared to longer timeframes (fifty years, for example).

Fossil Fuels

Fossil fuels currently comprise more than eighty percent (80%) of the world's primary energy production. Figure 1 uses the most recent data available from the U.S. Department of Energy's *Energy Information Agency* (EIA).

FIGURE 1. World Primary Energy Production 2005 (EIA)



Oil Will Run Down… But Not Out

Fossil fuels' contribution to the energy system twenty years from now cannot, of course, exceed the maximum production capacity. There is considerable contention regarding the upper limit of oil production in that timeframe. In this context, 'oil' is taken to include all liquid fossil fuels – including conventional oil, upgraded heavy hydrocarbons (tar sands, oil shale) and upgraded light hydrocarbons (through gas-to-liquids processes).

- **Business-as-usual optimists** believe global oil production will increase, generally through at least 2030, before declining.[i]

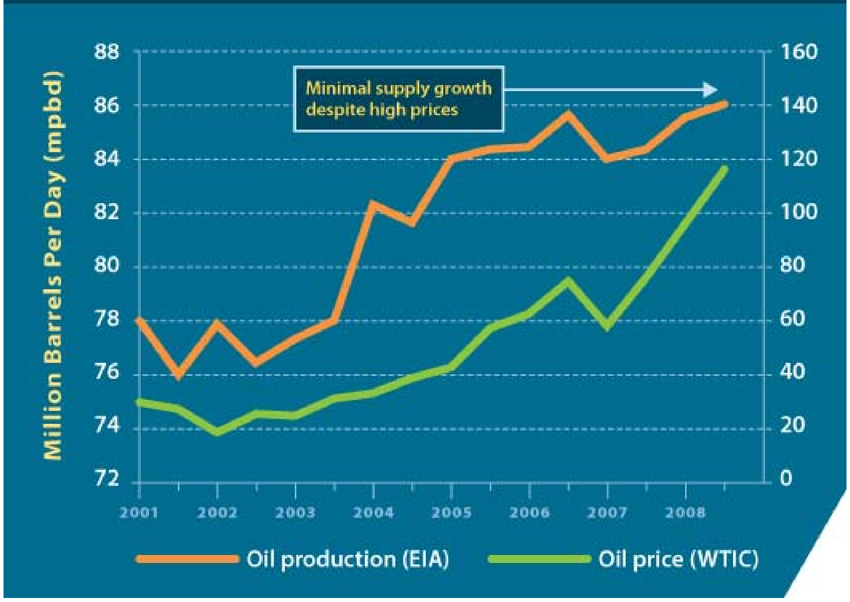
- **Peak oil pessimists** believe global oil production will reach a maximum ("Hubbert's Peak") by about 2012, then begin a permanent decline.[ii]

The past four years have been unkind to optimists. As per Figure 2, global production has flat lined at about 85 million barrels per day, though prices rose well above their January, 2005 level.[iii] Until the recent

OPEC cuts, there was little evidence of unused supply, and new supply came online only fast enough to offset depletion of production from existing fields.

While enormous unconventional oil reserves exist – primarily bitumen (tar sands) and kerogen (oil shale) – these are lower-quality deposits. Compared to conventional reserves, they offer a lower *energy-return-on-energy-invested* (EROEI). Energy-expensive processes are necessary to transform these hydrocarbons into useable oil, as are multi-year, up-front infra-structure investments.[iv] Perhaps for this latter reason, unconventional oil production has scaled up only slowly – *the milkshake is big, but the straws are small.*

FIGURE 2. Recent global oil and liquids production, and Monthly Price of Crude



We believe the pessimists are right. The slow ramp-up of oil production, despite extraordinarily favourable market conditions in an easy-credit environment, suggests that production will be lower twenty years from now. According to the data in the International Energy Agency's (IEA) recently released "World Energy Outlook 2008", four new Saudi Arabias' worth of production would be required, merely to maintain today's production rates in 2030.[v] We simply do not see that happening.

Coal And Natural Gas Will Not Even Run Down By 2030

Unlike oil, natural gas production appears likely to increase for many years, as output at the world's largest natural gas field – South Pars/North Dome – is due for considerable expansion. Shared by Qatar and Iran, this field is purported to contain more barrels-of-oil-equivalent energy than even the Ghawar field of Saudi Arabia (the world's largest conventional oil field), though this claim has been questioned.[vi] Peak oil advocates typically foresee natural gas production peaking by about 2030, so this can be taken as the conservative estimate.

Coal – by far the dirtiest of the fossil fuels, mainly used for generating electricity – also has a wide range of future production estimates. The EIA recently estimated global reserves at about 140 years at current usage rates, with production rising by more than half over the next two decades.[vii]

In contrast, Germany's Energy Watch Group predicts a peak in global energy-from-coal by about 2025, at levels approximately one-third higher than at present. Their recent coal report stated that global coal resource estimates decreased by half from 1980 to 2005, and noted that despite having the world's largest coal reserves, U.S. coal production, in terms of energy, peaked in 1998. Increased production of softer, less energy-dense coals has not made up the energy deficit due to depletion (and reduced production) of harder coals.[viii]

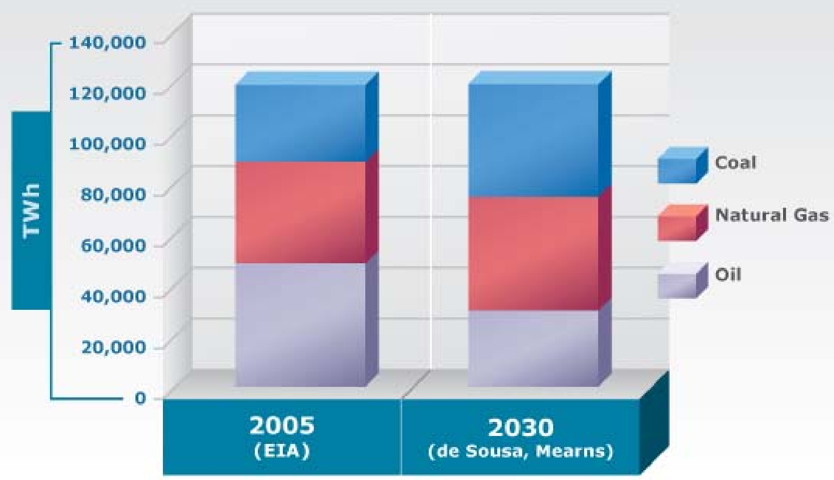
As an aside, carbon storage and sequestration will not affect coal consumption in this timeframe, as it is not estimated to even begin substantial deployment until 2030 – and then only if storage and business model challenges can be overcome.[ix]

Fossil Fuels In 2030

The take-away is that even conservative scenarios expect available fossil fuel energy in 2030 to be about the same as it is today (Figure 3), albeit shared across a larger global population.[x] And if the optimists prove correct, available supply will be even greater.

Whether or not fossil fuels continue to dominate the energy system in 2030, is therefore a question of *policy*, not *geology*.

FIGURE 3. Present and Future Fossil Fuel Energy Availability (conservative scenario)



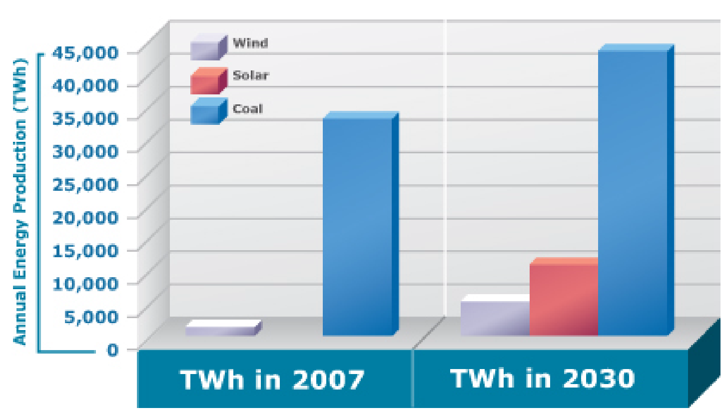
Public Policy

Public policy will determine whether we consume fossil fuels at maximum production rates, two decades from now. While a rapidly scalable alternative to oil for transport-tation does not appear to be on the horizon, renewables for power generation have shown robust growth. Unfortunately, even if current ramp-up rates extend to 2030, solar and wind would still only represent a small fraction of coal energy, alone (Figure 4).[1]

Strong public policy responses are warranted by the intensi-fying pace of climate change, which has thus far exceeded even the worst-case scenarios of the *Intergovernmental Panel on Climate Change* (IPCC).[xi] The importance of pricing carbon is nearly universally acknowledged, as is the need to wean us off coal to avoid catastrophic climate change.[xii] Given the renewables ramp-up rates required to substantially or completely replace coal in the 2030 timeframe, energy efficiency improvements – whether by conservation or innovation – would be tremendously enabling.

Given the current economic situation, climate action proposals that directly increase employment may experience the least pushback. National insulation upgrade programs might provide employment while reducing overall energy demand. Incentives to retool shuttered manufacturing facilities in favour of clean-tech industry, in conjunction with subsidies to accelerate market adoption, would also enhance private enterprise. Indeed, it would be a generational triumph to see renewables industries rise, phoenix-like, out of the metaphorical ashes of closed automotive factories. A wealth of human capital could be redirected into these emerging industries, from mature or declining ones.

FIGURE 4. Present and Future Energy Production from Wind, Solar, Coal (based on current trends)



[1] For coal in 2007, 2030: de Sousa, L. and Mearns, E., *Olduvai Revisited*, TheOilDrum.com, February 2008, http://europe.theoildrum.com/node/3565. For wind in 2007, 2030: Global Wind Energy Council, *Global Wind Energy Outlook 2008*. 2030 data represents moderate case. For solar in 2007: public data suggests 12.4 GW (peak) installation base. An assumption of 20% utilization capacity was used. For solar in 2030: continuation of growth rates projected by Lorenz, Pinner, Seitz, *The economics of solar power*, The McKinsey Quarterly, June 2008.

A more ambitious role for governments in the transition from today's grid to tomorrow's electron democracy, would be to co-ordinate with local business to develop global centres of excellence in targeted industries. In conjunction with mechanisms such as feed-in tariffs (whereby renewables / clean tech are guaranteed a favourable rate for their electricity) this would facilitate the development of regional technology clusters, with all the ancillary economic benefits they bring.

New Generation Capacity - Nimble Is Beautiful

Whatever the pace and vigour of public policy, we see a steady transition in power generation from centralized generation to distributed power. Substantial demand will come from companies and communities sourcing on-site energy to supplement (but not replace) the local grid, just as in recent decades these began sourcing on-site security to supplement (but not replace) police services. However, centralized utility-scale power will probably continue to be built in 2030 – though hopefully, of a non-polluting sort.

For traditional centralized power, due to the capital costs involved, planning is necessary over a multi-decade timeframe. For fossil fuel plants this introduces the risks of fuel supply and cost, and will drive the need to model a variety of carbon tariff scenarios (or budget accordingly for lobbying). Hydroelectric and water-adjoining nuclear plants have the challenge of ensuring adequate water supply, despite the potential for shifting rainfall patterns and thus river flows, due to climate change.[xiii] Furthermore, with the exception of hydroelectric, centralized plants cannot easily adjust to demand fluctuations….this leads to steeply discounted off-peak rates and the need to purchase additional, peaking power plants for high-demand periods. More broadly, an expansive transmission grid dominated by a few central power plants is vulnerable to disruption (due to natural phenomena or human malevolence).

In contrast, smaller-scale power generation can respond more nimbly to market demand, in a shorter timeframe, with lower capital costs. Filling the niche of supplemental power (as opposed to primary power) – *defeaturing*, as it were – allows for otherwise impractical generation options. Finally, a grid fed by a broad, physically dispersed heterogeneous mixture of power sources would be extremely robust against disruption.[xiv]

TABLE 1. Comparison of Traditional and Distributed Grid Energy Technologies

TRADITIONAL ENERGY SOURCES	Centralized Grid	Load Following Capability?	CLEAN TECH / RENEWABLE ENERGY	Distributed Grid	Load Following Capability?
Coal	Base Power	-	Solar & Solar Thermal	Intermittent	-
Natural gas	Peaking Power	Y	Wind	Intermittent	-
Nuclear	Base Power	-	Geothermal	Base Power	-
Hydroelectric	Base or Peaking Power	Y	Fuel Cell	Load Following Power	Y
Pumped-storage hydroelectric	Grid Energy Storage	-	Batteries / EV / PHEV[2]	Grid Energy Storage	-

Note: oil not tabulated, since its primary use is not power generation

Two Flavours Of Clean Tech

The trend towards a distributed grid strongly favours renewables and clean tech, since power plant-style thermal generation is generally unsuitable for smaller, point-of-use applications where factors like noise and particulates become important.

These emerging energy technologies can be divided into two groups -

- those that *leapfrog* fossil fuel networks; and
- those that *leverage* fossil fuel networks.

[2] EV = electric vehicles; PHEV = plug-in hybrid electric vehicles

"Leapfrog" technologies – such as wind, solar and geothermal – have already been touched on. While these can be deployed in utility scale, they can generally be implemented at the corporate and community scale as well. Here, solar photovoltaics may be the likeliest choice, though wind will be suitable in some areas. Geothermal energy is feasible in some regions at present and passive geothermal heat pumps – which don't create power, but reduce heating and cooling demands – also seem promising, particularly for new construction.

"Leverage" technologies – such as electric and plug-in hybrid electric vehicles (EV's and PHEV's, respectively) and fuel cells – should also ramp up, albeit from a much smaller base. These can extend and disperse the grid while making use of the large volumes of fossil fuel production likely to be available through to 2030. Biomass-to-ethanol processes are not discussed here, as challenges appear to remain in increasing their EROEI.

Given the size of the global automotive fleet – currently in excess of 500 million vehicles – EV's and PHEV's may not substantially impact demand for liquid fuels over the next two decades. They would, however, serve an important role as load-dampening infrastructure, soaking up off-peak power and feeding the grid at peak times, when parked. We'll decline to predict a market-entry for fuel cell vehicles, past predictions having been rather premature.

The reason we classify fuel cells as a "leverage" technology is that natural gas remains the likeliest source of hydrogen in the 2030 timeframe, given its relatively plentiful supply. Fuel cell solutions are presently being used for grid-supporting applications – backup and supplemental power (including cogeneration). We expect fuel cells to flourish in applications requiring on-site, on-demand guaranteed power.

Concluding Vision

Public policy will determine whether, twenty years from now, fossil fuels continue to dominate our energy system. Even conservative scenarios project fossil fuel energy to be available for exploitation at roughly today's levels.

Irrespective of public policy, we foresee a shift from centralized to distributed power generation (from *utility scale* to *community scale*), which will favour renewables and clean technologies. This distributed grid will *supplement,* not replace, the centralized grid. It will also create an *electron democracy* in which grid-tied power generation is no longer the exclusive domain of centralized utilities….but, is extended to individuals.

In the distributed grid, intermittent wind and solar power generation would be complemented by load-following fuel cell plants, in much the same way that peaking power and base load power plants interact today. EV's, PHEV's and batteries would serve as *grid energy storage* when excess energy is being produced, analogous to the role of pumped storage hydroelectric (in which water is pumped from a lower reservoir to a higher one, for later use in generating hydroelectric power) at the utility scale.

We are hopeful and optimistic that by 2030, our energy system will be less dependent on fossil fuels – particularly for power generation. Supported by a diverse array of renewables, we could provide for our energy needs with an overlapping set of complementary clean technologies, while strongly curbing our global warming emissions. We would then be poised not only to stabilize the climate, but to transcend the Fossil Fuel Age entirely, and open a *new Sustainability Age* in our human story.

END NOTES -

[i] Examples include the *Energy Information Administration* (EIA) and consultants *Cambridge Energy Research Associates* (CERA, led by Daniel Yergin).

[ii] Examples include the *Association for the Study of Peak Oil* (ASPO) and investment bank Simmons International (led by Matt Simmons).

[iii] Monthly worldwide production is available from the EIA at: http://www.eia.doe.gov/emeu/ipsr/t14.xls.

[iv] Long lead times also bedevil offshore oil projects. Claims that offshore drilling ten years ago would have increased current supply, ignore the fact that at the time (fall 1998) oil prices had reached all-time inflation-adjusted lows. There was no economic motive for oil companies to develop those fields.

[v] Calculations are from the *International Energy Agency*'s World Energy Outlook 2008. The executive summary is available at http://www.iea.org/Textbase/npsum/WEO2008SUM.pdf. Current supply is 84 million barrels per day (mbpd). 64 mbpd are required to reach 106-mbpd production in 2030, implying depletion from existing fields of (106-64) mbpd or 42 mbpd. New production required to sustain current levels is thus (84-42) mbpd or 42 mbpd. Saudi Arabian output is roughly 10 mbpd.

[vi] See *Simmons & Company International's* Qatar Report dated April 24 2006, available at http://www.simmonsco-intl.com/files/Qatar%20Report.pdf.

[vii] 140 years - EIA, at http://www.eia.doe.gov/oiaf/ieo/coal.html. Increasing more than half by 2030 - EIA, at http://www.eia.doe.gov/oiaf/ieo/excel/ieoreftab_2.xls.

[viii] *Energy Watch Group*, Coal: Resources and Future Production, July 10 2007. Available at http://www.energywatchgroup.org/fileadmin/global/pdf/EWG_Report_Coal_10-07-2007ms.pdf .

[ix] Nauclér, T., Campbell, W., and Rujis, J., Carbon Capture & Storage: Assessing the Economics, *McKinsey Climate Change Initiative*, McKinsey & Company, Sept 22 2008.

[x] de Sousa and Mearns completed such an analysis, appending the raw data for transparency purposes. See de Sousa, L. and Mearns, E., *Olduvai Revisited*, TheOilDrum.com, February 2008, http://europe.theoildrum.com/node/3565.

[xi] See for example, Romm, J., *The Cold Truth About Climate Change*, salon.com, Feb 27, 2008. http://www.salon.com/news/feature/2008/02/27/global_warming_deniers/print.html.

[xii] Many sources are available. See for example, Carbon Dioxide Levels Already In Danger Zone, Revised Theory Shows, Science Daily, November 8 2008. http://www.sciencedaily.com/releases/2008/11/081108155834.htm.

[xiii] In Europe, heat waves in 2003 and 2006 infamously caused the shutdown of nuclear power plants. The concern was that, with abnormally warm river temperatures and warmer plant discharge water (used for cooling) dissolved oxygen levels would be low enough to pose a threat to marine life. See for example, Jowit, J., and Espinoza, J., Heatwave shuts down nuclear power plants, The Observer, July 30 2006. http://www.guardian.co.uk/environment/2006/jul/30/energy.weather.

[xiv] A fuller exploration of these trends is available from Vail (A Theory of Power) and Robb (Brave New War) in their writings on *rhizome* at www.jeffvail.net and *the resilient community* at globalguerrillas.typepad.com, respectively.

****