The Four Horsemen

1. Oil Supply
2. The Pakistani Nuclear Weapons Programme
3. MENA Population Growth
4. Climate – the 210 year cooling cycle
The First Horseman

I watched as the Lamb opened the first of the seven seals. Then I heard one of the four living creatures say in a voice like thunder, "Come and see!" I looked, and there before me was a white horse! Its rider held a bow, and he was given a crown, and he rode out as a conqueror bent on conquest.

Revelation 6:1-2

Conquest: Oil Supply
The Oil Price: What will drive everything.

“One day we will run out of oil; it is not today or tomorrow, but one day we will run out of oil and we have to leave oil before oil leaves us, and we have to prepare ourselves for that day.”

Fatih Birol, Chief Economist of the International Energy Agency

3rd August, 2009
The most successful economic prediction ever made

King Hubbert predicted in 1956 that US oil production would peak in 1970.
King Hubbert at the peak of his predictive powers
US production decline has entered its fourth decade.
This is the cheap stuff - does not include shale oil, tar sands, natural gas liquids.
The decline will be 1.0 million barrels/day/year.
We are here.

Figure 13.9 from Report 117
Report 117 was suppressed by the Australian Govt.

Non-OPEC production will fall 20 million BOPD by the end of the decade.

Source: http://pubs.acs.org/stoken/presspac/presspac/full/10.1021/ef901240p
Oil Intensity of the US Economy continues to drop.

Oil Intensity of the US Economy 1980 - 2020
- barrels per thousand dollars of GDP
If the demand reduction trend continues
And it might get there much faster than that.
Typical Bakken shale oil production decline

Down to 15% by year three
The average production cost of shale gas is $5.20 per gj.
The shale gale will blow for about 20 years.

Potential Louisiana Gas Production Profile 2011 - 2041

800 Haynesville wells per annum for 10 years
Haynesville production totals 27 TCF
- energy equivalent of 4.5 billion barrels
Historic Oil Price

Oil Price 1861 - 2010

2010 US$

Period of inherent over-supply

First Oil Shock

Second Oil Shock
The oil price is up despite the weak economy.
Will the established trend hold - $200/bbl by 2014?
The oil price will drive nuclear plant building.

Oil Price Projection with trigger points

US$120 per barrel:
Economic to replace coal-fired power with nuclear to free coal for coal-to-liquids plants.

US$60 per barrel:
Coal to liquids provides an economic return.

Inherent over-supply
Tightening supply

Projection

2006
2016
Energy-related inputs relative to total operating expenses, 2007-08 average

Energy-related expenses, selected crops, 2007-08 average

"Impacts of Higher Energy Prices on Agriculture and Rural Economies"
by Ronald Sands and Paul Westcott. USDA
Based on the USDA figures and a US$200/bbl oil price:

Wheat and corn operating costs will be 60% higher in 2014.
Variation with Oil Price

Australians are paying US$190/bbl for petrol, Germany US$340/bbl.
The stupidity of displacing coal with natural gas to make electric power.

Continue to See Strong Long Term LNG Pricing

- Recent contracts point to strong underlying demand
- Pricing reflects new supply-demand equilibrium
- Long-term Asia-Pacific pricing remains oil-linked

Might as well be burning oil.

Source: Poten & Partners

Santos 4th March 2010
The optimal solution

Rebuild the energy sector:

1. **Coal-to-Liquids (CTL) and compressed natural gas (CNG)** replaces declining oil production.

2. **Nuclear** replaces coal for power generation as coal becomes too valuable as CTL feedstock.

3. **Develop thorium reactors** to replace uranium in nuclear energy.
China is leaving oil before the rest of us.
Coal-to-Liquids in China is advancing rapidly.

- Three Fischer-Tropsch and one liquefaction plant commissioned.
- A further three Fischer-Tropsch plants under construction.
- Total planned production in excess of 600,000 barrels per day.
- From ASIACHEM 2011: “Chinese CTL investors will pay active efforts in preliminary works for mega size CTL projects starting from 2011 and may realise commissioning of such projects before the year 2015”
- Who allowed the CTL gap with China?
Great Plains Synfuels Plant
North Dakota

Annual consumption is 6 million tonnes of lignite to produce 54 billion cubic feet of synthetic natural Gas – equivalent to 10,000 barrels/day.

It could be making diesel, and jet fuel.
Energy Density of Transport Fuels

- Ethanol
- LPG
- Petrol
- Avgas
- Diesel
- LNG
- CNG at 3,600 psi
- Ammonia
- Lithium Ion Battery

Energy Density per Litre

GJ per litre

0.04
0.03
0.02
0.01
0.0

Y-axis: GJ per litre
X-axis: Energy Density per Litre
Natural gas vehicles – the electric car alternative

Fiat Panda with capacity for 12 kg of natural gas and has 30 litres of petrol backup.

In a recent test in Europe, it did 720 km on €30 of natural gas - €0.04 per km.
Relative efficiency of use of natural gas

Therefore the electric car future should be nuclear-powered.
CTL will take our coal endowment 30% further than the power station / electric car route.

<table>
<thead>
<tr>
<th>Coal-to-Liquids</th>
<th>Electric Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00 unit of energy</td>
<td>1.00 unit of energy</td>
</tr>
<tr>
<td>0.60 conversion to diesel</td>
<td>0.36 conversion to electric power</td>
</tr>
<tr>
<td></td>
<td>0.32 delivered after transmission loss</td>
</tr>
<tr>
<td></td>
<td>0.23 after charge/discharge loss</td>
</tr>
<tr>
<td>0.30 power to wheels</td>
<td>0.23 power to wheels</td>
</tr>
</tbody>
</table>

Diesel is storable, electric power isn’t.
Thorium’s Two Compelling Reasons:

1. A Thorium molten salt reactor is walk-away safe – Uranium can’t be.

2. Thorium has one ten-thousandth the rate of high level waste production of the Uranium route.
Thorium Process Route
1 GWe year

Neutron

100%

Th\(^{232}\)

1 tonne

Neutron

100%

U\(^{233}\)

89%

Neutron

11%

U\(^{234}\)

100%

Neutron

18%

U\(^{235}\)

Neutron

100%

Np\(^{237}\)

0.02 tonne

Fertile

Fissile

1 tonne

Fission Products

Fission Products

Fission Products

Neutron

100%

Pu\(^{238}\)

100%

Neutron

38%

Pu\(^{239}\)

100%

Neutron

29%

Pu\(^{241}\)

0.002 tonne

Neutron

29%

Pu\(^{242}\)

100%

Neutron

37
Thorium 1 tonne

Uranium 250 tonnes

Enriched Uranium 35 tonnes

Spent Fuel 35 tonnes

Depleted Uranium 215 tonnes

Spent Fuel Composition

1.0 t Fission Products

0.3 t U$^{235}$

0.3 t Pu

33.4 t U$^{238}$

1 GWe year

Uranium Light Water Reactor Route
Relative Radio Toxicity
- time is arithmetic

Relative Radio Toxicity
- arithmetic scale for time

Uranium without reprocessing
Uranium with reprocessing
Thorium

Relative radio toxicity - log scale
100,000 years
One million years
Thorium

• Fertile but not fissile – needs a breeder reactor
• Four times as abundant as uranium.
• Half life of 14 billion years.
• By-product of mineral sands mining.
• The molten salt breeder reactor has the promise to provide low cost power with no long term, high level waste.
• The Chinese Government announced a molten salt thorium reactor project on 25th January 2011 – and specifically stated its intention to capture and control global IP on thorium reactors.
Two Fluid Thorium Reactor

Criticality achieved by increase in diameter

Neutrons from U233 in the fuel salt irradiate thorium in the blanket salt

Chemical separator

Th-232 in

Chemical separator

Fertile Th-232 blanket

Fissile U-233 core

New U-233 fuel

Fission products out

Heat
The "Fireball", or Aircraft Reactor Test, was the culmination of the ANP effort at ORNL.  
- Designed to produce 60 MW of thermal power  
- Core power density was 1.3 MW/litre  
- 235UF4 dissolved in NaF-ZrF4  
- NaK used to transport heat to jet engines at 1150 K  
- The "Fireball" pressure shell was only 1.4 meters in diameter!  
Flew with an operating reactor 1955 – 1957 as a test bed. The reactor was not connected to the engines.
The future nuclear fleet might be floating

Akademik Lomonosov, 75 MWe

Concept

Hull launch
St Petersburg 30th June, 2010
Fuel loading into the two Reactors in 2012
We have to get nuclear power right if we are going to have a future.

Hubbert 1965 “Nuclear Energy and the Fossil Fuels”
The Second Horseman

When the Lamb opened the second seal, I heard the second living creature say, "Come and see!" Then another horse came out, a fiery red one. Its rider was given power to take peace from the earth and to make men slay each other. To him was given a large sword.

Revelation 6:3-4

War
-The Pakistani nuclear weapon programme
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>President Bhutto decides to build a bomb</td>
</tr>
<tr>
<td>1974</td>
<td>India explodes nuclear device</td>
</tr>
<tr>
<td>1974</td>
<td>Dr Kahn smuggles centrifuge blueprints to Pakistan</td>
</tr>
<tr>
<td>1978</td>
<td>First enrichment of uranium</td>
</tr>
<tr>
<td>1983</td>
<td>90% enrichment achieved</td>
</tr>
<tr>
<td>1984</td>
<td>Bomb ready but test delayed due to Afghan war</td>
</tr>
<tr>
<td>1988</td>
<td>Missile delivery system developed, technology from China</td>
</tr>
<tr>
<td>1988</td>
<td>First plutonium reactor at the Khushab site</td>
</tr>
<tr>
<td>1998</td>
<td>First bomb tests - 6 devices in May</td>
</tr>
<tr>
<td>1998</td>
<td>programme was $20 million/year for 25 years</td>
</tr>
<tr>
<td>2001</td>
<td>Pakistan-sponsored attack on Indian Parliament</td>
</tr>
<tr>
<td>2002</td>
<td>Construction begins on second reactor at the Khusab site</td>
</tr>
<tr>
<td>2006</td>
<td>Construction begins on third reactor at the Khusab site</td>
</tr>
<tr>
<td>2008</td>
<td>Pakistan-sponsored attack on Mumbai</td>
</tr>
<tr>
<td>2011</td>
<td>Construction begins on fourth reactor at the Khusab site</td>
</tr>
</tbody>
</table>
Location at:
32° 00’ N
72° 12’ E

Khushab Plutonium Production Complex

Reactor 1
Reactor 2
Reactor 3
Site of Reactor 4
Heavy water production plant
First reactor at Khushab
Beyond deterrence, a war-fighting capability

<table>
<thead>
<tr>
<th>Bombs</th>
<th>Missiles</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current arsenal of approx. 100</td>
<td>Hatf 9</td>
<td>60 km</td>
</tr>
<tr>
<td>Upon completion of Khusab 4,</td>
<td>Hatf 2</td>
<td>180 km</td>
</tr>
<tr>
<td>build rate of 40 x 20kt bombs</td>
<td>Hatf 3 (Ghaznavi)</td>
<td>300 km</td>
</tr>
<tr>
<td>per annum</td>
<td>Hatf 4 (Shaheen 1)</td>
<td>700 km</td>
</tr>
<tr>
<td></td>
<td>Shaheen 2</td>
<td>2000 km</td>
</tr>
</tbody>
</table>

Meanwhile, Pakistan has a literacy rate of 55% and frequent power blackouts due to fuel shortages.

Like Pakistan’s population growth, there will be no end to Pakistan’s bomb-build in the absence of an external event.
Possible Futures

1. Pakistan uses its nuclear weapons in a regional war.

2. Failed state outcome - weapons are sold to regional players with the funds.

Either way – the genie is out of the bottle and middle powers find that they can survive an exchange of low-yielding weapons.