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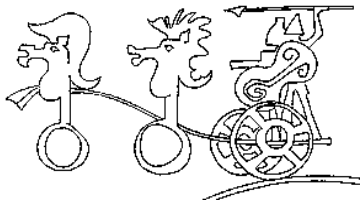

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Post-Carbon Australian Options for Railway Locomotives:

(or what industry can do when it can no-longer afford diesel.)

Folio:1:g5 Germinal Material

Numerous instances of drafts for this project where initially released on the net for public comment as **PCAL_dfX.pdf.** *This new restructured set of documents can be found at;-*

http://www.auzgnosis.com/pgs/auzloco.htm

Any and all feedback to the author via email (as above) is most appreciated. Thanks.

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NOTE: The author is sympathetic with the Open Source movement. Thus proposal to include Post-Carbon Auz Railway Locomotive Options (or parts of) in Open Source strategies of software development and dissemination may receive favourably consideration.

Table of Contents

Down by the rail-yard,
early in the morning.

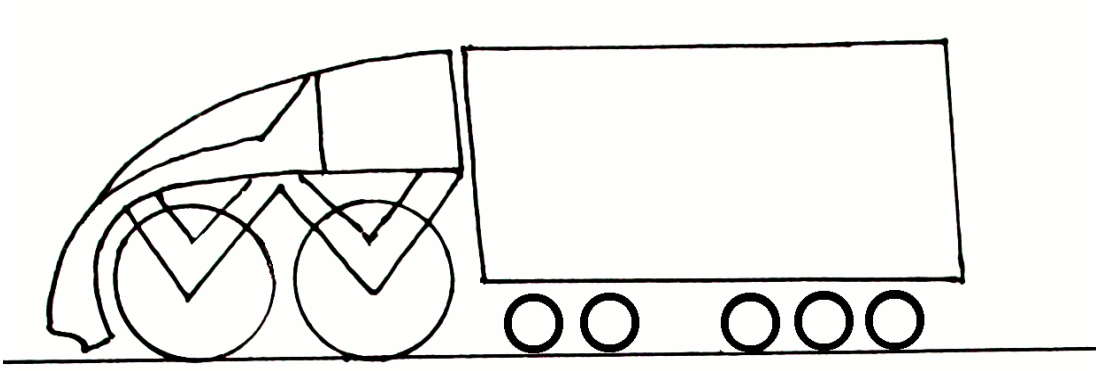
See the little sun-puffers,
chilling in a row.

See the big-old gantry,
loading up 'em hot-box-es.

Zip, zip.
Hiss, hiss.

Off we go.

W.Shawn Gray © May 2010 after the traditional nursery rhyme "*Down by the station"*



Executive Summary.

Over the millennia of humanities evolution from grass-land wanders to inhabitants of our everyday modern world, optimism validated itself as vital characteristic of our species. For with our deep complex human psychology the alternative of a rigidly pessimistic disposition would have inextricably lead to the species demise at any of the many difficulties our ancestors survived in a large measure purely by courage and optimism.

The downside being that humanities hard-wired optimism renders us ever more vulnerable to unexpected change in the acceleratingly fast-paced modern world. For while mistakes in past centuries had undesired outcomes, the full consequences of errors of judgement played out at the same slow pace of those by-gone days. That leisurely pace being more akin to the ancient context in-which our optimistically biased psychology evolved. The slow pace which decision's full repercussions (traditionally) eventuated afford wise minds some safety margin to upon second thought quickly remedy earlier errors.

Modern business practices about project and risk management, to some degree mitigate the short coming of human psychology to safely operate in the modern world. Unfortunately the effectiveness of such mitigating activities is confined to the immediate narrow business concerns of the employer.

Professionally I enjoyed the excitement of working at a technological bleeding edge, before an uncommon virus bequeathed me a brain-injury. Thus removed (for over a decade now) from fairly fixated concern to my latest assigned task, I have had the time to ponder wider perspectives. The sum of my research hopefully proffering a "Plan B", for when the current "Business as usual" [BAU] strategy dramatically fails sometime in the foreseeable future. Not wishing to be alarmist I sadly caution failure after many years searching for sustainable options. **While for much of the globe the oft heralded Hydrogen economy holds the promise of a smooth transition from a fossil fuelled to a post-carbon business as usual model, Australia will be the exception.** This sad predicament is not due to any; economic, political, cultural or other structural short-comings. **The continent of Australia unfortunately lacks the one critical prerequisite for any Hydrogen economy, being a plentiful reliable water supply everywhere one wants to travel.** So while the global economy tools up for a Hydrogen future Australia desperately will need to develop their own solutions. Conceivably if extended my research direction may provide some insurance to buttress the continued success of land-transport in a very uncertain future.

Objectives of Project.

1. Emphasise the conveniently neglected compounding commercial and logistical challenges that come to light when the implications of Climate Change to an evolving Post Carbon world are re-framed by the insights garnered from the Peak Oil discourse.
2. Reappraise historical trends of the broad sociological structuring function engendered in choice of power sources within the evolution of an industrial society.

   Then Addressed in 2nd folio: Technical Material:
3. Explore carbon neutral options for long-distance land transportation.
4. If plausible, investigate (non-domestic) industrial scale engine-types to be exclusively fuelled by outputs from renewable power sources.

Outline.

The double whammy of the unfolding Peak-Oil quandaries simultaneously as Climate-Change ever worsen pose complex, intertwined challenges for humanity in the 21st Century and beyond.

This first paper then very briefly maps the interdependences of the major themes byway of a little historical background. Focusing then on the peculiar mix of concerns that will come to define the post-carbon world, thence the challenges all that will pose to long-distance land transport. Finally

concentrating on difficulties to be faced by heavy-rail, so heralding the following documents' technical examination of some options for railway locomotives.

Preamble.

This is the first paper from a collection of graded documents. While this first paper is aimed at a general readership, the remaining documents are of a more technical nature. The expectation being that any reader of those latter documents will already posses the required level of knowledge to understand the complexities in the content of a given paper. Due to the breath of material envisaged as possibly comprising the final collection it is unlikely that any single individual will be familiar with all the nuances raised by these investigations. Unfortunately as necessitated by the introductory nature of this first paper it may touch on may things unfamiliar to lots of readers.

Housekeeping.

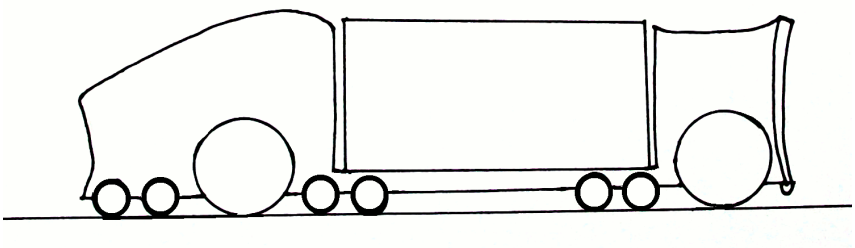
World Wide Web URLs [web addresses] have been included as links to more detail background if the reader requires such. Not as any implied endorsement (of quality or completeness,) Wikipedia will be cited in many instance, primarily for the simplicity of the treatment, combined with list of good links to more rigorous sources. However two website frequently cited here-in; www.5at.co.uk and www.martynbane.co.uk for knowledge of second generation steam locomotives I'd unreservedly endorse both of them. The web addresses were verified and correct at the time of publication.

Legals & Personal.

As detailed on my company website: [http://www.auzgnosis.com/pgs/thinkin.htm] this document like other similar works via AuzGnosis is distributed as-is. ***AuzGnosis supplies ideas, with No Guarantee or Warranty. You are totally responsible for your own judgement as to the ideas' plausibility, suitability and desirability, thence any utilization and implementation, you may, or may not, undertake.***

Personally my resume and other such things can be found on my AuzGnosis website.

W. Shawn Gray



Part 1: Challenges thence Ramifications.

Say What? When?

Caution Contextual.

First a spot of context for this research paper, I make no claims to being a disciple of futurology. [http://en.wikipedia.org/wiki/Futures_studies] An altogether unsurprising admission given that futurology is a dusty academic dalliance inebriated in statistical methodology it has scant regard for the breathtaking beauty, nor a trace of insight into the systematic significance of the butterfly. [http://en.wikipedia.org/wiki/Butterfly_effect] Rather my modus operandi, while closer to the Strategic Foresight crowd, is more that of the eclectic old-time Futurist.

On 20 July 1969, NASA's Apollo 11 mission all too briefly enabled the first astronaut to walk on the surface of the Moon. Four years prior on 22 February 1965 Metro-Goldwyn-Mayer announced backing for Stanley Kubrick's next film which became "2001: A Space Odyssey". [http://en.wikipedia.org/wiki/2001:_A_Space_Odyssey_(film)]

When the film premiered in 1968 (in the full heat of the "Space Race"), the film embodied the most technically accurate forward-projections by the aerospace industry professionals (at that time) as to what they highly expected would be reality by 2001. When the calendar did eventually tick over to 2001, Kubrick's Space Odyssey seemed less plausible 30 years after the film's creation, than it once had been in the days when the film was first released!

For a whole bunch of reasons and uncertainties (touched on in part here-after) picking plausible future paths is a lot more difficult now than it was those short fifty years back. When contemplating the hopes of "*the business as usual*" chorus it is well worth recalling how far off reality history has proven the aerospace industry plans circa 1960s actually were.

To remove any potential for confusion the issue here is not the predictive success rate brilliant visionaries imagining some future. Such as Jules Verne recently discovered novel "Paris in the Twentieth Century" that uncanny parallels of the reality of Paris at the end of the last century. [http://en.wikipedia.org/wiki/Paris_in_the_Twentieth_Century] Rather the issue is the inherent uncertainties of the future, even when the foundation is rigorously crafted commercial scheduled works already in development. Scanning even a small sample of projects "*in the pipeline*" at the time Kubrick's "2001: Space Odyssey" film was researched evidence the heady optimism of the era. [http://en.wikipedia.org/wiki/Boeing_2707 , http://en.wikipedia.org/wiki/Spaceplane & http://en.wikipedia.org/wiki/Rockwell_X-30]

Hubbert Curve.

The American geophysicist M. King Hubbert in 1956 successfully predicted the collapse of conventional oil supplies in the Lower 49 states of the USA. Hubbert had created a method of modelling the production curve from discovery rates, production rates thus cumulative production by time. [http://en.wikipedia.org/wiki/Hubbert_peak_theory] Besides the supplies of conventional oil, Hubbert's theory has since been applied to many other mineral resources, with wildly varying success. Despite those modelling exercises being so spotty they did start raising question as to the long-term resilience of the resources that underpin our modern technological society.

Unsustainable Growth

In the 18th Century, when the sum of humanity was still below the 2 billion (10^9) persons mark for Earth's long-term sustainable human population, petty self aggrandisement or expansions of nation

states was not a fatal affliction for the human species in totality. The Industrial Revolution, with the dramatic rise of coal consumption bootstrapped humanity in it's overshoot of the Earth's carrying capacity. [http://en.wikipedia.org/wiki/Overpopulation & http://en.wikipedia.org/wiki/Carrying_capacity]

Limits To Growth

The 1972 book commissioned by the Club of Rome, that was a trail blazing use of computer modelling as to possible global outcomes from unchecked economic and population growth with finite resource supplies [http://en.wikipedia.org/wiki/Limits_to_Growth]. Upon publication the book was strongly ideologically attacked from both ends of the political spectrum. Seen by many critics as an unrealistic dystopia, resulting from too simplistic flawed modelling. But in 2008 Graham Turner from the CSIRO in his paper "*A Comparison of 'The Limits to Growth' with Thirty Years of Reality*", showed that the past thirty years of reality closely match the Limits to Growth predictions for economic and societal collapse in the 21st century!

Peak Mineral Resources

[http://www.bbc.co.uk/bbc.com/future/BBCF_infoData_stock_check.pdf ,
http://www.bbc.com/future/story/20120618-global-resources-stock-check?selectorSection=science-environment ,
http://www.newscientist.com/article/mg19426051.200-earths-natural-wealth-an-audit.html?full=true
& http://en.wikipedia.org/wiki/Liebig's_law_of_the_minimum exacerbated by
http://en.wikipedia.org/wiki/Jevons_paradox]

Energy Supply Peaks.

Peak Uranium

[http://en.wikipedia.org/wiki/Peak_uranium]

Peak Coal

[http://www.theoildrum.com/files/coalmodel.pdf]

Peak Gas

[http://en.wikipedia.org/wiki/Peak_gas]

Peak *Conventional* Oil

In the authentic sense Peak Oil [http://en.wikipedia.org/wiki/Peak_Oil] is a technical term for the ***point in the life of a region's [conventional] oil supply where half of the [conventional] oil reserves have already been extracted*** *(in the given region)*. Unfortunately due to sloppy mass-media reporting in the popular-culture the term has been misconstrued as all the problems that are expected to befall the modern world with a hyped imminent crashing of the globe's oil reserves. The confusion being further confounded by the habit of some commentators for abbreviating the related technical idea of Oil Peak Production to as "Peak Oil"! (Which is the same sense that Peak Uranium is defined as).

So here I hope to tease-out the implication of "Peak Oil" as point where the finite (projected and known) conventional oil reserves passed the point that more viable oil had already been extracted than what was left in ground for the whole world. Global Peak Oil does not mean that the 'Age of Oil' will rapidly come to a shuddering halt; rather what Oil is left will get ever more expensive as supplies and quality inextricably deteriorate.

Implication from Conventional Oil's Peak.

All this is explored in great detail in the web-pages I co-wrote with Rupert Edward's [http://www.reocities.com/RainForest/Canopy/2265/nonew-oil.htm]. On the web-page Oil-Less Life [http://www.reocities.com/RainForest/Canopy/2265/no-oil.htm] to get some feel for how declining oil

resources will impact on society I provided the following formula.;-

$$Be = Po - (Ya * ff)$$

Where;- **Be** is the **Before Equivalent year**,

Po is the year that **Peak Oil** is believed to have been, or will have reached in/ by.

Ya is the number of **Years After** the Peak.

***** means multiple preceding variable by following variable.

ff stands for **foolishness factor**. Nominally equated to a value one for rough calculations assuming that everything (population, environmental health, energy demand, etc.) magically remain static after the peak passes.

During the current production plateau it has been noted that the *Conventional Oil* Peak will only be clearly discernible sometime after the event. Highly regarded experts have variously suggested that Peak was [http://en.wikipedia.org/wiki/Predicting_the_timing_of_peak_oil] 2004, 2005, 2006, 2008. As for the fall off the plateau, sliding down the far-side nobody is saying 2010; the optimist are punting for 2030 while pessimist say 2012. The collapse of conventional oil supplies is expected to proceed at a rate of 3% per year or more.

From Australian government 2009 funded research the political distasteful answer is a cliff at 2017. Too close for the ten years of preparation the report advised is needed to allow a smooth transition to the new commercial reality, along with necessary social adjustments. That "BITRE Report 117: Transport energy futures: long-term oil supply trends and projections" is free online [http://www.manicore.com/fichiers/Australian_Govt_Oil_supply_trends.pdf]

Non-Traditional Supplies a.k.a. *Unconventional* Oil

[http://en.wikipedia.org/wiki/Unconventional_oil] The biggest surprise since passing peak production from conventional oil supplies, is how the more expensive non-traditional sources such as Deep-Sea oil, Arctic-oil and Canadian Oil-sands have been so smoothly (at least for now) trickled into existing oil processing infrastructure as to perpetuate the illusion of a seamless continuation of endless affordable oil supplies. Thus in the short term petroleum products at retail outlets is unlikely to vanish, but as evidence already internationally they have begun to dwindle. However it does not follow that such fabricated petroleum offerings will be either economically attractive, nor that demand will remain as carbon pricing and other changes finally force the oil companies to internalises the externalities that historical the public unwittingly were forced to pay. But biggest unknown now is what fossil fuel will ever make it to market, as the globes economically recoverable fossil fuel resources contain far more carbon content than humanity can prudently release into the atmosphere while remaining below the +2°C above pre-industrial levels [detailed immediately below] supposed safety threshold.

Climate Change.

Climate Change [http://en.wikipedia.org/wiki/Climate_Change] is the disastrous imperilling of the sustainability of life on Earth. Since the dawn of humanity, the Earth's very complex (and still poorly understood or appreciated) life support systems have maintained the global environment within the narrow band of a few degrees temperature variation, required for life as we know it. Humanity's geologically recent rapid expansion and exploitative economic activity has significantly compromised our critical biosphere. Most significantly (in the context of Climate Change) is the burdening of the atmosphere with Greenhouse Gases [http://en.wikipedia.org/wiki/Greenhouse_gas] and particulate matter from burning fossil fuels (and other raw materials), globally accumulating from the Industrial Revolution to the present day.

Ignoring Global Warming [http://en.wikipedia.org/wiki/Global_warming] only increases the ever mounting risks of Climate Change disasters. At first there will be more wild weather, droughts, flooding rain and rising sea-levels. If one of the many identified tipping-points is passed then in a relative short-time otherwise eventually, Global Warming will inevitably progress to the collapse of biosphere with all life on Earth as we know it. Detailed in links in "Hell and High Water" [below].

Warming of 2° Celsius

Traditional civilised behaviour is that when you mess something up you are expected to fix it. So since the failure of the Kyoto Protocol to perform as designed, the current stitch-up aim to restrict Global Warming to a rise no-more than X degree above the some arbitrary historical baseline is in no sense a morally sound response to this ecological calamity. Anyhow the Copenhagen Conference in 2009 which was the 15th session of the Conference of Parties [COP 15] to the United Nations Framework Convention on Climate Change [UNFCCC] (in their 2011 report) phrased the target "*so as to hold the increase in global average temperature below 2°C above preindustrial levels*".

Since the start of the Twentieth Century (to 2011) the average temperature of the planet's surface has been raised by 0.8°C (*0.6°C in last 30 years)*. Even that tiny **0.8°C** rise has caused much more damage than pessimist predicted. The famous NASA climatologist James Hansen encapsulates the stupidity thus: "*The target that has been talked about in international negotiations for two degrees of warming is actually a prescription for long-term disaster.*" While the +2°C target once held hope of avoiding the then "known" tipping-points to ecocidal climate change, the target is at best a dangerously unscientific political compromise. The 2°C target first gained attention at a 1995 climate conference. (Coincidently Angela Merkel now the first female Chancellor of Germany, in her role then as the German minister of the environment had chaired that climate conference).

A rise of just **1°C** will wipe many island nations from the map as they are drowned beneath the rising oceans, expanding in volume as they will due to the rise in the oceans' average temperature. **1°C** will also be disastrous for most of Africa, thus the horror of the African conference delegates to the 2009 Copenhagen climate fiasco as it once again signed on to the **2°C** illusion of action. None of the attending nations individual optimistic promises for deep cuts to their own carbon emissions even pretend to be legally binding commitments. Nothing in the final "Copenhagen Accord" is enforceable by, nor on anybody.

But hang-on a moment "*pre-industrial levels*" is a long-time before the beginning of the 20th Century. If one holds the view that "*pre-industrial levels*" equates at least to being before the start of industrial revolution that is circa 1750, not 1900. The Berkeley Earth Surface Temperature (BEST) project collated 14.4 million observations from 44,455 location around the globe going back as far as 1753. The release of the BEST research report in July 2012 was a shock for everybody as the BEST researchers had authenticated a 1.5°C temperature rise over the last 250 years!

Hell and High Water.

Various strategies and conventions for curbing the release of greenhouse gas are currently under international negotiation (at a unrealistic painfully slow pace give the urgency and severity of the problem). The hoped for outcome is that the historical spiralling release of CO_2 (and other Greenhouse Gases) into the atmosphere is to be first arrested, then reduced to those recent past levels required for the long-term continuation of life on the planet. A major component of such efforts will be a drastic reduction in the burning of fossil fuels, which is very problematic to the future of transport.

If the captains of industry and National Leaders do not deliver binding, sane limits very soon then:

According to models, we could cook the planet by 4 °C by 2100. Some scientists fear that we may get there as soon as 2050. [http://www.newscientist.com/article/mg20126971.700-how-to-survive-the-coming-century.html , http://rsta.royalsocietypublishing.org/content/369/1934.toc] Early in 2013 James Hansen noted the last time the planet reached +4°C there were no ice-caps left, such that if it that happens again sea-levels are expected to eventually (in a few centuries or so) peak eighty metres above the current hide-tide marks. Well before reaching the full 80 metre rise in sea-levels we will see most of world's major sea-ports and dockyards vanishing beneath the waves. More worryingly not long after numerous heavily populated iconic cities will irrecoverably be submerged as so many modern day Atlantises. Latest projections from the business community acknowledge the trend now look like going as bad as +4°C by 2060. Thus one can only hope burning of any remaining fossil fuel without full carbon-neural offsetting will simply become unthinkable (that is without any worry about fossil fuel supply shortfalls or collapse). A USA oriented view of the same is here [http://thinkprogress.org/climate/2011/09/28/330109/science-of-global-warming-impacts/].

Still More Complications:

Global Dimming

[http://en.wikipedia.org/wiki/Global_dimming]

Scarce Water

[http://en.wikipedia.org/wiki/Water_crisis]

Unpacking a Post-Carbon World.

Niccolò Machiavelli(May 3, 1469 – June 21, 1527)

> ***"It ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things.*** *Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new.* ***This coolness arises partly from fear of the opponents, who have the laws on their side, and partly from the incredulity of men, who do not readily believe in new things until they have had a long experience of them."***
>
> *(as translated by RM Adams) Ch. 3 The Prince* (1513)

Fuel Sources as Driver of Socio-economic Change.

The discovery of the economic multiplier effect of industrial power provided by fossil fuels during the industrial revolution was a mixed blessing. On the positive side it underwrote rising living standards for most of the world's industrialized societies, but conversely it enable man to carelessly dream and go well beyond long-term sustainable consumption patterns. While the very awkwardness of Coal (a cumbersome, dusty, dirty, mineral) did provide some pause in the process, mineral-Oil's (rock oil) ease of production then use accelerated the world to the current extremes.

Coal thus bequeathed humanity with steam power, railways, the telegraph, tramp-steamers, ocean-liners, battleships, gas cooking, gaslight and the very form of the industrialized city.

Likewise Oil in turn added the petro-chemical industry, plastics, synthetic fabrics, the private automobile, urban-sprawl, air-travel, and the Green Revolution.

The eventual physical form and social quality of a society directly evolves from the primary energy source / fuel of that society. So moving to a Low-Carbon or Post-Carbon world is a bigger issue than just which fuel is chosen.

International Community Globalization.

The astute reader will notice that large scale organization of people, kingdoms, empires, pre-date the socio-economic stimulus of fossil fuels. However the first incarnation of Globalization, did have to await Coal's steam-powered shipping and the international telegraph system. From the mid 19th century to the World War I the world dallied with Globalization. Then in-turn WW1 prompted the forming of the 'League of Nations' as the first common platform of the International Community.

Unfortunately just as the 'League of Nations' failed in its aim of World Peace, the International Community's track record since does not provide too much hope that sound and just solutions will be reached in time to effectively mitigate the double disaster of Climate Change plus Peak Oil.

Response Deficit.

{ I have summarised myself for this following section. There is a far more detailed argued version of these points at [http://www.reocities.com/RainForest/Canopy/2265/markets.htm].}

The response to the certain demise of abundant cheap oil, the consensus of mainstream media, the business community with their cohorts in government, has been to affirm their blind faith in the magic of free markets. Prior to the Industrial Revolution, Adam Smith, in expounding his concepts of how the ideal market functioned, postulated the effect he coined: 'the Invisible Hand'. The idea being that 'free' (of external manipulation) open markets lead to the efficient allocation of commodities between competing interest, as if allocation decisions where being made by some by some impartial 'Invisible Hand'.

Nice theory. Unfortunately Oil is just not just another everyday commodity. Oil is power, conveniently liquid packaged energy, and at this point in history the life blood of modern civilisation. While 'Prior to the Industrial Revolution' Adam Smith's idea had a lot of merit, it does not any longer. With an increase in speed, thence volatility of markets, in-concert with trading hydrocarbons fuels (coal and oil) which by being 'power' distorts the market, the 'Invisible Hand' is now a positive impediment to the wise allocation of resource!

The reliance on market signals to determine allocation of the worlds finite oil heritage, makes about as much sense as a General waiting to count his dead at the end of a battle, before settling on his plans about how that same battle should be best fought! This is not to deny the argument that as the demand for a commodity exceeds the supply, prices will rise so theoretically reducing demand. At the same time the use of substitute energy increases as in-turn they gain economic appeal from the now higher priced commodity having exceed what was once viewed as an expensive alternative. As potent a signal that rising prices for oil in the market will be, that signal will only arrive after it is too late to be of much use.

The spin that higher oil prices will encourage the uptake of alternatives is meaningless if those more expensive alternative's infrastructure is non-existent when the demand for it erupts.

The whole 'switching to alternatives' position becomes more bizarre when it is realized there are no alternatives that match oil's unique mix of appeals (with quantifiable high volume long-term supply prospects). All the so-called 'alternate energy' solutions are niche answers for a small handful (from a mind-boggling large collection) of technical problems to be faced in a post-carbon world.

Exacerbating the whole lack of alternative infrastructure obstacles are more trouble-some incestuous unfathomable quandaries:-

- For which of the many alternatives should there be investment made on infrastructure roll-out prior to any demand?
- Is there enough time left before the Post-Carbon challenge bites too hard to allow the roll-

out of said infrastructure?

- To what extent will the current financial crises hinder timely responses to Peak Oil and Climate Change?
- Is there enough time still remaining to educate the required future skill sets? Transport fleets take time to turn-over / replace (~ 15 years). Do we have enough time?
- Do we also still have enough time of between 5 to 20 years required to research and develop some new transport modes before even replacing the existing technology?
- To what degree and where will Climate Change impact the nations local economies along with agriculture and population distributions?

EROEI of the Energy Challenges.

Irrespective of whatever the international community eventual decide to do, or not to do, about Climate Change thence the choke of liquid fuels, it is quite certain even now that we have seen the last of "cheap", sweet oil. In the future all fossil fuels along with any carbon based alternatives like bio-fuels will be more expensive in real-terms than for the most of the past century. The further into the future one contemplates the more prohibitive such carbon fuels will become, if they are obtainable in required quantities at all!

The astounding engineering utility of Oil should be clear in our minds, before any audacious future gazing. Historically from fresh young oil-fields the black-gold flowed to the consumer for as little as a hundredth of the energy invested in obtaining it. The oil industry proclaiming that oil was the most abundant user-friendly and energy dense fuel know to human-kind.

Excluding the current seductive short gulp of cheap natural gas to petroleum band-aid, all the other much touted alternatives of oil-sands, shale-oil and bio-fuels may display the same usage advantages but sourcing and distributing can consume as much if not more energy in total than is represented by the end product! This concept Energy Return On Energy Invested or **EROEI** (aka EROI) [http://en.wikipedia.org/wiki/EROEI] being deployed in such discussion. EROEI is often is to compare the energy efficiency of competing transport alternatives as a "Well to Wheel" modelling exercise. Proving (in applicable circumstances) that in comparison to a petrol guzzling late model sedan an electric-car's clean green hallo is extremely dishonest when said electric-car is being recharged over-night at home wall-socket feed by the dirty coal fired relic of a power-station. EROEI is also instructive in the economic analysis of competing energy source pathways. So during analysis one can choose the lowest available cost point for X amount of energy, then examine the upward cost spiral driven by each additional steps to get various fuels to market in an attractive convenient form. Historically rock-oil could be supplied as petrol to the motorist for less than an additional tenth of the energy the motorist fuel would contain. But some of the alternate petroleum replacements that are seriously being touted now necessitate the consumption of more energy in their production and distribution than that which is embedded in the fuel the user purchase. In other-words the alternative has a negative EROEI as less Energy is Returned in the fuel purchased by the consumer than the amount of Energy Invested (consumed) On the task of producing the fuel!

Liquefied petroleum gas and other natural gases [http://en.wikipedia.org/wiki/Natural_gas & http://en.wikipedia.org/wiki/Methane] maybe obtained and delivered to the consumer near oils historical low EROEI figures, but conversely all these gas are markedly lower in the energy density rankings than gasoline or diesoline everywhere. As regards to Fisher-Tropsch and other such process see Alternate Hydrocarbon Concoctions. particularly CTL : Coal to Liquid. [sections below.]

Finally we must not forget the fact that irrespective of what EROEI a fuel may represent, each extra step in a fuels production and distribution will more than likely also come at the impost of

additional carbon released into the Earth's already overburdened finite atmosphere. (A 100% renewable energy power sources being the obvious exception).

Loss of Energy Density.

A troublesome concern with any inevitable move away from energy dense liquid hydrocarbons, is the increased storage & transportation volumes, combined with refuelling difficulties associated with less dense alternative fuels. Diesel fuel has 42.3 MJ/L whereas LPG propane = 25.3 MJ/L which requires about half as much space again to have the same amount energy. From there all the other alternatives are more space hungry. There is only 10 MJ/L with compressed natural gas at 200 bar, about the same as Liquid hydrogen's 10.1 MJ/L, thus needing four times more space than same amount of energy in diesel. But in our list so far the only non-hydrocarbon is "Liquid" hydrogen, being cryogenically cold is not an easy fuel to readily store or deploy, so the most popular proposed form is compressed gaseous hydrogen (at 700 bar) that is only 5.6 MJ/L meaning that you need a 7.55 larger gas tank that will take at least 7.55 times longer to refill. Or you could have a larger fuel tank and refill it seven times more often!

Gassy Hydrocarbon Stopgaps.

In comparison to the liquid fuels (as touched on above) the gasses hydrocarbons forms have lower energy densities. That is to say using the gasses hydrocarbons will either require larger fuel tanks, or have a shorter range on what fuel-tanks are available, or both short-comings combined!

Unfortunately, lower energy densities are by no means the end of these gasses obstacles to wide scale adoption. The subtle differences in this multiplicity of options is a problem of its self. Fuel tanks and engine designs have to be twigged differently for each case, militating against cheap multi-gas input configurations. There being no clear common gas solution for all applications, nor any obvious hierarchy of matches between gas option to task niches, will mean an added cost burden to society of multiple underutilized parallel delivery infrastructures, to supply all fuels to all niches.

LPG (Liquefied Petroleum Gas) [http://en.wikipedia.org/wiki/Liquefied_petroleum_gas & http://en.wikipedia.org/wiki/Autogas],
Shale Gas (Natural Gas) [http://en.wikipedia.org/wiki/Shale_gas]
LNG (Liquefied Natural Gas) [http://en.wikipedia.org/wiki/Liquefied_natural_gas],
CNG (Compressed Natural Gas)[http://en.wikipedia.org/wiki/Compressed_natural_gas],
Coal Seam Gas (CBM) Coalbed Methane [http://en.wikipedia.org/wiki/Coalbed_methane]
HCNG (H2CNG) [http://en.wikipedia.org/wiki/HCNG]

Depending on the rates at which industry, the public and governments judge the short-coming of the gassy hydrocarbon options to out-weigh the difficulties of obtaining scarce dwindling liquid hydrocarbon supplies it would have been rational for the community to gradually switch from liquid to gassy hydrocarbon fuels. While switching would have been the most energy efficient strategy, the judgement of the oil industry has been it is far easier, especially in the current oil cost structures to simply convert numerous gas input to familiar petroleum. [http://en.wikipedia.org/wiki/Gas-to-liquids , http://en.wikipedia.org/wiki/Synthetic_fuel]

Excluding any enlightened international quarantining of particular fuels for particular niches (along with a prohibition on conversion of said sources to other gas forms), the historical occurrences of Peak Oil versus Peak (Natural) Gas maybe simultaneous; even the most optimistically wide gap is under twenty years. Meanwhile fracking [http://en.wikipedia.org/wiki/Hydraulic_fracturing] enthusiast are happy to jeopardise the health of much of the planet's ground water in pursuit of non-sustainable short-term profits.

Alternate Hydrocarbon Concoctions.

Rock-oil's Lost Advantages.

To recap the highly significant advantages formerly associated with mineral crude oil. It is by far the easiest to handle, highest energy density fuel known to humanity. For most of the last century in energy terms also the cheapest fuel to utilize. Of the energy represented by a barrel of crude oil, less than a tenth was required to initially find, then extract, transport, refine, before final distribution to the end consumer. That is to say an EROEI of nine! compared to many oil-alternatives which are lucky to get anEROEI much over one!

CTL : Coal to Liquid.

The South Africa company Sasol is the world leader in CTL (coal-to-liquids) technology. Supplying 28% of that countries liquid-fuel requirements from coal equates to a foreign exchange saving over R29 billion (AUD$ 4.434 billion (per exchange rates the day I wrote this)) a year.

Sasol produces 150,000 barrels of synthetic liquid fuel per day at their commercial scale Secunda plant. In the 50 years since Sasol started in 1955 they have made 1.5 billion barrels of synthetic oil from 800 million tonnes coal. That is about 1.875 barrels of synthetic crude per a tonne of coal.

As1.875 barrels of crude weighs only about 0.256364153 tonne (metric ton †[a]). That means that typically CTL gives 1 ton of oil for every 4 tons of coal feedstock. { One metric ton of crude oil fills approximately7.3138 barrels.}

To put that into perspective International Energy Agency reported that in 2007 the world produced 6,488 Mt. (Mt. = 10^6 megatonne) of (Hard+Brown) Coal. Compare that with total world Oil production of 3,937 Mt. If all the worlds coal production was converted via a CTL operation to oil, you end up with only 1,622 Mt of oil, which is less than half the *current* global oil consumption! (per year?)

Bio-diesel.

As a supplement (to rock-oil sourced diesel) or total replacement, bio-diesel from Algae (along with minimally processed waste streams) is a plausible carbon neutral and environmentally sound option. But not all Bio-diesel is so meritorious. Bio-diesel created by upgrading Bio-oil [see below] has a poor total EROEI and an unacceptably high price for an addiction to fuels in familiar forms. Likewise Bio-diesel from palm-oil and other agriculture is a far more dubious and unsustainable proposition. Either way whatever diesel-fuels remains after Peak Oil bites will be in short supply while getting increasingly more expensive, at some point exceeding the economic justification for usage as fuel in various tasks.

Bag-gas and Biomass

As detailed by Bruce McCammon in the context of the 5AT project, in his unpublished paper "Review of Carbon Neutral Fuels with Potential for Use in Modern Steam Locomotives" [http://5at.co.uk/uploads/Articles and papers/Carbon_neutral-fuels_10.pdf] most biomass are generally unsuitable as alternative fuels for our modern transportation needs. The exception being closely linked source with niche usage scenarios, such as sugar-cane trash to fuel narrow-gauge sugar-cane railways.

Pyrolysis Oil aka Bio-oil.

Pyrolysis Oil (sometimes called Bio-oil) is extracted from bio-mass (such as sewage sludge) by high temperature (+500°C) oxygen starved destructive distillation. [http://en.wikipedia.org/wiki/Pyrolysis_oil, http://www.bioenergywiki.net/Pyrolysis] The process also has a

[a] **metric tonne**, is the Standard International unit of mass equal to 1,000 kg (10^3 kilograms) 2,204.62 lb. Not to be confused with; the 2,240 pounds (1,016 kg) of the old Imperial long ton, or US customary unit for 2,000 pounds (907 kg) of a short ton.

side advantage that the main by-product is bio-char, allowing carbon to be readily buried in an agriculturally advantageous fashion. Containing too high an oxygen content to be a hydrocarbon, Pyrolysis Oil has a fair EROEI.

Pyrolysis Oil's high acidity and a Cetane number (CN) of only 10 makes it unsuitable as a diesoline substitute (diesel engines requiring a CN from 40 to 55). Unfortunately the business-as-usual inclination is to "upgraded" the bio-oil stock to more user friendly lighter gasoline and diesoline like familiar liquids, but proceeding with such further cracking / refining having a high energy cost engenders miserable EROEIs and environmental outcomes.
[http://www.combio-project.com/download/PDF/Presentation_Chile_Nov2004.pdf]
Because pyrolysis distillation can be efficiently and effectively performed in small scale local plants it opens up the possibility to convert vastly different and incompatible biomass sources to a common standardised usable fuel-type. One plant maybe converting saw-mill waste or an agricultural bi-product to bio-oil, while the next one is transforming inputs not at all suitable as direct fuel-inputs like municipal garbage or sewage sludge to bio-oil.

Renewable & Alternative Energy

The all too common response from the business as usual camp to the challenges of Peak Oil, is that the wonders of modern science via the free-marketplace will magically fill the gap left by fading conventional and unconventional crude oil supplies with exciting new alternative fuels such as Bio-diesel and Bio-ethanol. As great a scientific accomplishment that some of these alternative fuels may represent, for reasons defined by the EROEI contexts there simply cannot be enough of alternative fuel available as quickly as required when the crunch comes. As even the oil industry now acknowledges, with today's world of exponential population growth, married with ever more frequent ecological and economic crisis, it is quite implausible to think that the current oil production, distribution and utilization infrastructure, that has taken about one hundred years to roll-out then fine-tune can be duplicated by an equally extensive and complex parallel alternative system in the most favourable case under twenty years. That was assuming the highly unlikely situation that the spare capital for such a huge undertaking could even be found, then willing left in as idle, non-performing assets until the inevitable oil crunch arrived. Somehow I don't think so.

So for stationary power demands, renewable energy sources:- Wind, Solar Photovoltaic, Solar-Thermal, Tidal, Waves, Geothermal are all promising options. Unfortunately excluding Wind, none of the renewable power sources provide any unmediated direct output for transportation.

Timeliness, Base Load, Energy Storage and Energy Transfer Mediums

The primary criticism of all renewable energy sources is that the place and time they are available is driven by the fickle natural logic of the source, rather than when human demand requires them most. This unfortunately has lead to the fallacy that renewable energy is unsuitable for base-load electricity generation. While energy storage is in no-way a trivial problem it is readily solvable, as opposed to the coal industry's fantasy of CCS (Carbon Capture then Sequestration) which like Fusion Power are proving to be ever receding dreams.

For the transportation sector the very stationary nature of renewable generating capacity poses major difficulties. Electric powered transportation is an option in the context of large urban settlements. Public transport via electric trains, trams / light-rail, electric trolley-buses are well proven solutions. Electric railway goods locomotives have also a long history of success along high freight volume routes. As promising as some view them, electric private cars may yet prove to be a highly dubious addition to the worlds transportation mix for various reasons. If any city's current fleet of cars magically morphed overnight to become plug-in chargeable electric-cars, the additional demand for electricity generating capacity could well exceed many a city's natural endowments of renewable resources (in the location of that city). There are also real concerns about mineral

resources required for a world-wide supply of all the those exotic batteries. See "Peak Mineral Resources" [above]. What is needed are various of Energy Transfer Mediums, that can be collected / empowered at renewable-energy capture facilities. At the moment Hydrogen gas is the most favoured such Energy Transfer Medium, but other folk of late have also proposed Biogas." *Methane is chemically the same stuff regardless of source. The only difference between fossil natural gas and biomethane is the source."* '**Biomethane as an Energy Carrier**' [http://www.renewableenergyworld.com/rea/news/article/2009/10/biomethane-as-an-energy-carrier]

Hydrogen as Fuel.

[http://www1.eere.energy.gov/hydrogenandfuelcells/storage/storage_challenges.html U.S. Department of Energy - Hydrogen Storage] The case for Hydrogen as an Energy Transfer Medium has a significant number of obstacles: equipment durability and performance life-time, transportation, safety and storage. These **obstacles effectively limit the commercial deployment and consumption of hydrogen to under a hundred miles [**160.9km**] from where it was produced!** Due to Hydrogen's unique chemical properties, the historic distributions practices (that worked so well for natural gas or oil) like long distant pipelines, or a network of retail nodes regularly replenished by fleets of road tankers, simply are not feasible. With current road-tankers such a fleet would needed (at a minimum) eight times more trucks each with only an eighth of the range of current diesel fuelled tankers. [See "Loss of Energy Density." above]

Despite the difficulties in time a Hydrogen Economy is a plausible future for many places, but generally Australia is not one. [http://www.reocities.com/RainForest/Canopy/2265/h2.htm]
This is because **Hydrogen generation requires abundant water and renewable power close to points of intended consumption.**

Re-Localization.

Common among those Energy Transfer Mediums that have seriously been proposed to date Hydrogen, Cryogenic Liquid Nitrogen, Compressed Air, and Thermal Batteries, all are best consumed close to source. The Sun radiating energy fairly-evenly over vast tracts of the planet also argues for solar-generation close to the point of consumption [http://www.det.csiro.au/science/r_h/nsec.htm].

Likewise the logic of Co-generation facilities is about generating power where it is envisaged to be used. Thus the future will have fewer large centrally located heavy-industry like power-station, but rather numerous smaller (unmanned / automatic) Renewable Energy Capture / Electricity Generating / Energy Storage Facilities.

Globally Alternative Resources Unevenly Spread.

While this becomes obvious with a little consideration, few people stop to realize that the Alternative Energy Potentials of various localities are no more equitably empowering over the globe, than historic rock-oil or minerals treasure are now haphazardly dispersed. The vast majority of countries have no geothermal potential. Only lands with coastlines onto major oceans have any opportunity for wave and tidal power. Then the sun doesn't shine, nor the wind won't blow with the same intensity, all year round, everywhere on the Earth's surface. As alternative sources are now being enthusiastically adopted by some countries, the finite quality of this bounty for a given locality is becoming starkly obvious, as certain communities already fully utilize their particular natural blessing.

Now What??

Some may argue that this paper is overly pessimistic regarding the Post Carbon World that has been sketched so far. Working from the Global Conventional Oil supplies having Peaked in 2006, 14 years later comes to 2020. So using the above formula *Be=Po – (Ya *ff)* with a *ff* (foolishness

factor) of 3 {being the current multiplier of world population beyond the long-term sustainable level of 2 Billion}, we get *Be = 2006 - (14*3)* giving a result as *Be = 1964*. That is to say by 2020 oil availability, cost relativity and usage pattern will be somewhat akin to those experienced in 1964. That is assuming that governments where honest and serious about the miserable promises they made in 2009 at UNFCCC COP15 Copenhagen Conference, otherwise we can look forward to the self-destruction of modern human civilization! [http://thinkprogress.org/climate/2012/06/28/508563/game-over-hoffert-on-unconventional-gas-oil-and-unconventional-self-destruction-of-civilization/?mobile=nc#more-508563]

Options on Transportation Difficulties.

At the moment most transportation fuels invariably are of one or another reformulation from Crude Oil;- Bunker Oil (for shipping), Diesel, Petroleum (for Land Transportation), Av-gas / Aviation Fuel / Jet Fuel (for aircraft). For each case the future has no perfect single replacement but rather holds a mix of contenders with teeming niche appeals and trade-offs, which will in their turn curtail then fragment transport technologies, modes, options and solutions.

Niche Solutions.

Ships & Trains.

After animal / human muscle power, wind in a boat's sail is the oldest source of transportation energy. Some less urgent shipping will inevitable return fully to sail. (During the 1970s Oil-shock the Australian Wool-board went as far as investigating design for new sailing ships.) High-tech sailing boats with photovoltaic collector incorporated into the sails are also starting to appear. Trials with fuel saving of up-to 25% (along trade-wind routes) have been reported for current ocean going freighters augmented by giant kite-sails.

As was so emphatically demonstrated by the demises of the Axis force in World War Two, no matter how terrifying, huge, well disciplined, or technically sophisticated a modern military machine maybe, it all counts for nought without reliable unrestricted endless supplies of fuel. Even with the world's largest (to then) Coal-to-Liquid effort the Nazi war-machine could not be guaranteed fuel [see 'Alternate Hydrocarbon Concoctions' above for further details]. Given the precariousness of crude oil in the future, contrasted to Australia's vast coal reserves it would be prudent for the Australian Navy (surface fleet at least) to be so augmented to allow burning of coal or pyrolysis-oil, for steam power once again. Other international shipping (despite the associated handling and safety concerns) will probably also slowly return to coal as the fuel of last resort, if not desirable choice.

Besides Electric Trains already discussed above [4th paragraph of 'Renewable & Alternative Energy'], a return to Coal or Pyrolysis Oil, fired Steam Locomotives in some niches maybe a desirable option among other things [see below].

But before leaving shipping it must be asked from an energy consumption perspective when is it more efficient to rail something across the country than to ship it by coastal shipping? And vice-versa?

Aeroplanes.

To the future gazer the post-carbon possibilities for flight are the most cloud obscured transport mode. Tersely put without the fading historical bounty of cheap energy dense mineral oil, air travel will most probably become once again a very expensive luxury. Av-gas from algae, as expensive and restricted as it maybe, is the most direct solution for a post-oil age. While Tupolev flew a hydrogen powered Tu-154 in 1989, then in 2008 Boeing test flew a two seater hydrogen fuel-cell aircraft, 2020 is the earliest date expected for purpose built hydrogen aircraft test, with regular services unlikely (if ever) before 2040. The Europeans and Japanese are investigating sub-orbital scram jet hoppers. The Russians among others are developing Ground Effect Vehicles (GEV) [

http://en.wikipedia.org/wiki/Ground_effect_vehicle] flying only a few metres above the sea they promise aircraft like speeds for as little as a third of the fuel consumption.

Cars and Trucks.

The futures of cars and trucks are the crunch point of the Peak Oil and Climate Change impacts on transportation. With the exception of some modes of air-transport, cars and trucks are the most energy expensive, ecologically unsound, least safe option for moving anything around the country. What advantages such road transport has enjoyed in the recent past will drastic collapse in the post carbon age. Powering the vehicle will either be markedly expensive, or have technically mandated dramatically shortened maximum daily travel range, but more commonly both! The current internal-combustion engine mid-size car, that comfortably seats four adults to take all the family on holidays travelling hundreds of kilometres on a tankful of petrol, will soon only be a nostalgic memory. By contrast, the future proffers a less appealing selection of long-trip vehicle options. Hydrogen cars with fuel tanks four or more times larger than long-loved petrol predecessors, compelling markedly less seating and /or luggage room. Electric cars with heavy batteries, dramatically limited in range to under a couple of hundred Ks (kilometres) per daily recharge, coupled with brick like performance. Or reconfigure your disincentives as astronomical expensive fuelled hybrids. But for the real nightmare now consider how those same limited fuel / power options will shake out for the heavy big articulated trucking-rigs that are the back-bone of long-distance road transport. One could be considering B-double rigs where most of one trailer is devoted to carrying the Hydrogen consumed by the the rest of the truck moving the other trailer, definitely not the cost structure risks for any adventurous solo owner-driver operators.
[Challengingly see 'Edward Pritchard' in Technical Material Folio.]

Agricultural Machinery.

The situations of farming's future must be the ultimate synergy of localization and niche transport / fuel solutions. Bio-diesel made on the farm, or close-by from farm waste (straw, manurer etc.) to fuel the farm machinery as needed and not much more, is about the only realistic solution for broad-acre cropping, or the vast rural meat or wool properties of the Australian outback. Air compressed on farm by a wind-mill for use in compressed-air machinery is another option that may suit smaller, or mixed farm properties. This is in contrast to the cost of supplying pre-packaged fuels from long distances, that with poor EROEI will prove to be a dubious at best business proposition.

Mining and Construction Plant.

While this paper initially arose from musings on **Post-Carbon Australian Options for Railway Locomotives** when considerations moved to the Objectives of Project section [above] it was observed that while the alternatives explored there would not be readily scalable to domestic motor vehicles or road-transportation more generally, at least the water-free contenders would however be applicable to large mining machinery or similar plant. Like 797B Caterpillar heavy hauler mining trucks, or drag-lines and mining shovels.

Infrastructure.

Much of energy efficiency features of rail transportation are attributable to infrastructure engineered for long shallow inclines [see below]. Contrary to popular myth, it does not hold that road transportation would magically acquire the same energy efficiency as rail, if the road network also featured such long shallow inclines. The fallacy (of such wishful thinking) becoming stark and unavoidable when curves (of aliment) are included in the scenario. Likewise it is equally erroneous for the road transport industry to trumpet their superior performance or functionality by comparison to rail-transport, especially when the road freighters traverse a (subsidised) up to date road network against much of rail network hog-tied to antiqued infrastructure conceived the century before last!

Without strategic realignments of funding the post-carbon world will witness escalating political

policy tensions between long distant transport modal choices. While their superior energy efficiency bodes well for rail's long-term sustainability, the collapse of fuel density will herald a string of nightmares for the road transport industry. That is not to say, a post-carbon world will mean round trips by road over a couple of hundred kilometres will never be undertaken, just that such trips will be exceptional and increasingly difficult. The real cost of ownership the road network will spiral upwards as dwindling crude-oil supplies drive-up the price of bitumen and other inputs required in construction, thence ongoing maintenance of the road system. This will be nothing unexpected for the many Australian road authorities who since the mid 1990s have had choirs of economic rationalist bean-counters telling them that on the basis of cost-benefit analysis (way back then two decades ago) all rural roads should just be dirt! By contrast railway construction materials, rocks and steel cost should remain static or marginally fall.

Simultaneously the disproportional human cost of the road transport industry (on private motorist) will become less acceptable as motor-vehicle design criteria radically diverge in a post-carbon world. Even with current (fossil fuelled) road vehicles standards, 20% of all road fatalities (in NSW) involved trucks despite trucks only accounting for 2.5% of vehicles registered in the state and 7% of all kilometres travelled by vehicles in the state [Source NRMA's journal "Openroad" quoting RTA website]. Post-carbon vehicle designs will only exacerbate such risks as private electric cars become lighter in construction to extend their battery range, while trucks become larger to carry sufficient low density fuel required by traditional schedules.

Therefore a prudent strategic realignment of funding for the dawning post-carbon world will be to; upgrade intense railway freight trunk routes to world best practice with regards to longer passing loops, the quality of the permanent-way, aliments and loading gauges. Concurrently there should be an urgent re-establishment of a functioning branch-line network of a density and coverage no-less than what existed prior to the advent of diesel powered road transport. Hydrogen converted diesel trucks, electric and hybrid trucks will then be concentrated in the niche (they are most suited for) of short (under 100 km) rail-head to street address freight transhipment.

Fast Trains.

Often with any consideration of the Post-Carbon transport outlook for Australia, it doesn't take long for talk to move to the pseudo-wisdom of replacing airlines by very fast trains. While Melbourne to Sydney is one of the highest demand short-hop airline routes in the world, that does not automatically translate to a sound business case for any VFT (very fast train) project between those two cities. Attested to by the historical litany of unrealised dreams. [http://en.wikipedia.org/wiki/High-speed_rail_in_Australia] The commercial case for VFT has as much to do with population density as any perceived demand. Many international intercity airline hops simply do not have the same demand as Sydney to Melbourne because much of any potential demand is already accommodated on existing (fast) rail services between those two points. But probably more significant is the need for such travel in the first place. The sparse population geography of Australia with near uninhabited wide-open spaces punctuated at vast distances by only a handful of sprawling cities is internationally speaking very unusual. The normal form is for more continuous clumping of higher populations at shorter more regular intervals. The shorter interval being critical to transport mode choices.

A significant concern of mine about all this post-Peak Oil stuff is how most people tend to look at the future with an identical mind-set and assumptions as they view the present. Their imaginations seem too paralysed by fear to get their heads around just how fast and how much everything will change. Returning to the VFT question given the efficiencies of renewable generation and online storage of electric power, at what point would the transmission losses entailed in overhead catenary wiring make the concept of extracting hydrogen from sea-water via renewable techniques to fuel A380 shuttle flights a far more energy wise strategy for rapid moving travellers between Sydney and Melbourne?

When I first came to researching this paper I was preoccupied with identifying niches that maybe exploitable by fully renewable energy transport solutions. The operational demands of rural railway branch-line presented a promising opening scenario to focus on. But for this investigation's completeness, along now with the prominence of fast-trains in the thoughts of the general populace musing on transport futures, some consideration needs to made of issues that arise in view of how the technological proposals later in this paper may-be fashioned to any requirement or public hankering for High-speed rail. First some definitions of High-speed rail (HSR) [http://en.wikipedia.org/wiki/High-speed_rail];-

200 km/h (124 mph) for upgraded track
250 km/h (155 mph) or faster for new track by the European Union
260 km/h (161 mph) standard gauge track on Shinkansen lines in Japan.
350 km/h (217 mph) for China's high-speed conventional rail lines.
574.8 km/h (357.2 mph) France's V150 world record for conventional high-speed rail
581km/h (361mph) for comparison is the world speed record (by the Japanese experimental MLX01) for the Maglev technology. [http://en.wikipedia.org/wiki/Maglev] Given Maglev's the higher infrastructure (and power) cost, that less than 10 km/h margin is a miserable benefit compared to the familiarity and simplicity of conventional high-speed rail technology.

Historically the lower end of this range was achieved with steam traction [see following table] in the 1930s. Given the technological innovations in steam design [see 'Visionaries for the, 2nd. & 3rd. Generations of Steam' above] since that date the 260 km/h mark would be plausible. The open ended question at this point is if 350 km/h would likewise be feasible with steam, but more importantly (by extension) could operational solutions (especially in light of Australia's distance) be found within the technical scenarios proffered at the end of this paper.

km/h (mph)	Train	Type	Location	Date
164 (102)	GWR 3700 Class 3440 City of Truro	Steam	England	9 May 1904
160 (100)	LNER Class A3 4472 Flying Scotsman	Steam	United Kingdom	30 Nov. 1934
200.4 (124.52)	Borsig DRG series 05 002	Steam	Germany	11 May 1936
202.6 (126)	LNER Class A4 No. 4468 Mallard	Steam	United Kingdom	3 July 1938
320.6 (199.2)	Alstom CC 7107	Electric	France	28 Mar. 1955
238 (147.88)	Class 43 (HST)	Diesel	United Kingdom	1 Nov. 1987
275 (170.8)	UAC TurboTrain	Gas turbine-electric	United States	20 Dec. 1967
319 (198.1)	Class 961 Shinkansen	EMU	Japan	7 Dec. 1979
408.4 (253.7)	SNCF TGV Sud-Est Set No. 88	EMU	France	12 Dec. 1988
574.8 (357.18)	SNCF V150 (TGV POS Set No. 4402	EMU	France	3 April 2007

EMU = Electric multiple unit

Fast Train Corridor Infrastructure.

The critical prerequisite for successful fast-train deployment often overlooked in the public imagination is the rail-line itself. Very Fast Trains are not just an exercise in purchasing flashy locomotives with complementing rolling stock. For no matter how good the rolling stock maybe it can only safely travel as fast as the curves and quality of the line will allow. Fast train routes are equally about use of continuous welded rail, long slow curves with radius in the order of five or more kilometres, gradients as close to flat as possible. All that entails a lot of expensive tunnelling and bridges in the pursuit of a suitable railway corridor / easements before even laying one sleeper or erecting a solitary signal. The railway network sketched out across Australia in the 1800s was barely up to demands at the end of the last century, ignoring any dreams for Very Fast Trains.

Railways aka Railroads.

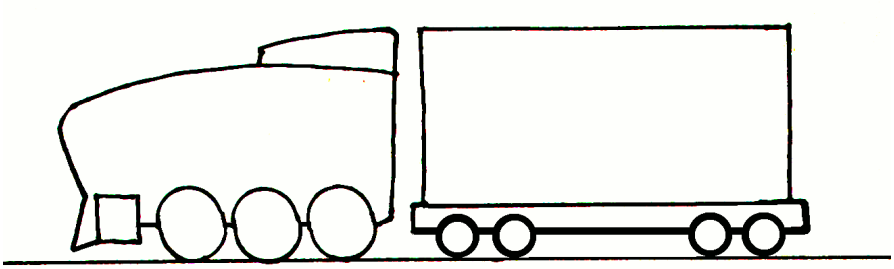
Within all these gloomy future land transport scenarios, railways are the one bright spot because of a cluster of historical technological determinants. The original business drivers nourished by the technological limitation at the dawn of railways have bequeath the 21st, century with an ideal land transport mode for the low (input and operational) energy demands of the Post Carbon World. From a time when double digit horsepower rating where impressive, railways where ever about maximising business results with tight (and by today's standard paltry) power outputs. Steel wheels onto steel rails have a very low rolling resistance thence friction penalty. With minimal grip between vehicles and rail-surface inclines by necessity have been engineered long and shallow, thus requiring minimal energy to continue travelling along. Solid rails sitting on coarse ballast provides a relative hefty carrying capacity for comparative little wear and tear. Trains allow large complex loads to be organized then moved simply over vast distances. The traditional configuration of locomotive with tender negates much of the negative impacts other modes of transport will encounter in having to accommodate the larger fuel stores necessitated by lower energy density fuels. Lastly coal fired steam engines are a historically proven power vector not requiring crude-oil feedstock for fuelling.

At this point I must mention;-

Trains Unlimited in the 21st Century

ISBN / Catalogue Number: 9780733328343

This recently published work by (Australia's former Deputy Prime-minister) Tim Fischer is a good entertaining book exploring the global trends, thence promise of rail transport in this new century.



Strategy Matrix for Migration of Locomotives to Carbon Neutral Operating Regime.

The following knowledge rule hierarchy, when read sequentially functions as a decision tree for the selection of appropriate carbon neutral rail traction options, ordered thus;-

First layering by operational speed zones (being the mode speed target for the given rail-service).

Second layering is the abundance or lack of sustainable carbon neutral diesel like fuel input.

The following ordering of the last three layers is not the only possible ordering, nor for that matter the ideal. Rather this ordering was just the first that came to mind.

Third layering is the abundance or otherwise of water by operational speed zones (being the mode speed target for the given rail-service).

Forth layering is the distance of regular journeys.

Fifth layering is the type of carbon neutral fuel input available.

Question	Answer	Dialogue ~ Commentary
#1		Operational Speed zone above 250 kph (kilometres per hour)
	Yes	Electric traction operating on dedicated infrastructure. Power feed via overhead catenary systems supplied from Carbon Neutral Electricity Generation Source.
	NOTE	*For regular railway operations above 250 kph electric traction from a catenary supply is really the only practical traction power option. This is because any-other traction option has to additionally carry sufficient generation capacity to feed the hungry electric traction motor needed to reach then maintain such speeds. Not forgetting the mandatory lugging a none too insignificant supply of low-energy density fuel.*
	No	Go To Next Question.
#2		Electric traction operating at speeds below 250 kph feed via overhead catenary systems.
	Yes	Upgrade Electricity Generation to certified 100% Carbon Neutral status.
	No	Go To Next Question.
#3		Currently diesel operations with journey lengths less-than 100km. Sufficiently high-value + high volume to justify conversion to electric traction feed via overhead catenary systems.
	Yes	Make it so.
	No	Go To Next Question.

Question	Answer	Dialogue ~ Commentary
#4		Typical return journey over 1,000 km. Using current/ traditional diesel traction, at speeds between 250 kph and 50 kph. Along with a sustainable carbon-neutral diesel or diesel analogue/ alternative readily available with secured guaranteed long-term supply.
	Yes	Continue current diesel operations using carbon neutral fuel.
	No	Go To Next Question.
#5		Freight traffic with typical return journey over 500 km. Currently using traditional diesel-electric traction, at speeds between 170 kph and 50 kph. With guaranteed Hydrogen supply at one end of the journey.
	Yes	Continue operations with current diesel locomotives modified to run on Hydrogen. Additional one (or more extra) hydrogen tanker-tenders will need to be added immediately following each locomotive, as required by the trip length.
	No	Go To Next Question.
Set of Operational Service Options Remaining.		Routes currently serviced by diesel (hydraulic or electrics) locomotives but without secure carbon-neutral liquid fuels, nor any guaranteed Hydrogen supply. While journeys are less than 200 km, they are not simultaneously high value and high volume services,
#6		Is service prestige long distance high value passenger service for average journey speeds in the 160 kph to 200 kph. Operating in regions with (sufficient for service needs) reliable, regular water supply all year, year on year. Along with carbon neutral sources of fuel suitable for external combustion.
	Yes	SGS or TGS Stream Renaissance Locomotive (Porta's 2nd or 3rd Generation). [See "*Ing. L.D.Porta* (1922~2003)" section under the heading "Visionaries for the New Generations of Steam." in the Technical Folio]
	No	Go To Next Question.
#7		Medium to short distance regular at average journey speeds below 160 kph. Reliable, regular water supply year on year, along with carbon neutral sources of fuel suitable for external combustion. (e.g. sugar cane trains)
	Yes	Second Generation Stream (Porta's) Renaissance Locomotive.
	No	Go To Next Question.
	NOTE	*The existence of any reliable, regular water supply will not automatically equate to an ability (or desirability) to generate hydrogen at a given location. Firstly their could be insufficient water to justify the business case for constructing or operating a Hydrogen generation facility there. There may not be sufficient carbon neutral electric power available at the location.* *The amount of reliable water required for a railway service (especially with re-condensing tenders) would be dramatic less.*
#8		All of Australia's other inland railway lines; local, regional, industrial and rural.
		[See "**Part 6: Exploring Solution Spaces.**" in the Technical Folio]

Paths to Current Mix of Transport Modes.

As I discussed above ***The eventual physical form and social quality of a society directly evolves from the primary energy source / fuel of that society.*** likewise an examination of the development of business practices goes a long way to understanding the current mix of transport modes, but more importantly to our task, how those modes will continue to evolve over time in response to the twin pressures of Climate Change and Peak Oil.

Manpower versus Fuel Costs.

At the start of the industrial revolution the availability and cost of fuel was by far a greater business concern than supply or pay of extra hands. Engineering was focussed on maximising the work performance, productive value of machinery, rather than reduction of employee numbers. As mineral oil, packing both a high energy density with minuscule acquisition cost, started to percolate through the world economies the balance of business concerns shifted to trimming manpower cost, now that energy cost had fallen as low as they could been possibly hoped for. By the 1960 the pendulum had swung hard against manpower cost, with everything else being equal (cost of capital, profit potential, output quality, timing etc.) options with lower manning requirements would be the most attractive. Traditional steam locomotives [http://en.wikipedia.org/wiki/Steam_locomotive] with their high messy daily manual maintenance regimes no-longer had any edge over diesel locomotives, once diesels' had matched the old steamers' impressive power. [http://en.wikipedia.org/wiki/Diesel_locomotive] (For details of one of the last great face-offs between big steam versus new diesels see [http://en.wikipedia.org/wiki/Norfolk_&_Western_2156]).

Flexibility versus Efficiency.

The more recent (historically speaking) move from rail to road as a significant mode of freight transportation has little, or nothing to do with questions of manpower and fuel cost. This shift was precipitated by the solders experiences of mobility during World War Two. For the first half the twentieth century prior to the diesel gaining majority preference as trucking engine of choice, less powerful motors had restricted trucking to a local delivery or short hop functions. Moving goods from original source to some major transport hub, be that airports, rail terminals or sea port, thence once the goods arrived at the nearest hub to final destination they typically where reloaded onto trucks again for the final leg of their journeys. With the building around the war years of the Autobahn and other National Highway networks, in combination with diesel trucks open the possibility of doing away with the delays of multiple unload, reloading of goods at many transshipment points. While direct trucking initially was more costly, it was accepted as a small premium for faster more secure and direct delivery. In time the increased business opportunity and flexibility from faster, direct trucking out-weighed (then falling) marginal cost of trucking versus rail or sea. Thus a trend to shorter notice shipping, combined with improved telecommunications spurred the whole just-in-time management philosophy. The demands of short warehouse inventories flowing from just-in-time techniques then reinforced the move from, efficient but slow rail and sea to a more responsive road transport vector. Rail and sea tended over time to be restricted to primarily high volume bulk items, coal, wheat and the like, or over such long distances (Perth to Sydney) that a solitary truck-driver would be unwilling to regularly undertake said journey.

Capital and Costs: Public versus Private.

For a complete picture this critical socio-economic trend should be mentioned.

Infrastructure Bias viz Modal Choices.

If only to construct the said vehicles, any innovative transport solution will require some new infrastructure, what is at issue is how much. So far (as in Response Deficit above) I have tended to talk about infrastructure as a single conceptual blob. But I need to elaborate a little on various types

(extraction, production, manufacture, warehousing, distribution, transportation, command and control, social) then the particular challenges there-in. Infrastructure Bias is the psychological tendency of people to be attracted to what they already are accustomed to thus are comfortable with or feel safe with, augmented by the social inertia at the political level not to change that which appears to working, combined with the commercial or economic imperative to maximize return from a given investment before scrapping it. Thus the modal choices that then result are restricted to what is already in place or minor populist extension of same, unfortunately Peak Oil and /or Climate Change is set to render much of the existing infrastructure irrelevant if not a downright budgetary liability.

Provision of Transport Routes & Networks.

During the early years of the industrial revolution nearly all railways where owned by private entrepreneurial companies. By contrast roads (beyond the walled city) where usually of a poor quality being common, public or state property. With the ascendency of the working man then universal suffrage coming to most industrialized democracy by the 1930, the standard of roads inevitably rose as a big flashy political sop to the voting public. Despite the excessive damage done by heavy trucks to road-infrastructure, the road transport industry in most countries eventual bore little or no charge for the provision of the road network (their cost being effectively externalized on to the whole community). By contrast rail transportation was still required to recoup (from their users) the cost entailed in the provision of the rail networks, thus gifting the road transport a sizeable price advantage.

For the Post-Carbon future another troubling aspect is logic behind, thence implication of where routes actually are, or go. {An introductory treatment of the philosophical dimension of this vast topic can be garnered from two books;- "All That Is Solid Melts Into Air" by Marshall Berman © 1982, ISBN 0-14-010962-5, along with; "Pure War" © 1983 Semiotext(e) and Paul Virilio}. Climate Change will inevitably force some modification of routes if for no other reason than rising sea-levels. Likewise having a highway primarily for trucking needs soon will make little sense. Because of Peak-Oil this will be our last chance to get the routes correctly positioned as just maintaining what routes we have will get prohibitively expensive in the Post-Carbon world.

Future Energy Supply Chain Kinks.

Transportation infrastructure is much more than just the rail-lines or the highway pavement. Where routes now go, is the historical accumulation of the decision from the interplay, yea even conflicts, between Public, Private or both: costs, benefits, profits and capital. Any route in-time evolves to be the inter-connecting ribbon through the social geography of a landscape. So the route becomes more than a line on the map, but the sum of the importance of all the (Public and Private) facilities and services strung out along the journey. The most significant aspect to the traveller decision being reliable support for the journey, with refuelling points having critical importance. In our current rock-oil buttressed affluence even availability of fuel is not much more of a concern than the distance to the next town when the fuel-tank is getting low. Here in Australia nearly all of the modern highway network was gradually built over seventy years, by Public funding upon routes blazed earlier by the various State Government's railway networks.

Harking back to 'Infrastructure Bias & Modal Choices' [above] if the public at large along with commercial operators have no certainty of fuel supplies and minimal social infrastructure they require for a given journey, it is quite unlikely they will make said journey via that transport mode. As less people travel a route the social infrastructure supporting that route will starved of cash wither away. Putting this into the context of the challenge posed by Peak-Oil, simplistic answers such as a Hydrogen, Boron, LPG (or any other exotic mix) fuelled vehicles become irrelevant if the required refuelling infrastructure is not already established before one may wish to go some-where. Rolling-out any new fuel contender will take years if not decades. Then as the market place

fragments by conflicting demands from multiple transport niche solutions, the business justification steadily becomes a less attractive gamble, that losses of idle capital during a risky infrastructure roll-out, for some uncertain future payback should the public up-take of the investor chosen technology will ever eventually pay-off. Even where this high-risk strategy is a success the sheer process will increase the cost of the fuel, inextricably lowering the hip-pocket appeal thence utilization by any motoring public that may still remain in such days.

So it is not the least bit surprising that even the extreme market fanatics of the USA Republican Party pushed government under-writing of the roll-out of Hydrogen refuel station along the so-called Hydrogen Highway in California. But in Australia given our sparse population distributions with critical water supply even the easiest option Hydrogen, will be a non-starter for ubiquitousness fuel supply across the continent.

Over-Extension and Other Obstacles.

While all of the above is rather gloomy for private (and small commercial) road transportation, where the pre-exiting railway infrastructure remains the picture is markedly brighter. As teased out in the previous section the lack of a guaranteed locked-in consumer of a fore-known size is what makes the roll-out of any of the competing new fuel technologies so risky. This is in part because the competing commercial influence on private purchase of vehicle and travel decision are small and not tied to a particular locality. By contrast purchasing a locomotive to service a particular line is a big investment that automatically justifies the (less pricey) roll-out of dedicated fuelling infrastructure. So in a Post-Carbon world just as the fickleness of numerous private niches transport choices will wither road infrastructure demand, the converse will strength the role of railways. There is for rail however another trump card in the energy efficiency battle of transportation modes, the more attractive energy options available to large locomotives that are unsuitable for more compact lighter constructed road vehicles. One of the distinct advantage of many of this paper's proposals, along with the European Hydrail [see Technical Material Folio], is that they do not need any 'distribution' infrastructure (pipe lines, supply networks, retail sales points and the like) as the energy is captured close to or at the point of consumption. Dispensing with the cost, complexity and roll-out uptake risk of any distribution infrastructure, is an immeasurable advantage for Alternative Energy railway operations.

Australia's Unique Situation.

While all the above discussed factors were at work on the Australian scene, some local peculiarities give the continent's transport development an unique spin.

Background with Contexts.

The initial British perception of Australian was that of an ideal penal colony. Some inhospitable undesirable place on the other side of the world, where convicts could be safely dumped an awfully long-way from home, well and truly out-of sight, and out-of mind. Those folk so dumped and their conscripted overlords unsurprisingly where dismissive of Australia's special qualities, rather they had more than the usual hankering for all things from, and like as found in the old-country. Sadly this precipitated many tragic irreversible agricultural and ecological errors.

Economic Geography.

After the initial settlements located for their quality as punishment. Agricultural then Mineral (gold, silver, lead and zinc) wealth transformed the individual colonies into jealous competitors. One of the sad legacies of this misguided competitiveness is Australia's annoying break of (railway) gauges. [http://en.wikipedia.org/wiki/Break-of-gauge] Once with 22 different railway gauges, Australia has the dubious honour of having the most gauges in a single country. (Stephenson) Standard Gauge (4 ft 8½ in = 1,435 mm) that used by the majority of the worlds railways is used in New South Wales, as well as by Trans-Australian lines and Pilbara Railways. The Irish Broad Gauge (5 ft 3 in =

1,600 mm) was deployed by Victoria and parts of South Australia for it heavy carrying capacity. Cape Gauge, Narrow Gauge (3 ft 6 in = 1,067 mm) is the third most common gauge used by railways around the globe, also used in New Zealand, Southern and Central Africa, Japan and Indonesia. Cape Gauge was selected because of the cost-saving in building a network over long distances in Australia, used in Tasmania, Queensland, parts of Western Australia and in South Australia (being the only state to run all three gauges concurrently).

Hot Dry Climate.

Except for the thin coastal strip where most of Australia's population resides, the land is primarily desert of one form or another. Unfortunately the early free settlers' opinions of Australia where mislead by arriving during a century long bout of what is now seen to be well above historical average rainfalls. (Even then long distance steam locomotive runs required the addition of water gins. [see 'Traditional Tender Locos + or −.' in Technical Material Folio]) The scarcity of water in Australia has since been exacerbated by the over allocating to irrigation what water (from biased wet baseline) people thought there was. So much so that country towns are now needing to truck in drinking water for the residents. All this makes the concept of any revival of thirsty steam-train to the country-side quite a sick joke.

The flora of Australia in adapting to the harsh dry climate, while often fast growing when rain infrequently stops by, is finely balanced by vast rampaging bush-fires. The current scientific wisdom about future impacts of Climate Changes, is that the continent will become hotter, dryer, with more server weather events, increasing frequency and severities of droughts, floods and bush-fires.

International Relevance.

Where Australia's situation will have the most international relevance is as proof of concept for Post Carbon Railway Locomotives suitable for use in hot dry climates. If global temperature rise can be arrested at not much more than 2 ºC, then that will be the deserts of Southern USA, the Horn of Africa, North and West Africa, China, Central Asia, India, and South Africa. Developed early enough all these location may provide lucrative export markets for an Australian pioneered Post Carbon Railway Locomotives along with related spin-off technologies. However if global temperatures rapidly spirals past a sane +2 ºC then most of the world will be hot climate far too soon for comfort. In all likelihood global temperature rises beyond +2 ºC will be accompanied my political pressure and /or mandates to out-law the burning of all forms of carbon, thus stimulating demand for rail transport option as envisaged by this paper.

Part 2: Issues of Philosophy and Design.

Prior to James Watt [see Technical Material Folio] much of what passed for as engineering was more an ad-lib craft-work underpinned by a few rudimentary calculations. With the Industrial Revolution, universities' education of engineers, the profession gradually began to annex methodologies with philosophies to ratchet-up the effectiveness of their prior rigour with materials. So to these often over-looked thence forgotten theoretical under-pinnings we must now focus.

Life-cycle of Unnatural Things

While the consideration of [http://en.wikipedia.org/wiki/Product_life_cycle_(engineering)] Product or Project Life-Cycles [*Systems Development Life Cycle* (SDLC), or *Software Development Life Cycle* http://en.wikipedia.org/wiki/Project_lifecycle], is only a fairly recent addition (the last quarter of the last century) to Engineering's theoretical resources, it is however a good frame of reference form which to explore the Engineering's theoretical riches. Ancient engineers (the military or civil flavours) along with their brother architects, had scant concern with any life-cycle management of their creations. The intuitive steps of; Plan, Construct, Forget having as they do a ring of common sense! Fitting snugly in the mindset of an era when everything was built to last as long as the Gods allowed. Happenings beyond the Construction Phase where after all only concerns for the owners not the builders. Even to the mid-20th century there had only been minor tweaking to the approach. After some spectacular failures of engineering during the early intoxicating days of the Industrial Revolution, the deadly serious importance of the Design Phase was acknowledged. The following Build Phase while more technically demanding, acquired more attention with the Automation of work practices. With engineers (and the money behind them) now owner operators of railway networks and steam-ships, the significance of the Operational Phase to the design and build phase gained importance. But the Scrapping at the end of the life-cycle still remained an after-thought.

For comparison now-a-days the classical **Product Life-cycle Management Phases** are;-
Conceive [Specification, Concept design]
Design [Detailed design, Validation and Analysis (simulation) , Tool design]
Realize [Plan manufacture, Manufacture, Build/Assemble, Test (quality check)]
Service [Sell and Deliver, Use, Maintain and Support, Dispose]
The possible milestones being; Order, Idea, Kick-off, Design freeze, Launch.

Paradigms and Diminishing Returns.

The superior quality of any functional design is the optimal satisfaction of the competing requirements of that particular design solution. But alas there is no such thing as a perfect solution, because any non-trivial design will inevitably necessitate trade-offs between near equally beneficial options, if not elsewhere, than more than likely in the realms of aesthetics, culture and fashion. With little study of various schools and movements throughout a history of design, the never-ending debate as to the optimal setting along the philosophical axis running between simplicity to complexity, could hardly be a more paramount aspiration.

Humanities experience of technological innovation within society closely tracks that of the philosophy of science's observation of paradigms. A new '*thingy'* (be that a technology, or a new paradigm of scientific theory) arise to address some bunch of awkward demands, not readily placated with-in the status-quo. This *thingy* then grows in usefulness and popularity as the community at large invests increasing credence, time and energy into tailoring the *thingy's* appeal and utility. The tailoring process is typically accomplished by numerous additions of add-ons or features to address new issues encountered as the *thingy's* exploitation expands over time and spaces. This increase in complexity in time falls foul of a (what in economic theory is called the) Law of Diminishing Returns. While early adopted tweaking by minor increases in complexity invariably yield substantial gains in utility or efficiency of the *thingy*, but ever subsequent

improvement has less prospective benefit that can be potentially delivered by ever increasing complexity. Eventually at some future time innovation's usefulness stagnates or worse becomes an encrusted burden greater than the benefit it delivers. Fortunately the story after is that the changes in time and space act as stimulus, updated requirements spurring the revolutionary innovation that both signifies then enables scientific and sociological transformation. Thence in this preceding context it is worthwhile looking a little closer at the risks, cost, benefits associated with movements along this simplicity ~ complexity axis.

Form ~ Function.

Now-a-days the average person often subscribes to a common-myth that the products of engineering are primarily rational creations. Such false belief flow from the hackneyed mantra that *form follows function*. That is to say, the shape of a machine is determined by the function it designed to perform. However in the 1980s it was discovered that '*form*' does not inexplicably follow '*function*', but rather '*form*' is a product of '*method*' as delineated by the social construct '*custom*', thus now formula runs "*forms follows method determined by custom for given function*". As a quick example before the Spanish arrived in the Americas most chairs there had three not four legs.

So what does this have to do rail-locomotives? Just because traditionally (the custom in the industry was) something was done, or arranged, or configured a particular way does not equate to that solution being best solution going forward into the future, especially in the face of the enormous challenges posed by the Post-Carbon Age.

Complexity Simplicity Counterpoint.

Intuitively people gravitate towards the least demanding from any set of possible solutions. The simpler a process is, then the less there is to go wrong. But it is an all too common fallacy to extrapolate from such everyday wisdom that the simplest answer is automatically the best answer. Merely increasing the level of detail at which something is investigated or documented explodes the quantity of data to be assimilated, thus inextricably expanding the complexity of the problem thence the solution also. The trick to navigating the Complexity Simplicity Counterpoint is to discover the appropriate balance between the two poles that optimize the advantages while minimizing disadvantages from any selected approach.

The advantages or disadvantages entailed in the flux between a desire for simplicity versus the necessity of complexity, vary in surprising, often contradictory fashions over the different phase in any large project.

Conceptual Phase.

At the very beginning of a project it is critical to begin with a simple concise objective. The mere act of executing any project will by itself inevitably accumulate complexity that is reflected in the final outcome. To commence an undertaking with complex objectives is a recipe for chaos usually concluding in failure. Complex objectives at the commencement of a project tended to be the result of poor decomposition of the challenges or routes to potential solutions. That is to say complex objectives bespeak a confusion of multiple separable potential projects, that would be best addressed via some tightly structured interfaces between competing demands or by sequential accumulative resolution of the competing subsets as smaller simpler tasks. However while striving for simplicity of objectives the broadest exhaustive examination of any and all factors, data, issues etc. should be tackled so being intermittently aware of the project's scope no nasty surprises remain lurking for later potentially catastrophic discovery.

Materialization Phase, then Operational Phase.

These two phases bring us to the crux of the complexity simplicity counterpoint's relevance to historical precedents thence future development of railway locomotives. As alluded to in the 'Paths

to Current Mix of Transport Modes' section [above in main body of paper] despite Steam Engines being a simpler technology than the more costly, exacting, complex alternative of Diesel, the latter won-out on the day because diesel where less labour intensive on a daily operational basis.

The more straight-forward a design is the easier it is to comprehend, thence simpler it will be to build. With like materials the simpler a widget is, the more robust it tends to be operationally, as there just less that can break. The quicker and hardier a construction materializes, the more time saving equate to a lower cost per the finished unit. But as mentioned before all this simplicity count for nought if the final bottom line (not development or purchases investment) of ownership expense do not also favour the simpler option! As an overarching philosophy one should aim for the solution to be as simple as piratical, while simultaneously being as complex necessary to optimise the solution to the task. Think Swiss-army knife.

Decommissioning, Deconstruction, Disassembling Phase.

Nothing especially of interest to railway locomotives here, beyond the essential importance that implication for this phase must always be addressed in every consideration of earlier phases.

Made to Order vis-à-vis Off the Shelve.

Prior to the industrial revolution everything by virtue of being hand-made could (at least within the context of this analysis) be regarded as effectively made to order. Speculative (as in without prior order) mass production of interchangeable uniform sub-components (as opposed to completed items) flowed from the cultural paradigm shift of standardization that came with of the industrial revolution. In 1760 English brothers Job and William Wyatt patented the first screw-cutting machine capable of consistently repeating the same thread on numerous screws (unlike predecessors where each thread cut would probably be different from that of all its' fellow screws).

Even in the case of prototypes the greater percentage of Off the Shelve components incorporated rather than being especially Made to Order the better. Not only because of the potential economy of Off the Shelve components, but also the more commonly used in a diverse range of application various components are, the larger the pool of experience exist with said components within an industry. The attraction of the Made to Order strategy is immediacy combined with the flexibility to tailor a solution to local conditions. Enticing as such easy customization maybe the big-picture result is an unwelcome fragmentation of markets and industries, reducing potential savings from market standardization. (As can be clearly seen in the history of the dieselization of rail transportation.)

Analogue or Digital.

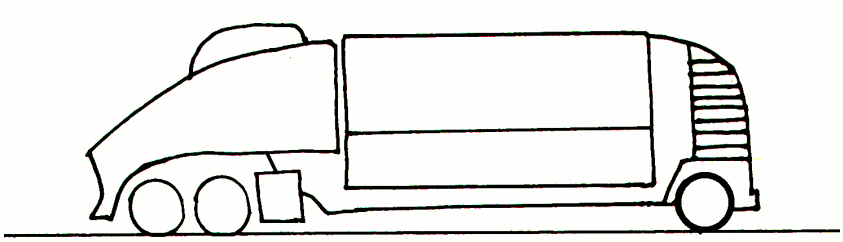
One of the more contentious aspects of the 5AT project [see above for details] was their decision to stick with traditional hard-linked controls, rather than updating to computer or by wire driving controls. Commendably the team's aim to minimize risk to the 5AT venture by sticking to proven technique is prudent. However while hard-linked controls are more immediate in providing direct feedback to the operator, by requiring strong physical linkages their mandating is problematic in the design process exploration of configuration options.

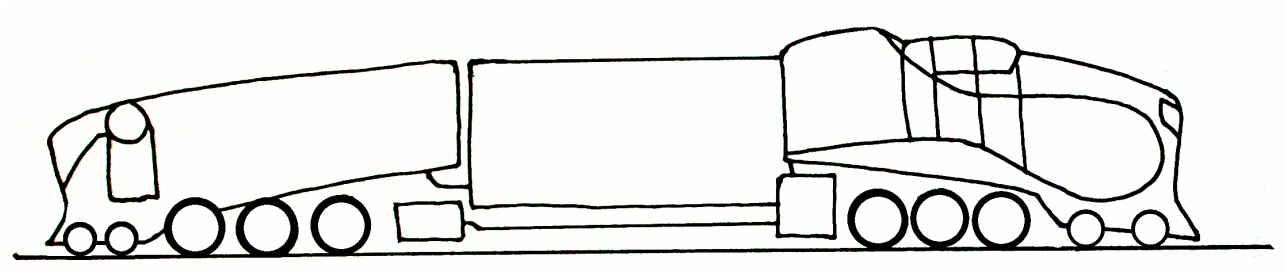
Analogue telemetry is the half-way case between traditional hard-linked controls, contrasted against a full digital by-wire paradigm. For single crew, control of multi-locomotive set-ups some sort of analogue telemetry at least, is required. As good as analogue telemetry maybe the technology generally has already been superseded by the further flexible digital tool-box.

The biggest advantage of the digital approach is how it free designers to automate complexity away from the operators consciousness, lowering stress while simultaneously providing very sophisticated powerful control interfaces. Such as the fuzzy-logic found in the latest washing machines.

Quality

Living in the Post-Carbon world will entail many adaptation to humanities economic structures thence commercial paradigm. Dispensing with the chicanery of built-in obsolescence will be one of the most significant. Philosophical questions along with the economic implication of Quality will become central concerns in any new major development. I do not intend to wander too far from this paper thrust here only to reference an earlier paper of mine which seeks to deal with the Quality question in a way accessible to most readers. **Quality and Cyberspace** [http://www.auzgnosis.com/pgs/qal_arcl.htm]





Part 3: Looking Forward

A vision of a possible future:
Down by the heliostats[b] early in the morning.

Feeling a touch dislocated today, even though the year 2040 is shaping up to be a lot calmer than the past couple of decades. I am standing in the grounds of a medium sized solar thermal power station in the middle of the Australian outback. That is nothing out of the ordinary; there are hundreds of fairly similar collections of heliostats, sterling-converts or solar towers dotted all over the country nowadays. I suspect my feelings have something to do with the gigantic levy/come /railway embankment blocking out the rising sun. Recalling that the supervisor of this facility boasted that if a bi-decade flood ever made it over the levy the power-station could keep operating two metres underwater till the flood went down. The standard gauge railway line on the top of the levy is a straight line in both directions, all the way to the horizons. A bit like the track across the Nullarbor thousands of kilometres south west of here. Each side of the dual mainline run some long parallel sidings that only overlap each other for a short distance where each has a straggly looking gantry half over the respective siding with a long tail running back down into the power-station.

I am quite familiar with the strategy of operating solar-thermal power-stations as base-load facilities by the addition of a thermal-energy storage-farm. The excess solar-thermal heat energy of the hot sunny days is being pumped into thermal reservoirs or phase-changes arrays, which can be drawn down over the evening hours, thus keeping the generator turbines spinning despite the dark. Given that this place is not connected to any long distance power-grid, it seems excessive for the local one pub town with only a handful of residents. Obviously, I'm missing something; oh the levy! That reminds me. This bull-dust[c] channel-country is flat as pancake for as far as the eye can see, so where did the rock for that levy come from? Given the sky high price of energy since the implosion of the hydrocarbon markets, it cannot have been dragged much distance.

Early in the 21st century there was all that doom and gloom about sky high oil prices when the oil supply crashed. The Hydrocarbon market implosion proved life is definitely stranger than fiction as hardly anybody saw that one coming. Who would have thought that a few insurance industry insiders could flip business as usual logic like that?. Lloyds of London filed that class-action in the European Court against the oil giants to recoup staggering re-insurance losses directly attributable to climate change. Filing in the European Court was a smart move given how the Exxon-Valdez compensation case had become a farce in the US High Court. Anyway, the result was beyond an anti-globalisation anarchist's most feverish dreams, and sent all the oil giants bankrupt along with Venezuela and a couple of the other more prominent oil producing countries with their state owned oil companies.

The plant supervisor did say something about the levy rock being left over from digging the town's cistern, but even if it cistern only fills once in a decade, when the Queensland cyclones push the floods this far west, what do they want so much water for in this little town? No mining here. Mt Isa is long way off and I can see no pipe-line. With global-warming the cattle industry disappeared also so that is not the answer. Hang-on, they still farm 'roos[d] and camels in these parts, witness the

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[b] Heliostats are the mirrors used in Solar Thermal power-station that automatically track the sun across the sky. [http://en.wikipedia.org/wiki/Heliostats]

[c] Bull-dust is the colloquial terminology for the red-dust characteristic of the landscapes of South West Queensland and North West N.S.W. Frustratingly fine, during dry spell this dust coats everything in the environment. Penetrating into all but air-tight containers. Then with just a spot of rain the bull-dust turns to a very sticky mud.

[d] Australian slang for Kangaroos.

loading ramp up yonder. No, that can't be it either; the farmers would need water on their properties. Yesterday when I flew out here I was surprised they refilled the aeroplane with hydrogen at the airport so that must be it, they use the water feeding a electrolysis hydrogen extractors. Hydrogen economy didn't run as smoothly as the pundits first wished. Beyond the odd short dedicated hydrogen highway link (Sydney, Canberra, Melbourne) there was negligible infrastructure. The problem became a circle: no supporting infrastructure, few wanted the vehicles, without that critical mass of demand investment for any infrastructure roll-out could not be found. Eventually they did start shipping hydrogen in Zeppelins of all things, from those automated off-shore wind and wave platforms down in the Roaring-Forties and the Roaring Fifties. So the bush can still get the occasional flight via an emergence (emergency?) aircraft. Biggest problem with it all was how they where going to get ready supply of hydrogen to the outback, as far a possible from the zeppelins restricted to flying only over the waves. Dry as it is here, you cannot expect to find spare water lying about for on-site electrolysis extractor either. A subterranean cistern is a good idea, but that still doesn't explain why the thermal storage is so big. I'm still missing something.

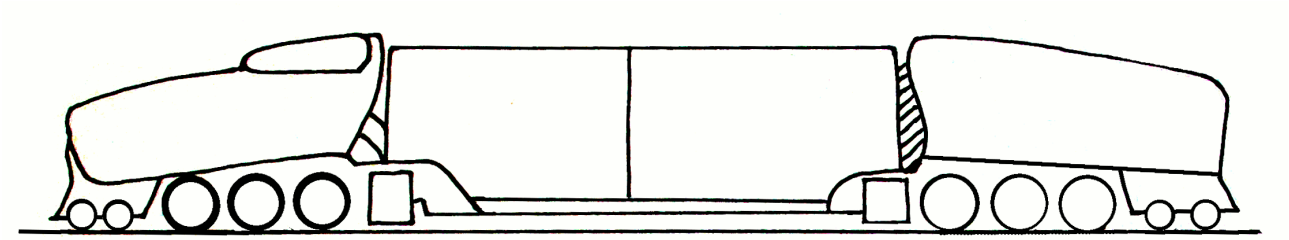
So let us think a bit more about this...

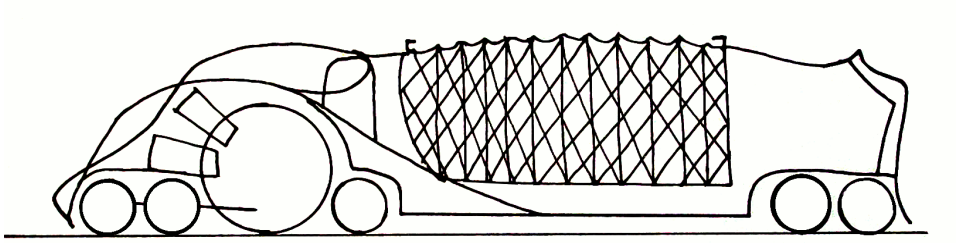
The gantries from the rail-line tail-back down into the thermal-storage farm, that would account for the standardised thermal-batteries I noticed. They do use thermal-batteries to power the odd rail-shunter; not much of a jump from those Canadian Green Goat railroad switchers with their electric fuel-cell, diesel hybrid drive-trains back at the beginning of the century. Steam-train buffs once thought that Peak Oil would herald a renaissance of steam traction. Alas they didn't count on how the melting of the Greenland ice cap with the drowning of those picturesque island paradises, would make burning any none renewable carbon source such a global anathema. But to many folk's surprise the 3rd generation steam locomotives did indeed make a comeback in the water plentiful colder climes of the Northern Hemisphere by boiling the water with "HotBox" thermal-batteries. However that is there, not here in the hot, dry dusty deserts of the Aussie interior.

Hey! Over there, my they have Cry'Gins in this farm too. Okay sorry for the jargon. " Cry'Gins" is short for cryogenic-gins, another standardised shipping container but this time filled with liquidised gas, sometimes Hydrogen in red colour-code containers, but as these ones are painted blue they have to be full of liquid Nitrogen. Any rail-historian will inform you that a "gin", is what they use to call the dedicated water tenders needed to get the old steam train across the dry heart back in the 1900s! When distance is not a major concern they have been using Nitrogen Cry'Gins as sort of extreme compressed air bottles on pneumatic locomotives. Now that hydrocarbon fuels are no-more, all-wheel drive off-road trucks combing Nitrogen Cry'Gins with Pritchard's Vee-Twin uniflow-engine have proved saviour of the outback. Ted Pritchard originally developed his revolutionary steam-engine to power a truck before the Arab Oil Embargo. Sadly, a great idea in the wrong place at the wrong time.

The railway, HotBoxes plus Nitrogen Cry'Gins - this place has got to be one of those Very Fast Freight Train hot-swap stops. Now, as if on-cue, screaming down from 270 km/h a big shiny black Garret style locomotive slides to a stop. Thanks to the boom-buffers the locomotive has stopped in perfect registration below the gantry. The grip-rack preloaded with fresh replacement containers now rips all the depleted hotboxes and cry'gins off the locomotive-frame to awaiting empty slots on the grip-rack next to the required replacements. Then in a blink of an eye the robot has perfectly snuggled the replacement containers into their respective target on the locomotive-frame . In a tad over a minute since slowing down, the fired-up "solar-soaker" engine with a shortish mixed-goods train of freight containers as well as a passenger carriage or two at the rear has flashed off to the horizon at breakneck speed.

Deploying HotBoxes combined with liquid for replacing water as the working fluid in solar-soaker locomotives has so many advantages. The Nitrogen can be used to scrub all the waste heat normally lost as the cylinders are expanded. A supply of partially compress gas in the reserves allows for regenerative breaking now possible by reversing the cylinder cycles. Also by the Cry'Gins being automatically engaged, the handling risk typically associated with liquid Nitrogen are removed.





Part 4: Proposed Investigation.

Strategy.

Hindsight

The wisdom of hindsight is often a dubious mixed blessing, for while it saddens us about lost opportunities it should also facilitate a clear understanding as to why events unfolded as they did. Despite being after M. King Hubbert's 1956 prophesy that oil production in the continental USA would peak in 1970, the North American automotive manufacturer's sad short-sighted lack of enthusiasms for Ted Pritchard revolutionary steam-car in 1972 is fathomable. In 1972 a barrel of crude-oil was only a few bucks and the economic dislocation of 1973 OPEC embargo price spike was the unforeseen future. But more importantly (as I well know from long personal experience) selling any new idea is hard work as acceptance implies change. Especially when you know that the human mind in making any decision, places more weight or importance on what is being lost than what is being gained by the decision. So for any technological revolution to succeed the advantageous benefits of the new thing must be so clear as to overwhelm all consideration of loss.

Phases

(For those readers who have yet to wade through the appendixes) Imagine for a moment a magician of yore. To answer a request from his patron he could *Conceive* of some mystical beast, then by his arcane magic *Manifest* that beast before him. Forthwith hastily *Ordering* it onto some obscure errand. Upon accomplishing of the desired task, the magician would then *Dismiss* the beast back to whence it came. While our monster conjuring Magician's Conceive, Manifest, Ordering, Dismiss routine may at first sight seem somewhat irrelevant to a paper on railway transportation it does capture the four main phases indicative of any endeavours life-cycle;- The Conceptual Phase, Materialization Phase, Operational Phase, lastly the Disassembling Phase.

As of this paper this technological adventure is early in the 'Conceptual Phase'. For this dream to move beyond the 'Conceptual Phase' will require other minds, hands and funding, to professionally explore the technical and business issues raised in this paper so as to avoid the inevitable Power down when the teeth of Climate Change and Peak Oil inevitable mesh. A nightmare in the making indeed for the unprepared.

Steps

If one were to allow only (an optimistic) six months elapse time to accomplish each of the following steps, it would take a minimum of eight years from now till there is broadly matched Post-Carbon locomotive in service. In real-life some steps of these steps will (at least) overlap in part, while other steps could prove to take more than few years in duration to complete.

- This **Post-Carbon Auz Railway Locomotive Options** paper to sketch issue thence explore the Problem Domain. (Five years elapse time to-date.)
- Publicising of Need for a Solution.
- Gather of like-minded individuals to carry project forward.
- 'Back of an envelope' Mathematical Validation as to Plausibility of Competing Proposed Locomotive Configuration Options. [For a starting sketch of this work see Technical Material Folio: Appendix 1: Pencil Chimeras].
- Precursory Business Needs, Requirements Study.
- Narrowing of Options for Consideration with Possible Forking of Spin-off Works.
- Project Planing of R&D (Research and Development) Concerns.

- Strategic Plan, Business Plan, Project Plan, Marketing Plan,
- Soliciting of Partners, Backing and Funding.
- Preliminary Design and Detail Mathematical Modelling of Locomotive Configuration Options.
- Theoretical and Virtual Modelling of Technology.
- Scale Testing then Proof of Concepts.
- Detailed Design of Solution.
- Tendering for Prototype Locomotive Construction.
- Real-world Acceptance and Performance Testing of Prototype.
- Public and Commercial Backing of Technology Roll-out.
- Site Selection, Planing and Approval thence Construction of Renewable Energy Power and Recharge Facilities.
- Tooling-up, Production then Commissioning of New Locomotives.
- Locomotive Solution in General Network Service.

Milestones.

Delivery points in the above strategy.

- This **Post-Carbon Auz Railway Locomotive Options** paper.
- Formal establishment of a working group to carry project forward.
- Strategic Plan,
- Business Plan,
- Project Plan,
- Marketing Plan,
- Selection of Locomotive Configuration for Theoretical and Virtual Modelling.
- Successful completion of scale test and Proof of Concepts work.
- Detailed Design of Specification with the Prototype Locomotive's Call for Tenders.
- Successful completion of Acceptance and Performance Testing of Prototype.
- Public and Commercial Backing of Technology Roll-out.
- Completion of Renewable Energy Power and Recharge Facilities.
- First Commissioning of New Locomotives.
- Commencement of 2nd generation Locomotive Solution Development.

Conclusions.

The arduous intertwined challenges posed by the cumulation of Peak Oil times Climate Change are such that the world does not have the luxury to ignore the lessons of the past that hindsight has to teach us all. Despite Gassy Hydrocarbons offering a comforting ten year stopgap against the Peak Oils worst-case scenarios, even the oil industries' most reassuring (many would chortle delusional) projections there is less than forty years to the day when ubiquitous cheap oil to fuel transportation will only be a found memory. The creation then roll-out, of any major technology has historically at best been a ten to thirty years adventure. Hydrogen enthusiast would attest how peachy those numbers fit with fuel-cell research and related transport solution developments. But unlike introduction of past technological revolutions where innovations had the luxury of supplanting a functioning predecessor, in the Post-Carbon case innovation must fill the gaping chasm left by the passing of cheap oil. As great a blessing as the Hydrogen economy may yet prove to be, it would be reckless in the extreme for society to put all hope into such a single solution!

So insane or crack-pot as Solar-recharged Thermal Battery and Cryogenic Nitrogen railway locomotive will be viewed by many, it is worthy of consideration as a long-shot that may yet prove beneficial to both the environment and human society. Particularly as such re-imagined steam-engine-like locomotives also holdout the promise to be a lower-cost more appropriate technology for the many location unsuitable for the high-tech hydrogen fuel-cell approach. If for no other reason than our grand-children's future the ideas presented in this should be exhaustively explored and competently tested by the global engineering fraternity.

From counting 'Steps' [above] it is estimated the programme of tasks outlined there, a minimum of eight years work exists between these ideas and the physical manifestation of some. Depending on how pessimistic one see the future that may or may-not be enough time to have solution in place when they are needed. 'Motivation' [see below] aside this vision would be best advanced by some grouping clustered around a regional centre like Lithgow or Newcastle in NSW Australia, or a University with expertise or histories in related fields. In our 21st century networked world some collaborative effort across secure web-links may also stimulate parallel efforts as far apart as North India to Southern Argentina then onto Dublin.

Final Word; Motivation

As I have undertaken the researching then writing of this paper in an unpaid capacity I would not be adverse to any financial recompense of these years of thinking and sweat. That said while I would very much like to have a some ongoing role in any projects flowing from this work, I am fully cognisant that my skill and health profiles preclude me from major or critical activities beyond this point.

The simple motivation for this paper with related research was that I saw a critical need in the gap between; business as usual approach, versus the rapidly coagulating symphony of environmental and future challenges that most people to date have insisted (at least conceptually) in addressing in a delusional simplistic isolation.