THE ROAD AHEAD FOR FUEL

iGAS ENERGY – INTELLIGENT GAS

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The USA and Canada are undergoing an energy revolution following the recent discovery of vast reserves of shale and coal seam gas, and the development of technologies to economically exploit them. Shale gas in particular has emerged as having enormous potential, causing many to refer to indigenous gas supply as being "the Saudi Arabia of natural gas[1]." Shale gas found in many areas of North America also has the additional benefit of containing condensates, providing additional economic benefits compared to coal seam gas, which is practically liquid free and essentially 100% methane.

Shale gas amounted to 27% of the overall U.S. natural gas production in 2010, and supported more than 600,000 direct, indirect and induced jobs. As the share of shale gas production increases to 43% in 2015 and 60% in 2035, development of this resource is anticipated to support more than 800,000 and 1.6 million jobs, respectively[2]. The resultant rush to market has seen the price of natural gas drop to as low as $2.56 per mmbtu following highs of $13.00 per mmbtu as recently as the winter of 2008/9. Such a low price is not sustainable as the production costs of shale gas are well in excess of the present prices in the market, but consumers can look forward to relatively low and stable gas prices as equilibrium is established in this very deep and liquid market. As you in Australia (and particularly shareholders in BHP Billiton) are well aware, major write-downs of investments in shale gas reserves have occurred when the reality of the prices paid for reserves and the resultant gas price and development cost pressures became clear.

Such is the surprise which this upgrade of reserves of natural gas has given the USA and Canada, that several liquefied natural gas (LNG) storage and re-gasification facilities which were commissioned as import facilities during the past few years are being considered for conversion to export facilities. Assuming the resulting political debate as to domestic energy security can be overcome, North American companies now plan to export LNG into lucrative and growing Asian markets, reversing the decisions made to import LNG just a few years ago.

The price of crude oil rises inexorably, whilst indigenous oil production has reached a plateau after a century of massive consumption. There has been some difference of opinion as to whether we have reached "peak oil", that is whether the world oil production rate has reached its peak and whether we face a steady decline in the daily production rate. If this were the case, then simple rules of supply and demand apply, and, if demand continues to rise, then the price effect is self evident, and we face higher prices for refined product.

I am not sure I want to weigh into the argument about world peak oil, as it can be a subjective discussion, and insufficient the data are available to support the various theories. There are however some pretty reliable data available regarding the costs of present oil production, and in

[1] President Barack Obama on January 26, 2012 at the opening of an LNG truck refueling station in Las Vegas, Nevada.

[2] http://www.anga.us/why-natural-gas/jobs/us-shale-gas-benefits

particular of new oil production, in North America which are very pertinent to the underlying question of future oil prices.

The first fact is that the cost of production is rising. There is a well understood equation that identifies the amount of energy required to produce a barrel of oil. It is called the Energy Returned On Energy Invested Ratio (EROEI), and is referenced by Dr. Kent Moors in a recent paper. It is commonly used in evaluating the viability of oil production. In the early part of last century we were able to produce 100 barrels of oil by investing or expending one barrel of oil equivalent energy; that is to say the EROEI was 100. By the seventies it had shrunk to about 25: in the nineties it shrunk further to around 10 as the amount of energy expended to develop and produce new energy increased. Today on a world wide average basis it is certainly in single figures and in some places may be approaching 3.

Dr. Moors tells us that for synthetic fuels, the problem is even worse. Most biofuels are currently being produced at a negative EROEI ratio (less than 1) requiring greater use of energy in production than is received from the end product. Ethanol is not that bad, but is still dreadful: the most efficient ethanol has an EROEI of 1.7, which means we use almost two barrels of oil to produce three. This problem is of course further underscored with the multi-year low levels of corn crop that we have recently experienced in the USA[3].

Another fact related to oil production is that new oil is no longer being discovered in easy production locations. Increasingly deeper water must be conquered for sub-sea reserves, and increasingly hostile environments must be faced for land-based reserves. The BP Deep Water Horizon massive oil spill in April 2010 along the Gulf Coast has focused the attention of the American public as to the risks associated with ever-deeper offshore drilling practices. That means greater exploration and finding costs as well as more energy expended for incremental reserves. There are greater technical and associated costs in development, compounded by approval delays and additional costs which must be incurred if development is to take place at all, with seriously increased risks and therefore costs post development due to having to manage environmental, social and political issues that have lifted the bar for all resource developers.

In another paper, Dr Moors discusses known alternative sources of oil. Shale oil promises to be an additional source as do tight oil, heavy oil, tar sands and other exotic sources, but each source has an underlying production cost which produces an underlying floor price. Energy input is a major and growing cost as we develop such techniques as hydraulic fracturing, horizontal drilling, miscible flooding, heat injection or other techniques for turning viscous fluids into pipeline moveable fluids or synthesising it so that it can be refined at all.[4]

The cost of energy imports has a profound impact on the US balance of trade. The United States imported 11.4 million barrels per day (MMbd) of crude oil and refined petroleum products in 2011. We also exported 2.9 MMbd of crude oil and petroleum products, so our net imports (imports minus exports) equalled 8.4 MMbd[5]. Thus we are exporting our wealth in exchange for fuel at an astonishing rate of approximately $800 million per day. That in itself is a huge balance of trade

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3 http://moneymorning.com/2012/08/06/what-eroei-is-and-how-to-use-it/

4 http://oilandenergyinvestor.com/2012/08/u-s-oil-and-gas-squeezes-alternative-energy-prospects/

5 http://www.eia.gov/energy_in_brief/foreign_oil_dependence.cfm

problem, at a time when the USA economy is struggling under massive debt overhang from the global financial crisis, and dealing with the domestic economy that so far has doggedly refused to respond to stimulus. Politically it is compounded by an uncertain oil supply chain that some perceive as a real and present security threat, with volatile prices that some perceive as manipulated by nation states which are at best "unfriendly" to the USA and its interests. The good news, however, is that U.S. dependence on imported oil has declined since peaking in 2005[6]. This trend is the result of a variety of factors including increased vehicle fuel economy standards resulting in a decline in consumption, along with shifts in supply patterns, and importantly from the vast reserves of natural gas now becoming available due to improved drilling and extraction methods which promise to displace liquid petroleum in many energy sectors – especially in transportation and goods movement, which is the focus of our business.

Politicians are therefore under pressure. President Obama has made energy security a pillar of his re-election campaign: *"We can't have an energy strategy for the last century that traps us in the past. We need an energy strategy for the future – an all-of-the-above strategy for the 21st century that develops every source of American-made energy."* [7]. His Republican Party challenger Mitt Romney is likewise emphatic on utilizing domestic energy sources: *"The United States must become energy independent. This does not mean no longer importing or using oil. It means making sure that our nation's future will always be in our hands. Our decisions and destiny cannot be bound to the whims of oil-producing states..."*[8]

The USA is an economy highly dependent on its road transport systems for 70 percent of goods movement. There are over 15 million trucks on the USA road system, including 3.2 million "Big Rigs" and this fleet consumes over 25 billion US gallons of diesel fuel each year: that is 87 billion litres of diesel, at a present cost of over $200 billion per year[9]. And, notwithstanding major efforts and innovation to improve efficiencies, the demand for this liquid and portable energy continues to rise as does the cost to produce it.

Powerful incentives for change exist. The USA must do a number of things:

1. Become more efficient in our use of energy
2. Reduce our dependence on imported liquid fuels
3. Focus on the use of indigenous energy is all its available forms
4. Reduce greenhouse gas emissions and other atmospheric pollutants.

The fundamental challenge for use of natural gas in transportation is that gas must be either compressed (CNG) or liquefied (LNG) so as to be stored on the vehicle. CNG stored at typical 250 bar pressure provides approximately one quarter the energy density of diesel. Cryogenic LNG improves on CNG yet still comes up short with just over half diesel's energy density, while at the same time introducing a host of new challenges associated with boil off, storage and handling. As a result, natural gas vehicles must be designed so as to accommodate larger fuel storage vessels relative to

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[6] U.S. Energy Information Administration, This Week in Petroleum, May 25, 2011

[7] http://www.whitehouse.gov/energy

[8] http://aboutmittromney.com/energy.htm

[9] The Wall Street Journal May 23, 2012 *"Will Truckers Ditch Diesel?"*

liquid petroleum fuels, and serve routes where more frequent refuelling can occur. Also, the high pressures associated with CNG and the cryogenic temperatures associated with LNG require the storage vessels to be considerably heavier than those for gasoline and diesel.

Large vehicles such as transit buses, refuse haulers, mining equipment, and over the road trucks are able to mount larger CNG or LNG fuel vessels with relative ease as space is generally available on the roof, on the rails, or behind the cab. Additional weight required for natural gas storage is somewhat negligible for these heavy vehicles as well. As a result, in the USA we have mostly seen natural gas vehicles proliferate into large vehicles, with most bus and truck OEMs now providing CNG or LPG options for new vehicle orders. While the incremental cost for these systems can reach $30,000 more than diesel models, each will save the operator $27,000 or more per year on fuel at current CNG and diesel prices[10].

In the consumer sector, both North America and Australia have been slow to adopt natural gas for light duty vehicles relative to elsewhere in the world. In the USA, use of natural gas vehicles has been primarily driven by clean air initiatives and indigenous fuel usage requirements for government fleets. Today, however, the aforementioned drop in natural gas prices relative to diesel has brought a wave of interest from both fleets and consumers. In response the “big three” US auto manufacturers are now starting to roll out consumer natural gas vehicle offerings, from pickup trucks to cargo vans and sedans in both dedicated and bi-fuel CNG/gasoline variants. American Honda has offered a compact dedicated CNG “Civic” sedan in the US market since 1998, with sales growing from just a handful to an estimated 2,000 last year with expectations of double this figure for the 2012 model year[11]. Also in response to heightened awareness of natural gas as a vehicle fuel, the US Environmental Protection Agency has recently relaxed previously burdensome requirements for the approval of aftermarket CNG fuel conversion systems, which has resulted in a wide variety of options for the consumer to convert to natural gas vehicles.

Refuelling infrastructure in the USA has proliferated dramatically in recent years as federal, state and local governments provide modest incentives to fleet operators for the construction of CNG stations. There are now over 1,000 public access CNG stations across the USA with considerable emphasis being placed today on growing fuel availability in areas of high gas production such as Oklahoma, the Rocky Mountain area, shale gas regions, and also in areas of air quality non-attainment such as California, New York and Texas.

These initiatives mirror Italy’s successful programs in recent years, which resulted in some 900 stations now in operation in that country[12] .

Many US states provide that electric, hydrogen, and dedicated natural gas consumer vehicles may also operate on our freeway system in less congested high occupancy vehicle commuter lanes with only a single occupant. This is a powerful incentive in areas such as California with its famously overcrowded freeways. Another time-saving option for natural gas vehicle owners is to install home refuelling appliances. One small gas compressor can dispense the equivalent of 3 gasoline litre

[10] *Ibid.*

[11] http://www.bloomberg.com/news/2012-03-07/honda-looks-to-u-s-dealers-to-boost-natural-gas-station-network.html

[12] http://www.businessweek.com/news/2012-09-17/gasoline-sticker-shock-fuels-fiat-natural-gas-auto-sales

equivalents per hour into a vehicle overnight, saving the need to stop for fuel and perhaps more importantly providing even lower cost fuel vs. use of public refuelling infrastructure.

Recognizing the burgeoning demand for natural gas fuel in goods transport, private initiatives totalling in excess of $250 million are underway to establish CNG and LNG refuelling infrastructure at truck stops in key areas along the USA interstate highway system.

Additionally, many high horsepower engine manufacturers have in recent years begun tooling up for the shift. Cummins has been in the forefront, offering a spark-ignited natural gas 8.9 litre engine in joint venture with Westport of Canada for many years. This engine is popular in refuse truck and school bus applications. The Cummins-Westport joint venture will soon be producing an 11.9 litre version in early 2013 for use in over the road trucking for lighter loads in flat regions of the country. These engine technology developments provide an expanding opportunity for NG as fuel.

The "Holy Grail" of gas as fuel is with diesel cycle engines in high pressure direct injection (HPDI) truck fleets. These vehicles consume as much as a litre of fuel every kilometre travelled, and they travel many thousands of kilometres every year. There are trucks running on Australia's highways as well as in the USA, Canada, Brazil and other geographically large countries that each travel over a million kilometres per year.

Suffice to say the world fleet consists of tens of millions of such trucks, they consume billions of litres of diesel fuel and exhaust millions of tonnes of carbon dioxide and other noxious emissions at great cost to the world economy and the environment.

When we began running LNG powered big-rig trucks – or "prime movers" as they are called in Australia – it became evident that if these trucks could instead run on CNG not only would our cost of fuel drop by almost one half, but that our refuelling options would be vastly improved. On our regular runs between Salt Lake City and Los Angeles we average just under $3 per diesel gallon equivalent (approximately 79 cents per diesel litre equivalent) for LNG whereas CNG is priced at approximately $1.75 per diesel gallon equivalent (46 cents per diesel litre equivalent). Along our route there is but one LNG station in Salt Lake City, one in southern Utah, one in Las Vegas, and about six in Southern California. Thus the risk of one LNG station being inoperative along the way could potentially cause unacceptable vehicle downtime and delivery delays for our customers.

On the other hand, along this same route there are well over 50 public access CNG stations, with a maximum of 170 miles (275 kilometres) distance between refuelling options on the stretch of highway in the sparsely populated Mojave Desert area between Las Vegas and Barstow California. Elsewhere, CNG stations are located within relatively close proximity from each other[13].

Our search for a technology to provide the use of high pressure CNG on these trucks led us to iGas Energy in Brisbane. We are impressed with how iGas is providing game-changing innovation in the way of CNG truck and refuelling station technologies for worldwide market application, as well as with the vast opportunities ahead for virtual pipeline systems in Australia and elsewhere.

I now turn the balance of the paper over to Jim McDonald, Chairman of iGas Energy Holdings.

[13] A useful reference is www.altfuelprices.com for locations and pricing for public access CNG and LNG stations.

The iGas Technology has at its heart the patented Pressurised Liquid Injection and Gas Transfer System (PLIGATS) which entails the compression, pressure management and delivery of high pressure compressed natural gas (CNG) by using an hydraulic fluid. The concept of hydraulic pressure management is not new, but iGas has pioneered its use in a number of unique applications which expands the opportunity for CNG as fuel by enabling CNG :

1. to be carried at high pressure as fuel on trucks, rail locomotives and off-road mining equipment and to enable the high pressure delivery of the CNG to the engine, displacing the liquid fuel (diesel) normally used in such applications,
2. to be transported in "virtual pipelines" to remote locations and there decanted for use as fuel for power generation and transport equipment beyond the reach of the pipeline system, again displacing diesel, and
3. to be compressed and held at low temperature and high pressure in storage containers at CNG re-fueling stations and to be rapidly discharged via metering systems to vehicles requiring CNG as fuel, a process we call "Cool 5000" CNG.

This technology therefore is a technical breakthrough to enable environmentally friendly CNG to be economically used as fuel in a wide range of new applications. Patents are pending in major world markets.

The iGas technology as applied to trucks is relatively simple in concept. It involves the injection at constant pressure of an hydraulic fluid (operating temperature as low as minus 40 deg. F) into a number of composite storage cylinders, containing CNG, mounted behind the cabin of a truck: the process maintains the CNG at pressure above the 300 + barg injection pressure required for the Westport HD High Pressure Direct Injection (HPDI) engine which presently powers the trucks.

The Westport HD engine which powers our three in service trucks, has been developed by Westport Innovations Inc., a Canadian engine technology specialist. It is a diesel cycle engine that runs on CNG with a 5% diesel pilot fuel. The power and torque characteristics of the Westport engine are identical to the equivalent diesel fuelled engine, however maintenance and engine life are significantly enhanced by gas fuelling, and greenhouse gas benefits are produced due to the improved carbon: hydrogen ratio of natural gas, with greenhouse gas emission reductions of approximately 27%. The Westport technology injects both the CNG and diesel directly into the engine combustion chambers.

Prior to iGas, gaseous fuel for the Westport HD engine has been carried on the truck as liquefied natural gas (LNG) in a number of cryogenic tanks (at minus 160 deg. C) with a pump submerged in the LNG pumping the LNG to high pressure before it is vaporized to CNG at 300 + barg, using engine jacket water as a heat source, and delivered to the engine as CNG. The iGas system replaces only the LNG tanks and pumps: the rest of the Westport system remains unaltered. CNG and LNG are therefore the same fuel at the point of injection into the engine, producing identical outcomes compared to diesel.

CNG as a fuel for heavy duty trucks has numerous advantages that are not intrinsic to LNG. The most obvious, and commercially most important, is the comparatively negligible capital requirement and low cost of production of CNG due to the general availability of natural gas from HP natural gas pipelines, the low cost of compression equipment, and short lead times for equipment delivery.

A second and very important benefit flows from the scalability of CNG compression equipment: it can be economical at a small fleet level. Scalability also brings with it flexibility which allows re-fuelling stations along highway routes (wherever natural gas pipelines exist) the number of which can be minimal in the first instance and can grow to match the market as it expands. Finally, CNG offers easier handling, transport and storage characteristics compared with minus 160 degree C cryogenic LNG. CNG also offers intrinsic on-truck and environmental advantages as it is stable in storage and consequently has less wastage due to venting and handling than can typically occur with cryogenic fuel storage in the absence of continuous service.

iGas has three Western Star 4800 Series prime movers fitted with the Westport HD 525 HP engines and the iGas CNG fuel system. During 2011 we undertook road trials with two vehicles, successfully demonstrating that the technology works. During Q4 of 2011, we undertook extensive off-road testing enabling us to simulate over 100,000 kilometres equivalent travel by circulating CNG through the on-board fuel pack and back to a storage / re-fuelling module we developed as a prototype. This enabled us to constantly observe the performance of the system and to monitor the behaviour of system components, which resulted in minor modifications. Additionally we were able to alter the geometry of pipework and instrumentation to provide better access. We have designed and commissioned manufacture of manifold blocks to contain multiple valve assemblies, removing a large number of single valves that existed on the prototype.

This testing is now complete, and we have commenced the early commercialisation phase of our development with the trucks now on hire into working fleets for both demonstration purposes and extended reliability testing. We have entered agreements with John's company, which is a Salt Lake City based trucking company which intends to trial an iGas truck in the American market. This truck will enter service between the Port of Los Angeles and Salt Lake City in due course and be our first North American demonstration vehicle.

In summary, the technology works, and we are demonstrating that it does to the market here in Australia, and, in due course, the USA.

The target market is heavy duty highway trucks in the first instance, with off-road mining equipment and locomotives to follow. There are an estimated 27,000 of such heavy duty trucks in service on Eastern Australian highways, and over 6 million "big rigs" in the USA. They typically have a "first life service" of 3 – 5 years and / or up to 1,500,000 kilometres. They are typically around 500 + HP (a little less in USA), travel over 250,000 kilometres each year and consume upwards of 150,000 litres of diesel p.a. At $1.30 per litre this represents an annual fuel bill per truck of around $195,000.

Natural gas to replace this amount of diesel should be able to be procured direct from wholesalers for approximately $60 – 70,000 ex pipeline, offering substantial gross savings.

In Australia, at average crude oil prices over the past year or so, diesel prices are around $35.00 per Gigajoule. Our model demonstrates that, at these prices, the iGas system owner will be able to offer an incentive by way of cost savings of up to $40,000 per truck per annum to install the fuel system, whilst providing an accelerated cost recovery of the infrastructure investment. It also demonstrates that we can offer considerably higher potential net-back to natural gas suppliers than gas feed-stock to LNG plants, higher than any presently known market, with significant further upside dependent on oil prices.

An iGas equipped truck does cost more than an equivalent diesel fuelled truck, maybe as little as $100,000 when some economies of scale are realized. Of this, about $60,000 is in the iGas fuel pack, the balance in the cost of the engine. This additional cost must be funded from fuel savings. The fuel pack will require periodic specialist service and maintenance and this cost must also be provided from fuel savings: it will, however, be off-set by reduced engine maintenance costs and benefit from extended oil change intervals and engine life as a result of natural gas fuelling.

The iGas fuel pack is designed to be easily removed and re-fitted when required for maintenance, and the business model provides for additional units to be kept for this purpose, providing additional security for customers.

New trucks are typically leased over 3 – 5 years before moving to secondary service. The iGas pack has a different and unique life span related to the permitted number of pressure cycles in the life of the storage cylinders (estimated to be 20 + years in iGas service). The fuel pack may therefore be amortised over a longer service life and viewed as "infrastructure". This creates the opportunity for it to be owned and maintained independently and rented or leased to the truck owner, with or without a fuel contract. Indeed, due to the technical maintenance requirements for high pressure management equipment and the life cycle record keeping requirements for the cylinders, it is desireable that be provided this way.

Fuel pack construction, ownership, supply and service is therefore a stand alone business opportunity and our model considers how this might be done.

iGas fuel packs will generally not be retro-fitted. The market therefore must be created from new trucks on dedicated routes. This will require substantial commitment from truck owners to order replacement trucks with the iGas system fitted, and will require re-fuelling stations to be in place at one or two strategic locations on each route in advance of the trucks commencing work.

We are conscious that we must demonstrate that trucks fitted with iGas technology are as robust and reliable as the diesel option. To this end, we plan to initially have an iGas owned and operated fleet in work as a clear demonstration of our faith in the technology.

A characteristic of the target fleet is that a significant proportion of the prime movers are dedicated to routes: for example, Melbourne-Sydney via the Hume Highway has several thousand trucks that traverse it daily and have no other duty. Anecdotally 5,500 trucks pass through the mid-point, Tarcutta, each day. The Port of Brisbane is another early target with some 4000 trucks "out and back" each day, many to the Darling Downs and beyond hauling equipment to coal seam and natural gas developers and producers.

An iGas fuel pack can carry fuel for up to 1000 kilometres between re-fuelling, so very few re-fuelling stations are required in the first instance to service these routes.

We believe there are a number of circumstances to encourage fleet owners to change. The first is that our model provides a significant financial incentive to commit: possibly as much as $40,000 per annum per truck will be affordable if oil prices remain at current levels, and this incentive can be maintained with falling oil prices, but at the expense of accelerated amortization of infrastructure. The second is that inter-modal logistic systems are creating new paradigms in highway transportation, providing the opportunity for new fuelling solutions as well.

This, together with the uncertainty in liquid fuel prices, the need to reduce emissions of all kinds, the political imperative to use indigenous fuel, and the abundance of natural gas from coal seam and shale gas ramp up creates an opportunity to:

- progressively but rapidly convert sufficient heavy duty truck sales to iGas sales,
- support the establishment of a number of strategic re-fuelling stations, and,
- provide sufficient cash flow to support the business case during iGas ramp-up.

A large number of heavy duty trucks exist that either operate within mine site lease boundaries or transport ore or product to market over limited distances on the road system in large road trains. All such remote applications consume vast quantities of expensive diesel and are potentially iGas opportunities provided gas is available. Many such sites have gas available via pipeline and are already contracted for gas supply for power generation.

iGas technologies are also adaptable to fuel large off-road machinery such as heavy duty mining equipment and rail locomotives. Machinery manufacturers are now designing engine packages to run on natural gas using Westport technology, and it is expected this market will also be available to natural gas technologies within the next few years.

iGas has developed a conceptual “virtual pipeline” wherein natural gas is sourced from a pipeline, compressed to 350+ barg and transferred to storage cylinders mounted on trailers for towing to remote gas use sites. As the PLIGATS transfer process is accomplished without the heat of compression that results from conventional compression and transfer, the iGas “virtual pipeline” results in the maximum quantity of energy being transferred to the cylinders and thence transported to site. Preliminary discussions have commenced with a number of potential customers to explore the opportunities for iGas technologies to service remote sites and captive fleets.

We have completed preliminary design of a “virtual pipeline” capable of carrying a nominal 800 GJ per trip in a “B Double” trailer configuration, and are in discussions with two remote mines together with a remote power generation specialist with the intention of conversion of the mines to CNG fuel via virtual pipelines.

CNG is emerging as a significant and desirable fuel for passenger cars, buses and the entire range of spark ignition engined trucks that service our towns and cities. In the USA, Canada and EU, there has been a quiet revolution in conversion of these fleets to CNG which is now becoming readily available on service station driveways in those countries. Within Australia, CNG has not yet made serious in-roads, but that is slowly changing.

Technical and commercial difficulties arise with conventional compression storage and delivery of CNG including the amount of heat generated when compressing gas, the temperature limitations on storage vessels, and time of day tariff and/or load factor considerations of pipeline companies providing the gas, as well as time of day and/or load factor impacts on electricity supply used to power the CNG compressors.

PLIGATS technology enables us to offer Cool 5000 CNG: that is CNG at 5000 psi and at constant cool temperatures. This results in the maximum quantity of gas being stored in a given vessel, and minimum power and gas supply prices as compression can be tailored to match the average off-take, eliminating the need to cater for the highest off-take gas rate.

PLIGATS technology also enables us to rapidly transfer CNG from storage to the customer vehicle with minimum heat generated in the on-board fuel tanks, thereby maximizing the quantity of gas sold at each fill.

Discussions have commenced with Lincoln Composites, the storage cylinder manufacturer, to jointly develop a modular Cool 5000 system for commercial application in the USA and Canada.

In conclusion, the discovery of vast reserves of shale and coal seam gas in the United States of America is fuelling an energy revolution in North America. The cost of imported liquid fuels is a severe drain on the struggling American economy, and reliance on an uncertain oil supply chain is seen as a security threat. Significant political impetus has been directed towards displacing this imported liquid fuel with indigenous gas. This has resulted in unprecedented demand for gas technologies and a rapid expansion in the reach and availability of both compressed natural gas (CNG) and liquefied natural gas (LNG) throughout mainland USA and Canada.

Australia also is blessed with vast reserves of natural gas in its various forms, and is poised to follow the North American lead in displacing imported liquid fuels with indigenous gas.

iGas Energy Holdings Limited (iGas) is a Queensland based technology company which has developed patented technology that enables CNG to be used to fuel High Pressure Direct Injection (HPDI) diesel cycle engines (in conjunction with engine technologies developed by Westport Innovations LLC). This application provides the opportunity for CNG to displace 95% of the diesel fuel consumed in heavy duty highway trucks and off-road equipment such as mining machinery and locomotives.

iGas has also developed high pressure hydraulic rapid fill and storage systems for CNG that avoid the heat of compression issues that restrict conventional CNG refuelling processes. This enables CNG to be compressed, stored and transferred at high pressures and low temperature, maximizing the quantity of energy that can be managed in a CNG storage and refueling system, whilst minimizing the input energy required to compress and transfer the gas.

iGas has also developed a "virtual pipeline" system based upon this technology that enables relatively large quantities of CNG to be transported economically by road train, creating the opportunity for natural gas to service energy markets such as mines and townships beyond the economical reach of pipelines.

An untapped market for natural gas exists in such applications. Gas is already penetrating the passenger vehicle and light transport markets with conversions available for spark ignition engines. The iGas technology provides an economic mechanism to:

- Enable CNG to fuel the new generation of heavy duty diesel cycle gas engines
- Enhance refuelling at all CNG depots with rapid fill Cool 5000 systems
- Extend the market reach of natural gas by enabling relatively large quantities of CNG to be economically transported by road train in "virtual pipelines"