Alternative Fuels for Engine Driven Combined Heat and Power

(CHP)

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Aquafuel™

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- Aquafuel is a technology company specialising in engine driven combined heat and power
- Aquafuel is located on the Kent Science Park www.kentsciencepark.co.uk a 27 hectare campus located near Sittingbourne in the UK

What is Engine Driven CHP?

- We can use an internal combustion engine to produce mechanical power or electrical power. When we do this fuel energy is converted to work via heat. Not all of the heat is converted and escapes from the engine from the cooling system and exhaust

- If we capture and make use of the unconverted heat the efficiency ratio of fuel energy conversion to useful work increases. The heat recovered can be used for process steam, building heat, process heat or ‘reversed’ into cooling

- This is known as combined heat and power (CHP) and its use can obviously reduce the amount of CO_2 released per unit work. If we use renewable fuels the net CO_2 release can be dramatically reduced.

CHP Diagram

What kind of engines can we use?

- **Spark ignited engines**. **Otto Cycle**. These engines when employed in CHP installations usually use natural gas or biogas. A homogeneous charge of fuel and air is compressed and then ignited by a spark. These engines can suffer from early ignition and therefore require high octane fuels. This is the same type of engine used in the gasoline automobile

- **Compression ignition engines. Diesel Cycle**. These engines when employed in CHP installations can run on Diesel oil, Bio diesel and larger engines on Heavy Fuel Oil. Air enters the engine and is compressed; fuel is then injected directly into the combustion chamber forming a heterogeneous mixtures of fuel and air. The temperature of the compressed air is high enough to ignite the diesel fuel. Fuels used in this cycle are required to have a high **cetane** number; the measure of ignition quality. This is the same type of engine used in diesel cars and trucks

- **Dual fuel compressions ignition engines**. These engines use a 'pilot' injection of high cetane fuel to ignite a fuel air mixture of natural gas or biogas. This type of engine is quite common in power generation and can be found in trucks an buses

- All of the above are reciprocating engines as opposed to gas turbines. Gas turbines are often used for CHP but tend to be very inefficient at low powers and extremely fuel sensitive

Alternative Renewable Fuels

- **Oils and fats**

  Plant oils
  Animal fats / oils
  Acid oils
  Algal oils
  Pyrolysis and synthesised oils

- **Gases**

  Bio methane
  Pyrolysis and synthesis gases
  Hydrogen

- **Alcohols**

  Ethanol
  Methanol
  Butanol
  Glycerol

Gases

- **Bio methane**

Can be used as a fuel in spark ignited engines and dual fuel engines

Electrical efficiency ~ 30 % for small SI engines (10 – 50Kwe) and ~ 35% for larger engines (50 – 1000 Kwe)

The emissions from such engines can be controlled effectively with proprietary equipment as long as Hydrogen Sulphide is scrubbed and halogens controlled

Very good potential for expanding CHP distribution due to bio methane production from anaerobic digestion of food wastes and plant residues

Improved electrical efficiency by using lean burn or dual fuel engines

Problems with fuel transportation, the gas needs to be compressed, is highly flammable and can be toxic. Best used where produced; which can limit CHP potential

Can be injected into gas grids but needs very thorough treatment before this is possible which adds cost and carbon

- **Pyrolysis gases**

  Can be used as a fuel in spark ignited engines and dual fuel engines

  Electrical efficiency ~ 30 % for small SI engines (10 – 50Kwe) and ~ 35% for larger engines (50 – 1000 Kwe)

  The emissions from such engines can be controlled effectively with proprietary equipment as long as fundamental contaminants are controlled during gas production

  Very difficult development curve to date. Problems with tar and particulate together with unpredictable composition lead to very low engine reliability and overall system efficiency

  Improved electrical efficiency by using lean burn or dual fuel engines

  Problems with fuel transportation, the gas needs to be compressed is highly flammable and can be toxic. Best used where produced which can limit CHP potential

- **Hydrogen**

Most abundant element in the universe however not very easy to get hold of here!

Once obtained from renewable sources why put it into an engine?

Oils and Fats

- **Plant oils and animal fats**

  Most plant oils and animal fats for energy use are converted to esters to better meet the specification requirements of the automobile and road transport fuel industry. This chemical process is costly and carbon intensive

  The resultant end product is mostly utilised in Compression ignition engines (CI) fitted to road vehicles where the fuel energy to work useful work conversion rarely betters 25%. When compared to efficient CHP use this equates to ~ 3 times the volume of scarce renewable resource per unit of useful work produced. **Silly!**

  As the future of road transport will be a combination of wholly electric or series electric hybrid vehicles it makes sense to concentrate on the application of such fuels to locally embedded combined heat and power

  All crude plant oils, algal oils and fats can be used in mass produced CI engines for CHP installations at very high electrical efficiency ~ 34% (10-100Kwe) up to ~ 38% (100-1000Kwe) if physically processed in the correct manner and used in the appropriate combustion and maintenance cycles

  The emissions from such engines can be controlled effectively with proprietary equipment as long as the fuel is correctly processed and the correct combustion parameters are maintained. Emissions of Nox and particulate need to be carefully controlled to ensure a reducing emission profile from embedded power rather than a rising one

  Larger CI engines are already running on refined oils. Although the electrical efficiency of such engines can be very high ~ 45% the engines are very capital intensive, of very large capacity and are limited by fuel suitability factors

  This type of fuel is portable and therefore has great scope for extended embedded CHP. The fuel tends to have a high flash point and low toxicity and can therefore be handled more easily than gases

  The fuel has great direct use potential in the local area of production

  The problems to overcome when using crude oils and fats are as follows

Engine problems to overcome when using crude oils and fats

- **Aquafuel** have developed patented fuel preparation and engine maintenance systems to enable the use of most crude oils and fats and mixtures thereof

- **Fuel system cleanliness and corrosion**

  Obviously the fuel has to be clean and simple filtration is not adequate, centrifugal clarification is required with secondary filtration

  The fuel is then passed through a process reactor which reduces the corrosive potential to within acceptable limits. The corrosive potential of crude oils can be extreme. Normally high acid oils and fats, acid number greater than 4-5 cannot be used (Bio diesel limit ~ 0.5). The Aquafuel process enables pure acid oils to be used, acid number over 280

  The fuel is then stored and delivered to the engine at a temperature required to comply with the viscosity specifications of the fuel injection equipment

  Without correct fuel treatment the fuel injection system can be irreversibly damaged within minutes leading to loss of injection pressure and damage to injector nozzle needles and seats. This in turn leads to incorrect fuel injection spray patterns, injector fuel leakage, increasing emissions, lubricant destruction and finally piston and cylinder liner damage

- **Injector deposits**

  Oils and fats have varying saturation (double bonds) which is described by the Iodine number. The higher the iodine number the more likely the oils and fats are to polymerise at high temperature

  Polymerisation products form as deposits on the injector nozzles inside the combustion chamber causing rapid alteration to the injector spray pattern with ensuing problems as previously described

  The iodine number cannot be reduced physically and therefore injector deposits are inevitable

  Aquafuel has developed a patented process that enables the engine to run on a polyol / surfactant mixture for a short period of time (INCIP). The mixture is renewable and removes the injector nozzle deposits rapidly (~ 5 mins) and then the engine is switched back to the operating fuel

  The regularity of clean in place cycles is determined by the iodine number of the fuel linked with simple and cost effective emissions monitoring

- **Lubricant**

  A compatible lubricant must be used. A lubricant made from renewable resources has been developed by a major manufacturer that meets all required engine standards

Alcohols

- **Ethanol**

  Can be produced from sugar cane, starch crops and wastes and residues. It is normally used in SI engines as an additive with, or replacement for, gasoline

  Until recently ethanol could only be used in CI engines of a particular type with the addition of cetane improvers. It can now be used in CI engine operating in a novel cycle without the cetane improver.

  Ethanol production is mostly focussed on the road transport industry and is rarely used in combined heat and power due to its flammability and cost of production.

  An ethanol engine

- **Methanol**

  Very similar to ethanol but lower in calorific value and toxic

  Again normally used in SI engines but can be used in CI engines in a new cycle

  Very little renewable methanol production

  Not used as a CHP fuel

- **Butanol**

  Mostly focused on the automotive demand as a gasoline substitute. Higher calorific value than ethanol or methanol and does not absorb water. Can be used in a CI engine in a new cycle

  Very little production at present

  Not used as a CHP fuel

Glycerol

Glycerol can be obtained as a by product from the bio diesel industry or from marine algal

Aquafuel have a patented process for the combustion of glycerol in CI engines using the 'McNeil Cycle', a new combustion cycle enabling standard engines to burn liquid and gaseous fuels of any cetane or octane number without additives or chemical processing.

Glycerol used in standard CI engines for CHP has the following advantages…

Very high efficiency, higher than any available bio, fossil or synthetic fuel. Small engines (10 – 50 Kwe) up to 37%, larger sets (100-1000Kwe) up to 42%, very large engines 1000 – 10,000 Kwe) up to 48%

Very low emissions. Absolutely no combustion particulate and due to the simple nature of the exhaust gas composition very high catalyst efficiency enabling exhaust emissions to 1/10 of the proposed Californian 2015 standard

Very easy to handle, transport and store. Totally bio-degradable and water soluble. Classed as non hazardous, non toxic and non flammable

As a resource the production of glycerol from algae could be greater than that of lipid as the yield can be as high as 60 – 80 % of the algal mass

Although little known as yet as a sustainable fuel source it has in our opinion the potential to play a major role in renewable CHP, desalination and shipping

Conclusions

- Renewable fuels are better employed in CHP than in road transport
- CHP will eventually form a very large part of the energy reserve for road transport
- Bio methane is a good CHP fuel if clean. Pyrolysis gases are problematic
- Pyrolysis oils are highly problematic. Synthetic bio oils are progressing
- Bio oils and fats are good CHP fuels in their crude form as long as they are correctly applied and are from a sustainable resource
- Ethanol , methanol and butanol are more suited to the road transport industry
- Algal oils have potential if marine
- Algal glycerol has great potential
- Glycerol has very great advantages as a CHP fuel