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Since establishing a utility grid electrical distribution network, engine-driven generator systems have been the primary source of emergency standby power when the utility goes offline. With the establishment of the Environmental Protection Agency (EPA), the permissible exhaust emissions of engines used for power generation (and many other applications) have become more stringent, with engine manufacturers developing technology to meet limits set by the EPA. Engine manufacturers are now meeting another challenge as many countries are setting dates for zero carbon emissions to limit carbon dioxide (CO_2) in the atmosphere, which is considered to be a major component of global warming. Currently, most engines use fuel that's by-product after combustion contains CO_2. This information sheet discusses the technology that can be adopted to ensure engines are not a factor in rising CO_2 levels and how engine-driven generators can be one solution to providing energy storage as the Utility Grid becomes more dependent on renewable energy.

1.0 DEFINITION OF NET ZERO AND GREENHOUSE GAS:

The Oxford Dictionary defines the noun "Net Zero" as:

"A target of completely negating the amount of greenhouse gases produced by human activity, to be achieved by reducing emissions and implementing methods of absorbing carbon dioxide from the atmosphere".

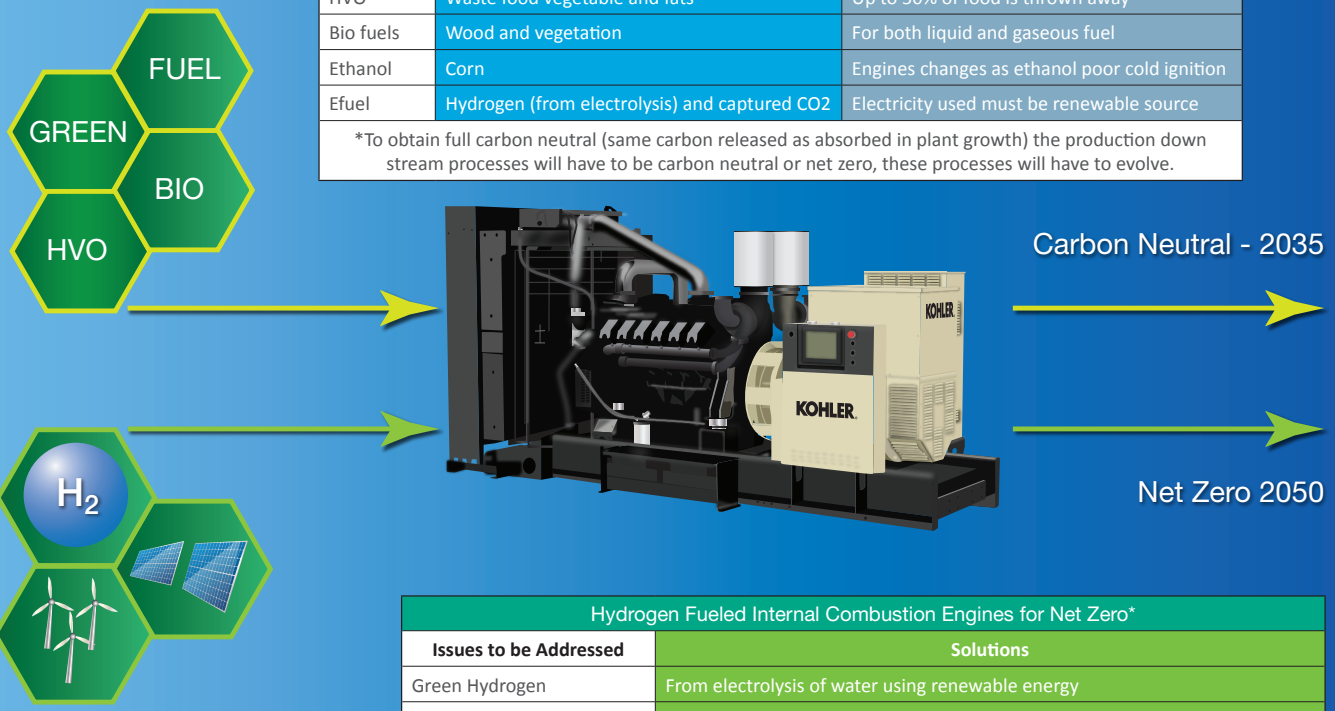
A simple definition of greenhouse gas is:

"Greenhouse gases (also known as GHGs) are gases in the earth's atmosphere that trap heat. During the day, the sun shines through the atmosphere, warming the earth's surface. At night, the earth's surface cools, releasing heat back into the air. But some of the heat is trapped by the greenhouse gases in the atmosphere".

Solutions to Engine-Driven Generators Meeting Carbon Neutral and Net Zero

Figure -2

Non-Fossil Carbon Neutral Fuel Solutions*		
Fuel	**Source Material**	**Comments**
HVO	Waste food vegetable and fats	Up to 50% of food is thrown away
Bio fuels	Wood and vegetation	For both liquid and gaseous fuel
Ethanol	Corn	Engines changes as ethanol poor cold ignition
Efuel	Hydrogen (from electrolysis) and captured CO_2	Electricity used must be renewable source
*To obtain full carbon neutral (same carbon released as absorbed in plant growth) the production down stream processes will have to be carbon neutral or net zero, these processes will have to evolve.		



Hydrogen Fueled Internal Combustion Engines for Net Zero*	
Issues to be Addressed	**Solutions**
Green Hydrogen	From electrolysis of water using renewable energy
Engine Modifications	Hydrogen leaks and makes some metals brittle requiring material changes
Fuel storage as gas or liquid	Very high pressures for gaseous or very low temperatures for liquid form
Hydrogen availability	Net Zero Hydrogen for fuel cells and energy storage, etc., will assist availability
*Most hydrogen today is from fossil fuels. It will require a considerable expansion of green hydrogen production from electrolysis with renewable energy to achieve Net Zero.	

2.0 GREENHOUSE GASES EMITTED BY TRADITIONAL FUEL ENGINE GENERATORS:

Figure 1 details the five main greenhouse gases and which ones relate to engine-driven generators:

Figure 1 **Five Main Greenhouse gases and those relating to Engine Driven Generators**

Greenhouse Gas	Principal Sources	Relating to Fossil Fueled Engines
Carbon Dioxide	Engine combustion; Deforestation-Cement Production	Traditional fuels for engines are diesel, gasoline, LPG and NG. Hydrocarbons that emit CO2 after combustion
Methane	Fossil fuel production; Agriculture-Landfills	After production, system leaks and release methane
Nitrous Oxide	Fossil fuel (Particularly diesel); Fertil-izes-Biomass production; Industrial processes	Nitrous oxide is a more significant problem with diesel, but EPA regulations have reduced considerably
Chlorofluorocarbon-12 (CFC-12)	Refrigerants	Not related
Hydrofluorocarbon-23 (HFC-23)	Refrigerants	Not related

3.0 THE COMPONENT IN FOSSIL FUEL POWERING AN ENGINE:

In fossil fuels, the combustible component powering an engine is hydrogen (H2). Ironically, when pure H2 combusts in air, it is relatively benign, with the by-product of combustion water (H2O). However, fossil fuels are complex hydrocarbons that originally formed on the earth millions of years ago, principally from plant life growth that absorbed carbon from the atmosphere in the process of growing. In fossil fuels, the hydrogen molecule is combined with carbon; in the combustion process, the hydrogen burns for power, and the carbon element during combustion combines with oxygen to form carbon dioxide (CO2).

The push to replace internal combustions with renewable energy, such as wind and solar, that have no CO2 emissions is driven by policies to lower carbon exhaust emissions.

4.0 CONSIDERATION FOR MAKING THE INTERNAL COMBUSTION ENGINE CARBON NEUTRAL: (SEE FIGURE 2)

Using fossil-originated liquid and gaseous fuels to power engines is widely accepted as a significant contributor to increased carbon emissions. Many countries are considering alternative fuels that do not emit carbon after combustion or carbon-neutral fuels. As the world transitions to Net Zero, the following fueling is being considered for internal combustion engines:

4.1 ALTERNATIVE FUELS FOR INTERNAL COMBUSTIONS ENGINES:

The internal combustion engine is not limited to running on fossil fuel. Already, most engine manufacturers have introduced versions of their engines that use hydrogen as their fuel source. Certain modifications must be made to fuel piping, combustion, and materials, but the ability to run on hydrogen is well-proven.

Current restrictions to using hydrogen as a fuel are:

- **Green Hydrogen Availability and Cost -** Most hydrogen today is made from fossil fuels, resulting in a large carbon release. Pure green hydrogen can be made from water electrolysis, which requires a lot of electrical energy. As we move towards Net Zero, many countries, particularly those in desert climates, are looking to make green hydrogen with solar energy. Hydrogen will also be needed for Fuel Cells for energy storage. *(See information sheet on Hydrogen)*
- **Hydrogen Storage -** As a very flammable fuel, transportation and on-site hydrogen storage will have to be worked out.

4.2 CARBON NEUTRAL FUELS:

As they grow, plants remove carbon dioxide from the atmosphere through photosynthesis; all the carbon in fossil fuels today results from plant growth, removing carbon dioxide from the atmosphere millions of years ago. As a transition to Net Zero by 2050, some developed countries are starting to use fuels made from plant growth instead of distilled fossil fluids. The thought process is that if we switch to fuels that take carbon from the atmosphere during their growing process when they are burned in combustion, such as engines, no burned carbon is released into the atmosphere than was taken out in the growing process. This is termed carbon neutral.

Sample Fuels made from plant growth are:

- **Ethanol -** For many years, Ethanol made from corn has been used as a fuel additive. Typically, gasoline contains E10 (10% ethanol and 90% gasoline. Ethanol is also available as E85 (for flex fuel), which can be used in flexible fuel vehicles.
- **Biogas -** A wide variety of materials can be broken down into biogas, including plant material, food waste, trash, and animal manure.
- **Hydrotreated Vegetable Oil (HVO) -** HVO can be produced from any kind of vegetable oil and fats consisting of triglycerides and fatty acids. It is also known as renewable diesel or green diesel. It is created from the lipids of vegetable and fat oil. These lipids are made of paraffinic hydrocarbons and result in low-carbon fuel.. *(See information sheet on HVO)*
- **Efuel -** To produce e-fuels, electricity (to be truly carbon neutral the electricity must be generated from renewable energy) is used to split water into hydrogen and oxygen. The hydrogen is then combined with captured carbon dioxide to make drop-in hydrocarbons like diesel, gas (methane), or jet fuel. European car manufacturers are looking to Efuel.

To fulfill our commitment to be the leading supplier in the power generation industry, the Buckeye Power Sales team ensures they are always up-to-date with the current power industry standards as well as industry trends. As a service, our Information Sheets are circulated on a regular basis to existing and potential power customers to maintain their awareness of changes and developments in standards, codes and technology within the power industry.

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