IGP ENERGY

http://igpenergy.com/IGP_overview.htm Feb. 10 2014

IGP energy is a global company which specialises in the butanol technology market with a special interest in reduction of carbon emissions.

Higher Alcohols

GP Energy is commercializing a process to convert syngas into high-value Higher Alcohols. The products that are made in this process are: ethanol, propanol, butanol, pentanol, hexanol, heptanol, and octanol. There are two primary uses for Higher Alcohols, either as base chemicals or as a high-energy, low-emission fuel oxygenate.

Sequential listing of alcohols starting with the simplest – methanol – and up to octanol

Alcohol	Formula	Carbon Atoms	Energy Released (kJ/g*)
Methanol	CH_3OH	1	22.7
Ethanol	C_2H_5OH	2	29.7
Propanol	C_3H_7OH	3	33.6
Butanol	C_4H_9OH	4	36.1
Pentanol	$C_5H_{11}OH$	5	37.7
Hexanol	$C_6H_{13}OH$	6	39.0
Heptanol	$C_7H_{15}OH$	7	39.9
Octanol	$C_8H_{17}OH$	8	40.6

*kJ/g = kilo Joules per gram

Higher Alcohols: Worldwide Markets

There are two large markets for our products worldwide: base chemicals and low-emission, environmentally friendly fuel oxygenates.

Base Chemicals: Higher Alcohols (HA) are used as feedstocks for manufacturing many product categories. The alcohols produced by the HA process have uses in: cosmetics, perfumes, flavorings, inks, solvents, and resins to name a few.

Fuel Oxygenates: Higher Alcohols are flexible fuel oxygenates with properties that allow for blending with both gasoline and diesel fuels. Higher Alcohols, used as a blended product, have been shown in numerous studies to reduce multiple harmful exhaust emissions such as CO, NOx, SOx, and the particulates that cause smog. They are an attractive alternative to both MTBE and Ethanol due to their high energy value and insolubility in water.

Higher Alcohols: Green Advantages

Process advantages:
The composition of Higher Alcohols (HA) produced by our process contains 7 alcohols from ethanol to octanol. Our use of off the shelf process technologies allows for rapid scalability after process optimization at our reference plant. Syngas (a mixture of carbon monoxide and hydrogen) can be produced from multiple types of feedstock sources, and the syngas can in turn be converted to Higher Alcohols.

Carbon capture is a foundational step in our process. Carbon Dioxide is undesired for downstream processing; as a result CO2 is separated from the syngas in conditioning section. This is accomplished through an Acid Gas Removal section, either low temperature methanol scrubber (“Rectisol”) or amine scrubber, depending on the situation, which are mature technologies used worldwide. Once the CO2 is separated it can be compressed and sold for enhanced oil recovery (EOR) to increase productivity of depleted oil fields. It can also be converted into industrial grade CO2 and used in soda bottling.

Fuel additive advantages:

The U.S. Department of Energy has done extensive research into the combustion characteristics of mixed alcohols focusing on methanol through pentanol. Their results show significant reductions in multiple vehicle emissions. Research has also been conducted into butanol for use as a fuel additive and fuel. Butanol has multiple advantages over methanol and ethanol, from ease of fuel blending to infrastructure integration advantages as well as emission reductions in both gasoline and diesel fuels.

HA combines the best of both pathways, by molecular weight our HA can be considered butanol, while at the same time it is a blend of 7 alcohols. The

benefits of blended products are best understood by three factors: energy released, latent heat of evaporation, and flashpoint.

HA Fuel Comparison

	Flash Point degrees F	Energy Released (kJ/g)	Freezing Point degrees C
Methanol	54	22.7	-97
Ethanol	55	29.7	-114
Propanol	65	33.6	-88
Butanol	82	36.1	-114
Pentanol	91	37.7	-90
Hexanol	185	39.0	-70
Heptanol	170	39.9	-34
Octanol	178	40.6	-15
Gasoline	-40	44.1	-40
Diesel	143	45.4	-34
MTBE	-22	-	-108
HA	92	35.81	-97
Ethanol	55	29.7	-114
Methanol	54	22.7	-97

Energy released: direct translation of energy transmitted to the engine. HA has 58% more energy than methanol and 21.2% more energy than ethanol.
Latent Heat: Is equivalent to potential energy. The lower the flashpoint the faster combustion happens. Gasoline has a flashpoint of -40 degrees F, while diesel fuel has a flashpoint of 140 degrees. Higher alcohols have flashpoints ranging from 54-185 degrees triggering a chain reaction during combustion that controls engine knock and increases oxygen content while completing the cycle of combustion. A more complete combustion cycle equals lower emissions.
All flame and combustion that we normally see is oxygen entering and forming the new compound with vaporized carbon, creating CO2 molecules. The cleaner the flame the clearer it is. For example, compare the flame of a wood fire with that of an alcohol camping stove. There are also other gasses in smoke (in addition to carbon dioxide) but they soon cool to form soot, so the cleaner the fuel the less soot. Soot is a main component of smog.

Compared to Ethanol, Butanol has higher heating value, lower vapor pressure and it is not corrosive to metal parts. Also Butanol fuel could well mix with

gasoline fuel without separation for a long time, which makes it possible to use the existing transportation and re-fueling infrastructure.

Higher concentration of Butanol blended gasoline fuel could be burnt directly without any necessary modifications to the engine fueling system. The unique advantages mentioned above make Butanol-gasoline blended fuel a bright market prospective.

Butanol has higher Octane number, the Butanol/gasoline blends have stronger knocking-resistance therefore larger compression ratio could be adapted to improve engine thermal efficiency.

The energy conversion efficiency of Butanol/gasoline blends is superior to gasoline fuel alone.

The Butanol-gasoline blends could improve the combustion process and significantly reduce raw HC and CO emissions.

The results showed that butanol/diesel blends up to 20% butanol can be successfully operated in a diesel engine calibrated for 100% diesel fuel. In addition, the results showed the significant impact butanol can have on vehicle emissions, especially particulate matter, without significantly increasing NOx.

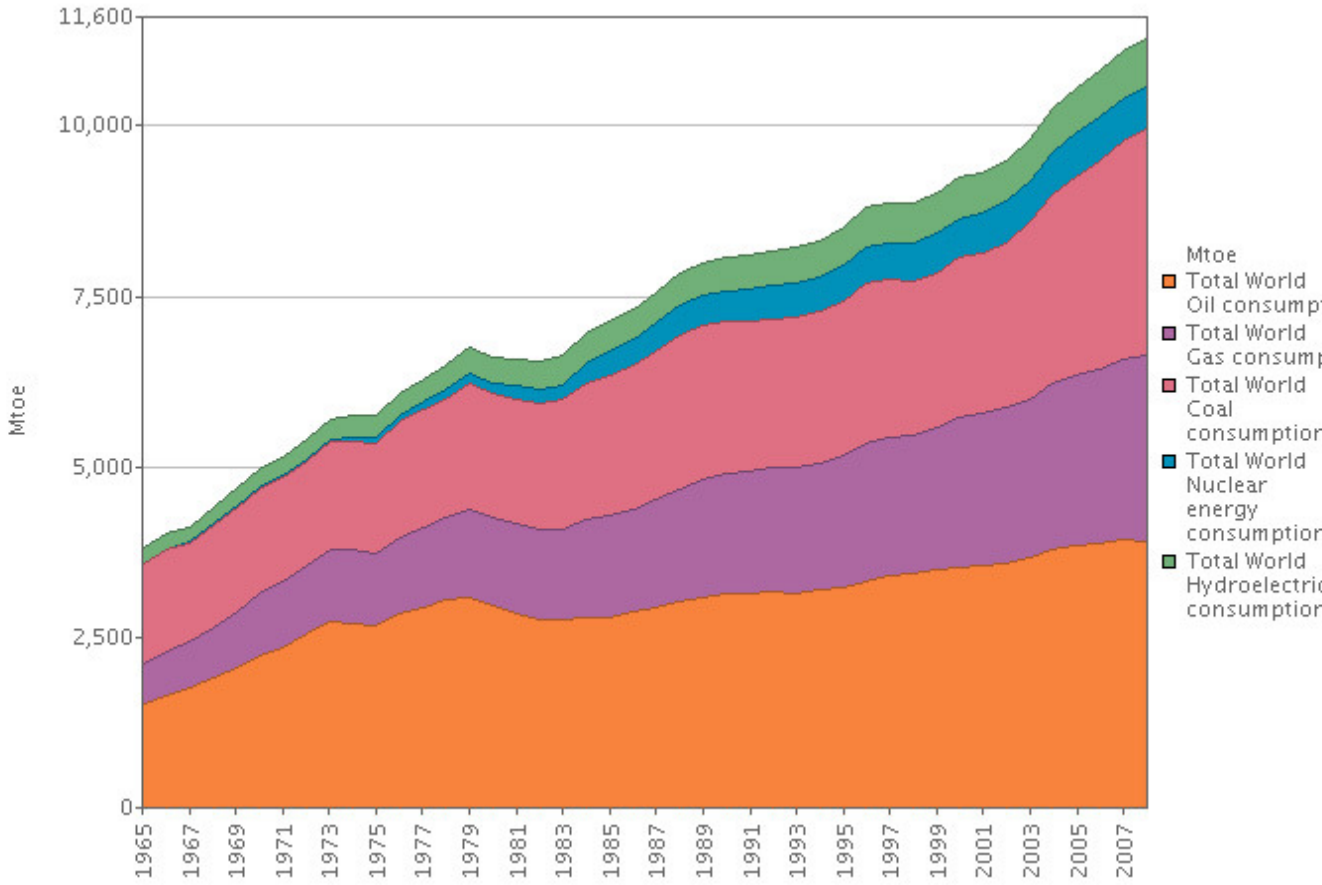
Increasing the quantity of butanol significantly reduced the filter smoke number from the engine during steady-state tests. An 80% reduction in smoke was realized for the 40% butanol/diesel blend Bu40 blend compared to the Ultra Low Sulfur Diesel (ULSD) fuel.

Global Energy Sources
ENERGY SOURCES

Fossil fuels will continue to provide more than 80% of the total energy demand well into the future, and
– according to the International Energy Agency – coal will see the largest demand increase in absolute terms, from some 2,772 Million Ton Oil Equivalent (MTOE) in 2004 to 4,441 MTOE in 2030. The greatest increase in the demand for coal will be in the developing countries, with 86% in developing Asia, where reserves are large and low-cost. India's coal use is expected to grow by some 3.3% per annum to 2030, more than doubling in absolute terms.

Energy security has become a key policy focus for governments worldwide. Recent supply disruptions, whether from severe weather, political reasons or environmental catastrophes have increased the pressure to provide environmentally sound, secure energy.

A key advantage of IGP Energy's technology is the flexibility to use multiple feedstocks to accommodate local sources.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Source: BP

The PM 2.5 Problem and the IGP Solution

This is not a picture of evening fog.

It's the CCTV building in downtown Beijing— during daytime.

The skies are choked with pollution dominated by fine particulate matter known as PM 2.5.

Particle pollution at this scale (2.5 micrometers in diameter and smaller) can cause serious health problems as it can travel deep into the lungs, and some particles may even enter the bloodstream.

Exposure has been shown to be linked to many health problems— from decreased lung function and increased breathing problems to irregular heartbeat, heart attacks, and premature death, especially for people with heart or lung diseases, children, and older adults. Even perfectly healthy people may experience temporary symptoms when exposed to elevated levels of particle pollution.

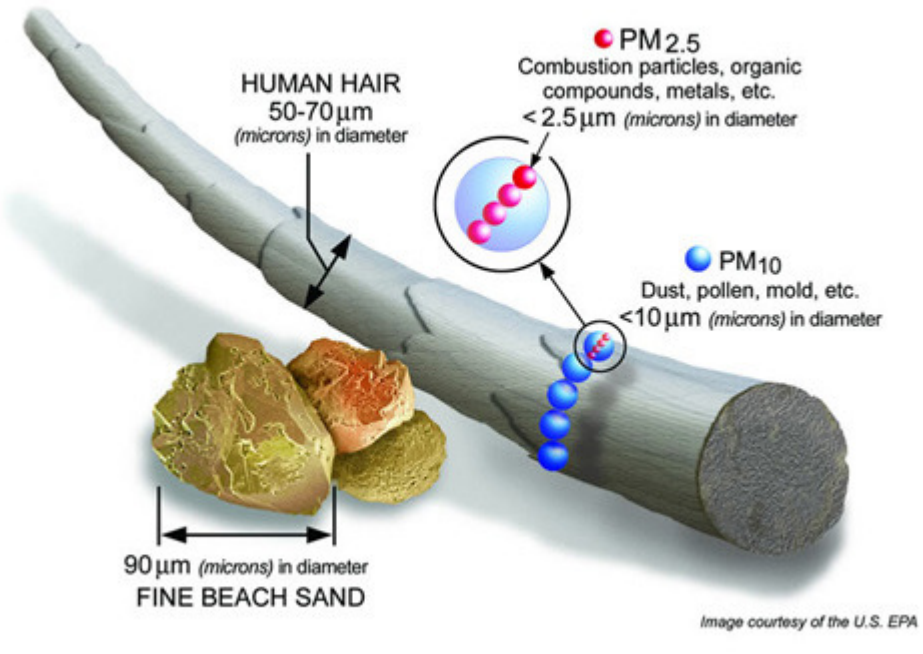


Image courtesy of the U.S. EPA

How small is 2.5 micrometers?

Sometimes known as microns, one micrometer (µm) is just one ***millionth*** of a meter— or about 0.000039 inches.

For reference, an average human hair is maybe 70 microns in diameter, so PM

10 particles (at 10 microns or less) are dwarfed by a hair, and PM 2.5 particles are truly miniscule. That's what makes them so troublesome— and not just to people. They can be windblown for great distances and acidify lakes and streams, deplete nutrients in soils and larger bodies of water, and damage forests and farm crops.

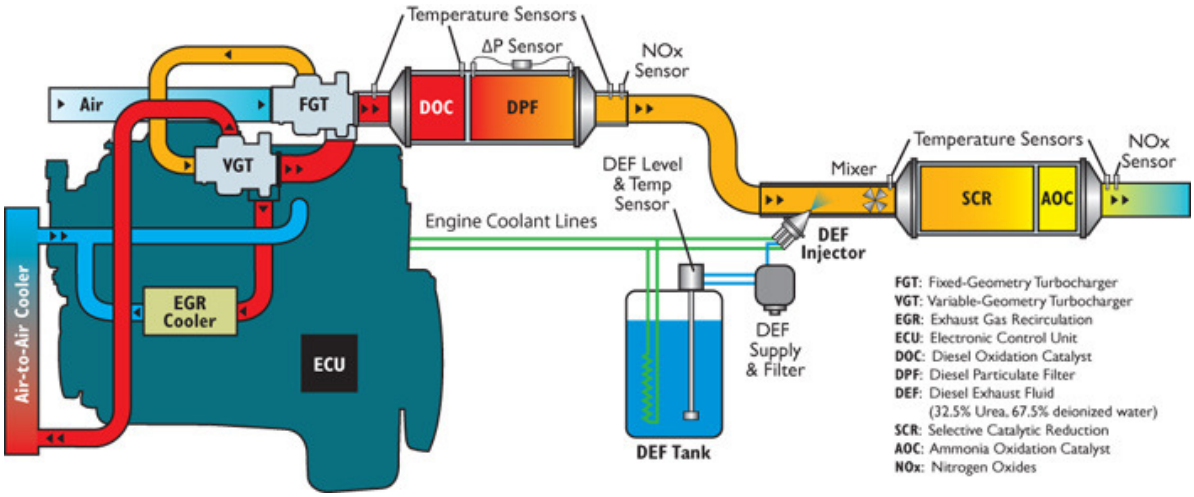
That black smoke is a Big Problem

Diesel exhaust is one of the world's most ubiquitous forms of toxic air pollution, and one of the top sources of PM 2.5. On many parts of the planet, exposure to diesel emissions is nearly impossible to avoid, and in some areas, the concentrations are truly shocking.

Many countries have put tighter emission regulations on new diesel engines, and this has cut emissions from those vehicles dramatically, but there are millions of diesel engines in operation around the world, some many years old. The turnover to new diesels has slowed, and many owners have chosen to rebuild older, dirtier engines to control costs, extending the life (and pollution output) of these vehicles for years to come.

Technology exists to clean up diesel exhaust, like the widely-used Diesel Aftertreatment system built around Diesel Exhaust Fluid (DEF) as illustrated below. This sophisticated process starts with a Diesel Oxidation Catalyst that converts and oxidizes hydrocarbons as well as providing heat for the downstream functions. The second major step is the Diesel Particulate Filter, which traps and periodically burns off soot in a regeneration cycle that exceeds 600° Celcius. Finally, the Diesel Exhaust Fluid is dosed into the exhaust stream from it's own heated tank and the mixture enters the Selective Catalytic Reduction module. In there, in conjunction with the Ammonia Oxidation Catalyst, the NOx and ammonia are converted into inert nitrogen and water.

Most of these "clean diesel" add-on technologies use an on-board computer to monitor and adjust mixtures to achieve some very impressive particulate emission reductions— reportedly **up to 85%**.



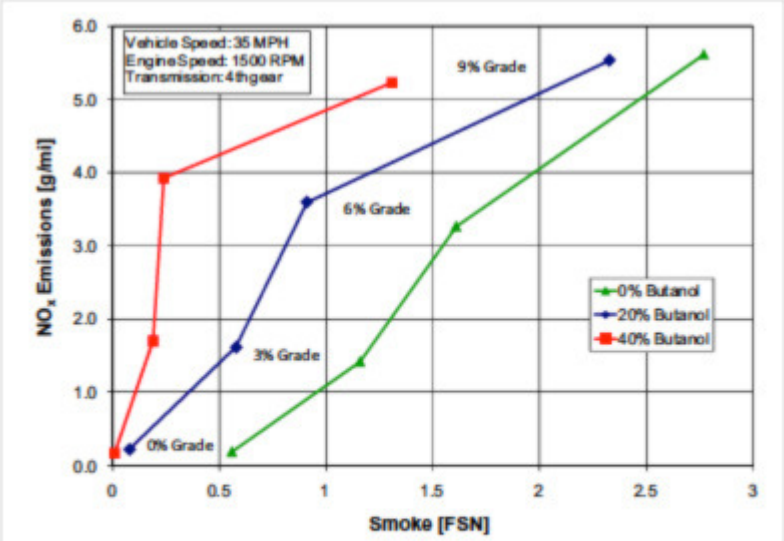


Figure 15: Steady-state NO_x versus filter smoke number at 35 MPH

IGP Energy Solution

For many operations around the world, replacing trucks and other vehicles with new equipment is not economically feasible. A far better solution is fuel-based, so all vehicles can easily benefit.

Particulate emissions from diesel engines can also be significantly reduced **up to 85% – without expensive equipment – simply by blending butanol with diesel fuel**.

The unique properties of butanol allow blending options that can be stored, transported and handled like ordinary diesel fuel, distributed and pumped

using current equipment, while yielding results potentially as impressive as a modern Tier 4 Diesel Engine, even in older vehicles.

Analysis by the Argonne National Laboratory showed that "In steady-state testing, **up to an 85% reduction** in the filter smoke number was shown using a 40% butanol blend at a road grade of 6%."

When the IGP/Yankuang Joint Venture Demonstration Plant comes online and begins production, further testing and field trials can continue to fully capitalize on this remarkable alternative fuel.