POWER PLAYERS

Although the industry and investors flirted with alternative fuels in the late 20th century, only recently has research and development flocked towards these innovations. Engine, airframe and fuels manufacturers march onward alongside venture capitalists, automotive companies and the energy sector. Some invest in known processes like Fischer-Tropsch, while others develop new ways to convert hydrocarbons into drop-in petroleum replacements that must also fit flawlessly into pipelines and the delivery infrastructure. A handful have a headstart running the gamut of safety and performance requirements – a feat aided by conversion technologies that produce fuels chemically identical to kerosene. This directory lists those whose proprietary processes or production facilities are operating or will soon be, and which aim to quench aviation's growing thirst for fuel. Others are just entering the field, and still others may one day tweak their process toward jet fuel from diesel or petrol substitutes.

JEFFREY DECKER OSHKOSH

Fischer-Tropsch fuels

AMERICAN CLEAN COAL FUELS

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Producing Plans for diesel and jet fuel.
Production facilities Commercial plant near Oakland in southern Illinois, online in 2012 and producing 9,857,000 barrels a year.
Feedstocks Mostly coal, to be steadily replaced over 15 years with switchgrass and municipal refuse.
Background Launched with assets earned by his hedge fund Stonebridge Asset Management, president Stephen Johnson means to begin with coal and continue directing environmentally responsible investments toward synthetic fuels. Director of technology Dr N Samuel Saliba brings expertise from years as an executive with BASF and Sasol.
Technological innovations None. Assembling proven Fischer-Tropsch techniques.
Emissions/lifecycle carbon A 50% cut in lifecycle emissions by using carbon capture and storage along with high levels of biomass feedstock, eventually reaching carbon neutrality.
Price $0.26/litre to produce, sold at rates equal to petroleum fuels.

DIVERSIFIED ENERGY

2020 W Guadalupe Road, Suite 5, Gilbert, Arizona 85233-2804, USA. Tel: +1 480 507 0297
info@diversified-energy.com **www.diversified-energy.com**

Producing Diesel, jet fuel, biogasoline.
Production facilities Laboratory produces 3.79 litres per batch, proving the process sought by the US Department of Defense through a grant. Along with Velocys, Diversified will design and build a portable system to turn military base waste into 190-1,900 litres a day of diesel and jet fuel.
Feedstocks Biomass, waste.
Background Diversified is collaborating with North Carolina State University to develop a new jet fuel and contracts its services to other research laboratories to facilitate commercial production of their fuels.
Technological innovations Its HydroMax gasification technology is one-tenth the size of typical Fischer-Tropsch gasifiers. It uses zero or very little outside hydrogen.
Emissions/lifecycle carbon Unknown.
Price Excluding feedstock price and return to

Airbus

Shell's Bintulu site provided the fuel for an Airbus A380 demonstration flight

investors, producing one litre of jet fuel could cost $0.10.

QATAR SCIENCE AND TECHNOLOGY PARK

Villa 1, Education City, PO Box 5825, Doha, Qatar.
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Producing Jet fuel.
Production facilities Small-scale laboratory in Qatar.
Feedstock Natural gas.
Background At the Dubai air show in November Qatar Airways sealed an agreement with Airbus, Qatar Petroleum, Rolls-Royce, Shell International and Qatari fuel company Woqod, to study the creation and use of synthetic fuels, with Qatar Airways intending to become the first carrier to operate services with gas-to-liquid synthetic kerosene. Qatar Science and Research Park was founded by EADS, ExxonMobil, General Electric, Microsoft, Shell and Total to be an incubator of new enterprises.
Technological innovations Final conversion process specifics are not yet firm, but could have rapid adoption by existing and future facilities of Shell and others.
Emissions/lifecycle carbon Unknown, but Qatar Airways chief Akbar Al Baker means the final process to aid environmental preservation.
Price Unknown.

MALMSTROM AFB

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Producing Diesel, jet fuel.
Production facilities Its 285Ha (700 acre) site at under-used base will produce 25,000 barrels a day starting in 2012, with jet fuel as 15% of products.
Feedstock Coal.
Background The USAF continues pushing private interest in Fischer-Tropsch technology after accepting its first test batch in 2006. USAF land and assistance will be put to work to make domestically produced fuel for all military vehicles and naphtha, a material used in the chemical industry. Engine testing continues to certificate the entire USAF fleet for 50% synthetic fuel use by 2011.
Technological innovations Unknown.
Emissions/lifecycle carbon Carbon capture and storage could reduce the lifecycle carbon footprint, which otherwise can be twice that of petroleum.
Price Unknown.

RENTECH

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ir@rentk.com **www.rentech.com**

Producing Diesel, jet fuel.
Production facilities Demi unit in Commerce City, Colorado complete in May, producing 17,000 litres a day of chemicals, diesel and jet fuel, with gasification units planned. A figure of 1,600 barrels a day will complete construction in 2011 near Natchez, Mississippi, with expansion to 190,000 litres a day planned to make fuels, waxes and chemicals.
Feedstocks Petroleum coke, coal, natural gas, biomass, municipal refuse.
Background The R&D company plans partnerships with municipalities to implement proprietary process. Rentech has partnered with The Wilds and Ohio State University to study ecosystem impacts of harvesting biomass.
Technological innovations Low temperature Fischer-Tropsch process marketed as practical and advantageous for municipal waste.
Emissions/lifecycle carbon Discharging CO_2 into existing pipeline will aid local mining operation while storing CO_2 underground, possibly dropping lifecycle CO_2 by 20% compared with petroleum.

QATAR SCIENCE AND TECHNOLOGY PARK

Qatar Science and Technology Park aims to incubate alternative fuel start-ups

ROYAL DUTCH SHELL

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www.shell.com

Producing Diesel, chemicals, jet fuel.
Production facilities Not now producing alternative jet fuel. Bintulu, Malaysia plant has operated since 1993 and produces 14,700 barrels a day. Construction could finish in 2011 at the 140,000 barrels a day Pearl GTL project in Qatar. Next year the Shell Choren demonstration plant in Freiberg, Germany will begin production and eventually produce 18 million litres annually from wood waste. Coal is being explored in Australia and the USA.
Feedstocks Natural gas, forestry waste.
Background The global giant has researched Fischer-Tropsch for 30 years. The Bintulu site provided the fuel for an Airbus A380 demonstration flight with a 40% blend in one engine, and for USAF tests. Cellana is a joint venture in Hawaii exploring algae as a power source.
Technological innovations Advanced catalysts and a multitubular fixed-bed Fischer-Tropsch process rather than a slurry process.
Emissions/lifecycle carbon Compares with modern oil refinery.
Price Unknown.

SASOL

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sasol.internet@sasol.com **www.sasol.com**

Producing 100% synthetic jet fuel, diesel, more than 200 fuel and chemical products.
Production facilities 43.8 million barrels a year of jet fuel produced, primarily in Secunda, South Africa. Intends to produce jet fuel at Oryx plant in Qatar, a joint venture plant in Nigeria and at potential ventures in China, India and the USA.
Feedstocks Coal and natural gas.
Background Sasol pioneered Fischer-Tropsch technology for jet fuel, earning approval for 50% blends in 1999 and for 100% synthetic fuels in April. Airports in South Africa and neighbouring countries rely on the blended fuel, bringing credibility to the concept. Ambitious expansion and development aim to keep Sasol at the fore.
Technological innovations Eighty-year-old gasification techniques were reworked for the 21st century and fuel standards rewritten.

Royal Dutch Shell

Royal Dutch Shell is exploring the use of algae as a power source

Diversified Energy

Glycerol burner for burning glycerol generated in Diversified Energy's biofuel process

Emissions/lifecycle carbon Not tracked.
Price Production costs are confidential. Fuel is sold at market rates.

SYNTEC BIOFUEL

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Producing Ethanol, methanol.
Production facilities To build a 45.5 million litres a year demonstration plant in nine months, with location undecided. A joint venture commercial plant will follow and produce 150 million to 190 million litres a year.
Feedstocks Forestry scraps, organic waste stream.
Background In April Syntec joined the Brigham Young University Fischer-Tropsch Consortium, giving it access to methods for preparation, characterisation and testing of Fischer-Tropsch synthesis catalysts and mechanistic/reactor models. Jet fuel development is in its very early stages.
Technological innovations Non-fermentation ethanol is produced by uncommon means of Fischer-Tropsch process, and is dependent on specialty catalyst.
Emissions/lifecycle carbon Unknown.
Price "The Syntec Process has the potential to revolutionise the ethanol industry with higher ethanol yields and lower production costs per ton of feedstock than any other ethanol production path in use," the company says.

SYNTROLEUM

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Producing Diesel, jet fuel.
Production facilities Pilot plant in Tulsa mothballed after supplying US Air Force with a first batch of synthetic jet fuel in 2006. Construction finishes in 2010 of 285 million litres-a-year facility, producing diesel and jet fuel for military market. Recently sold Nigerian interests. Initiating developments in China and Egypt.
Feedstocks Natural gas, animal fats.
Background Syntroleum's jet fuel has the advantage of rigorous USAF scrutiny beginning with Boeing B-52 tests in 2006. New commercial endeavours continue along with construction of a gasification and conversion operation under Dynamic Fuels, a 50/50 venture with Tyson Foods.
Technological innovations "Bio-Synfining" technology for converting animal fat and vegetable oil feedstocks into middle distillate products.
Emissions/lifecycle carbon Unknown.
Price Undetermined, but annual operating profits of Dynamic Fuels are forecast between $35 million and $60 million.

Biofuels from hydrotreated oils

GE GLOBAL RESEARCH

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Producing Jet fuel.
Production facilities Research laboratories.
Feedstock Biomass.
Background GE Global Research was one of three laboratories awarded Defense Advanced Research Project Agency biofuel contracts in July 2007, out of 30 applicants. In November the two signed a separate $3 million, two-year agreement to develop an alternative jet fuel for military applications. They aim for an energy conversion rate from crop to fuel of 85%.
Technological innovations Eventual integration of gasification and hydroprocessing to achieve minimum energy conversion of 60%.
Emissions/lifecycle carbon Lower levels of aromatics and sulphur than petroleum fuels.
Price Unknown.

IMPERIUM RENEWABLES

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Producing Biodiesel, jet fuel.
Production facilities Imperium Grays Harbor opened in August, producing 380 million litres a year to claim the title of "the nation's largest biodiesel plant". A laboratory in Seattle developed small batches of jet fuel, and the company is finding support for a new mass production facility.
Feedstocks Canola oil, soybeans, considering jatropha. Coconut and babassu used in Virgin demonstration flight not considered practical on large scales.
Background As Seattle Biodiesel, the bulk of Imperium's capital continues to be generated by biodiesel sales. No further demonstration flights are planned. Imperium hopes to renew its relationship with Virgin and Boeing.
Technological innovations Confidential.
Emissions/lifecycle carbon Emissions data from Virgin demonstration flight not yet com-

piled. Reduced CO_2 footprint due to absorption by plant feedstocks.
Price Intending to be lower than Jet A.

SWIFT ENTERPRISES

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Producing "Swiftfuel" avgas substitute.
Production facilities A demonstration plant at Lafayette airport could be producing 760 litres a day next year, and in 18 months it hopes to open a 7,600 litres a day pilot plant at Delphi airport, also in Indiana. Plants producing 76,000-190,000 litres a day planned.
Feedstocks Biomass.
Background Researchers at Purdue University launched Swift in 2001 to prepare their fuel for market. They have created an alternative jet fuel, but are focusing first on replacing leaded avgas. The Federal Aviation Administration initiated tests soon after the fuel's 18 April introduction to ASTM International.
Technological innovations Can convert existing ethanol plants into Swiftfuel factories. Fuel is not oxygenated like ethanol and other fuels.
Emissions/lifecycle carbon No lead, no carcinogens.
Price Unknown.

UNIVERSITY OF NORTH DAKOTA

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Producing Jet fuel, multipurpose military fuel.
Production facilities Research laboratories able to produce 3 litres an hour. It intends to build a 3.79 million litre a year pilot plant, and scale up to 190 million litres a year capacity in a commercial partnership or after leasing their technology.
Feedstocks Numerous vegetable oils, animal fats and aquaculture crops.
Background Before the university earned one of three Defense Advanced Research Project Agency contracts to develop a bio jet fuel, it had worked for four years to develop a military fuel for ground, air and sea vehicles.
Technological innovations Modelled directly on oil-refining tailored for application to oxygen-containing feedstocks.
Emissions/lifecycle carbon Will be lower than for petroleum-derived counterparts. It is also evaluating feasibility of carbon capture and storage.
Price Estimated at $125 a barrel.

UOP

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www.uop.com/secure/8071.asp www.uop.com

Producing "Green diesel" and "Green Jet Fuel".
Production facilities Pilot plants in Illinois, licensing technology to Italian refiner Eni Livorno, Italy, with production from early 2009.
Feedstocks Soybeans and canola, potentially jatropha and algae.
Background Wholly owned by Honeywell, UOP was one of three labs to win Defense Advanced Research Project Agency contracts to produce bio-JP-8. DARPA testing confirms the fuel has proper density, freeze point and flash point. A partnership with Airbus, Jet Blue and International Aero Engines will study commercial use of biofuels.
Technological innovations "Ecofining" adds hydrogen to deoxygenate feedstock oils, resulting in a fuel like diesel that is not an additive.
Emissions/lifecycle carbon Gives 50-70% greenhouse gas savings.
Price Ecofining integrates with existing refineries, minimising start time and capital expense.

Algal and advanced generation fuels

ALGAE LINK

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Producing Algae oil, biodiesel.
Production facilities Ten algae cultivation and oil conversion facilities in the state of Cadiz, Spain, producing 2t each of dried algae daily after beginning operation in late 2008. A pilot system in Netherlands will develop conversion techniques for jet fuel.
Feedstock Algae.
Background A partnership with KLM Royal Dutch Airlines put the spotlight on the closed-system algae operation of R & D chief Dr George Tsiropoulos. No jet fuels produced so far.
Technological innovations Closed loop reduces the risk of contamination. Small scale of each cultivation unit makes capital construction costs low and simpler to install remotely. Hydrocracking converts biodiesel to more complex fuels.
Emissions/lifecycle carbon Potentially equal levels of nitrous oxide and carbon dioxide emitted during fuel combustion are absorbed from the atmosphere as algae grows.
Price High.

AQUAFLOW BIONOMIC

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Producing Algae oil.
Production facilities Commercial scale continuous harvesting of "tonnes" of wild algae began in March at its Marlborough oxidation pond. Expansion continues. Planning for a network of small biorefineries globally around existing water treatment lagoons
Feedstocks Algae grown at sewage treatment plants, near farms, paper mills and other high-nutrient water locations.
Background Aquaflow is undergoing rapid expansion as it shoots to be the leader in converting algae into fuel. Interest from Air New Zealand and Boeing have brought added resources and attention, as the carrier means to fill at least 10% of its energy needs sustainably by 2013.
Technological innovations Proprietary and confidential, with more information expected by year's end along with a likely demonstration flight.
Emissions/lifecycle carbon Sequestration of carbon dioxide during growth of algae provides unknown amounts of abatement.
Price High.

GENERAL ATOMICS

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Producing Algae oil, jet fuel.
Production facilities Research laboratory, pond near Carlsbad, constructed on non-arable land by Excellence for Hazardous Materials Management. Future commercial applications may spin off into a sister company.
Feedstock Algae.
Background Advanced Process Systems Division of GA was awarded, with Texas AgriLife Research, part of the Texas A&M University System, a $4 million grant from the Texas Emerging Technology Fund for research into the development of biofuels using microalgae.
Technological innovations Proprietary.
Emissions/lifecycle carbon Unknown.
Price High.

PETROSUN

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petrosun@cox.net **www.petrosuninc.com**

Producing Petroleum, algae oil, jet fuel.
Production facilities Operations began at its commercial algae-to-biofuels facility on 1 April in Rio Hondo, Texas and will produce an estimated 16.7 million litres of algal oil and 49 million kg (110 million lb) of biomass a year from saltwater ponds. A total of 8Ha (20 acres) are reserved for production of a renewable JP8 jet-fuel.
Feedstocks Oil, biomass, algae using saltwater, brackish or wastewater.
Background A partnership with Science Applications International intends to devise a commercially viable conversion process from algae to jet fuel. Intends to supply militaries with renewable fuel sources designed to integrate into existing infrastructures.
Technological innovations Proprietary.
Emissions/carbon lifecycle Unknown.
Price Initially may exceed $5.2 per litre. Could require $250 per barrel of crude oil or more for these systems to be economically feasible. ■