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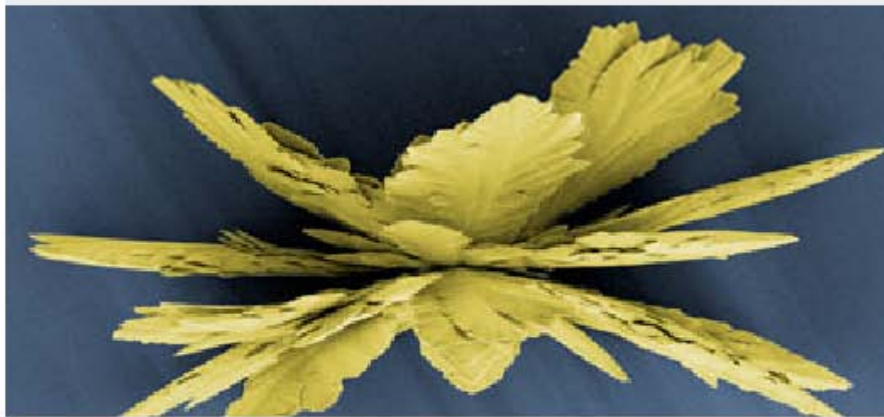
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Science 3 June 2005 308: 1373 [DOI: 10.1126/science.308.5727.1373c] (in This Week in *Science*)

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Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass

David Tilman, Jason Hill, and Clarence Lehman

Science 8 December 2006 314: 1598-1600 [DOI: 10.1126/science.1133306] (in Reports)

.....than can corn grain ethanol or soybean biodiesel. High-diversity grasslands had increasingly...ethanol and 14.4 GJ ha⁻¹ for soybean biodiesel (14). Thus, LIHD biomass converted...Estimates for corn grain ethanol and soybean biodiesel are from (14). Annual carbon.....

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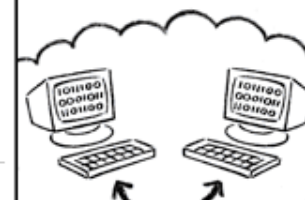
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Philip H. Abelson

Science 19 May 1995 268: 955 [DOI: 10.1126/science.268.5213.955] (in Articles)

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.....long-term pilot plant experience is missing. **Biodiesel** oil is a potentially important enhancer...esters of the straight-chain fatty acids. **Biodiesel** oil is in the early stages of development...containing 80% conventional fuel and 20% **biodiesel** oil has been employed. Tests using 100.....



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Renewable Hydrogen from Nonvolatile Fuels by Reactive Flash Volatilization

J. R. Salge, B. J. Dreyer, P. J. Dauenhauer, and L. D. Schmidt

Science 3 November 2006 314: 801-804 [DOI: 10.1126/science.1131244] (in Reports)

.....steady-state operation with refined soy oil, **biodiesel** (the volatile methyl ester of soy oil...Results for a similar experiment with **biodiesel** instead of soy oil are shown in Fig. 2. **Biodiesel** (the methyl ester of the fatty acids from.....

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Arthur J. Ragauskas, Charlotte K. Williams, Brian H. Davison, George Britovsek, John Cairney, Charles A. Eckert, William J. Frederick, Jr., Jason P. Hallett, David J. Leak, Charles L. Liotta, Jonathan R. Mielenz, Richard Murphy, Richard Templer, and Timothy Tschaplinski

Science 27 January 2006 311: 484-489 [DOI: 10.1126/science.1114736] (in Review)

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Science 3 November 2006:
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REPORTS
Renewable Hydrogen from Nonvolatile Fuels by Reactive Flash Volatilization
J. R. Salge, B. J. Dreyer, P. J. Dauenhauer, L. D. Schmidt

Droplets of nonvolatile fuels such as soy oil and glucose-water solutions can be flash evaporated by catalytic partial oxidation to produce hydrogen in high yields with a total time in the reactor of less than 50 milliseconds. Pyrolysis, coupled with catalytic oxidation of the fuels and their fragments upon impact with a hot rhodium-cerium catalyst surface, avoids the formation of deactivating carbon layers on the catalyst. The catalytic reactions of these products generate approximately 1 megawatt of heat per square meter, which maintains the catalyst surface above 800°C at high drop impact rates. At these temperatures, heavy fuels can be catalytically transformed directly into hydrogen, carbon monoxide, and other small molecules in very short contact times without the formation of carbon.

Department of Chemical Engineering and Material Science, University of Minnesota, 421 Washington Avenue SE, Minneapolis, MN 55455, USA.

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important process for using renewable fuels such as vegetable oils and liquids produced by hydrolysis or pyrolysis of biomass (1). Hydrogen is needed for fuel cells and for onboard combustion in vehicles for enhanced performance and reduced emissions, and syngas is used for the production of synthetic liquid fuels, chemicals, and fertilizers.

The conversion of gaseous and volatile fuels to H₂ is possible through pyrolysis (1), steam reforming (2), and partial oxidation (3-5), with or without catalysts. However, the direct processing of nonvolatile fuels such as vegetable oils, residual petroleum fuels, and liquid and solid biomass is more complicated because of their tendency to form solid carbon that interferes with process equipment and rapidly plugs pores in heterogeneous catalysts. Such heavy fuels decompose chemically before evaporation to form hydrogen, olefins, aromatics, and solid carbon.

Flash pyrolysis (reaction times typically 1 s) of heavy liquids and solid biomass has been shown (1) to produce primarily gases (syngas) and volatile liquids (bio-oils). Reaction times in these processes are limited by heat transfer into biomass particles to decompose reactants. Additionally, at least ~10% of the reactant biomass is reported to form a solid char that must be separated and removed. Nonvolatile solid biomass pellets have been shown to volatilize without the formation of carbon when exposed to very high heat fluxes (~10⁶ W/m²) (6) of focused laser light.

We used a catalyst-coated ceramic foam maintained at ~800°C by the reaction, it is possible to achieve steady-state operation with refined soy oil, biodiesel (the volatile methyl ester of soy oil), and sugar-water solutions with no external heat supplied. This process produces ~70% selectivity to H₂ with >99% conversion of the fuel. Carbon formation does not occur because the presence of O₂ produces rapid oxidation of decomposition products, and the resulting heat of reaction maintains a surface temperature of 800° to 1000°C that prevents quenching of the process that would lead to rapid carbon formation.

The reactor, sketched in Fig. 1, is similar to those described previously (5) and uses an automotive fuel injector to spray ~400-µm-diameter drops onto a catalyst foam containing Rh-Ce catalyst particles at typically 2.5% by weight of each component. We placed the catalyst ~2 cm from the fuel injector so that the cold drops impinged directly on the front face of the catalyst. Air flowed around the fuel injector to provide a uniform flow field and to optimize mixing with the gaseous products. Air and fuel enter at 20°C; no external heating was needed.

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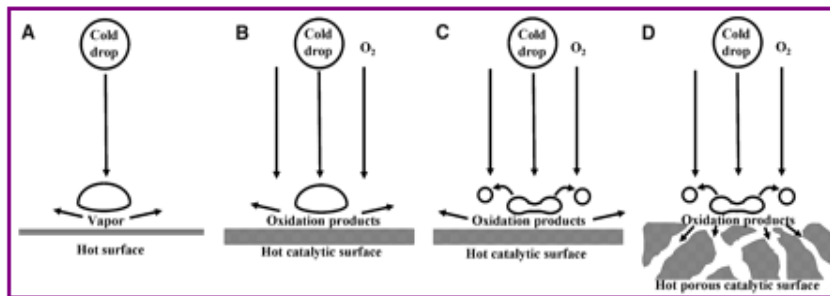


Fig. 3. Sketches of possible configurations of (A) conventional film boiling of a volatile drop on a hot surface, (B) reactive drop volatilization on a hot catalyst surface, (C) drop impingement and breakup on a hot catalytic surface, and (D) drop impingement and breakup on a hot catalytic porous surface. [View Larger Version of this Image \(71K JPEG file\)](#)

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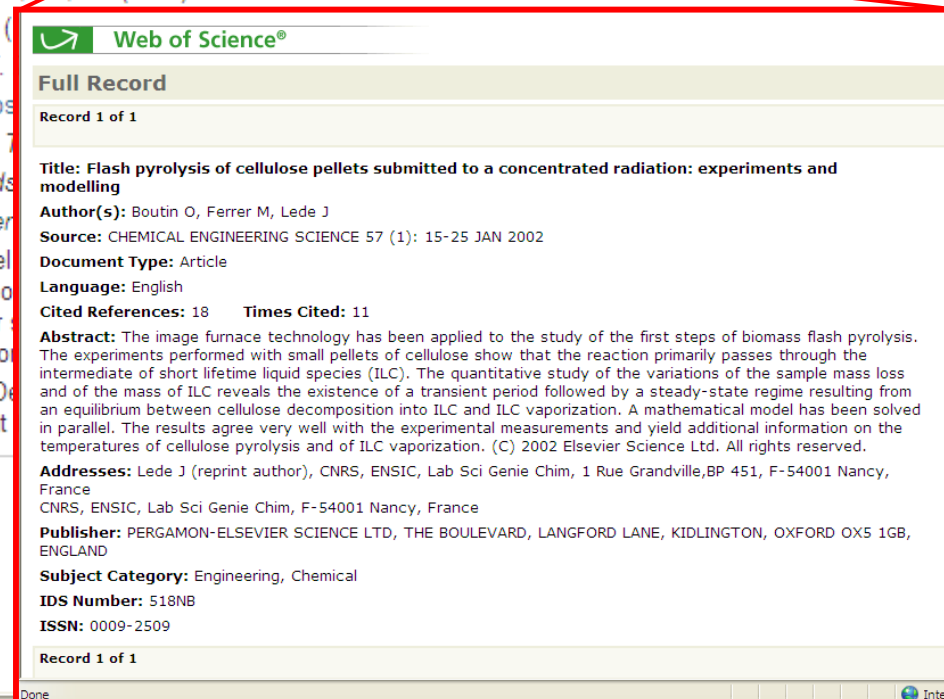
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14. Our system processes approximately 0.6 kg/day of fuel. A 10 cm diameter would process ~5.2 kg/day under identical conditions. Fuel injectors to obtain sufficiently low flows, but larger diameter injectors, or different methods for uniform drop formation.
15. This research was supported by grants from the U.S. Department of Energy Initiative for Renewable Energy and the Environment at

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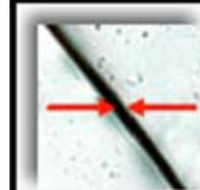
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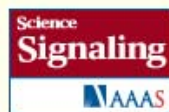
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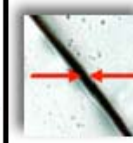


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