Project Gaia

A New Stove and Clean Liquid Fuel for Household Use in Developing Countries

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Abstract

The best way to avoid the many problems associated with burning wood as a household fuel is to stop burning wood. Instead, wood, and biomass generally, including waste biomass, may be used to make methanol, which is the simplest alcohol and the ideal clean-burning liquid fuel. This offers a cleaner and more efficient way to use biomass as the primary source for household energy wherever adequate quantities of biomass can be grown on a sustainable basis.

This opportunity exists because there is a proven stove that operates safely and effectively with methanol—the Dometic ORIGO® stove. Currently used in special applications where safety and air quality are all-important, this stove is being adapted for use in developing countries. Dometic AB is building a sturdy, functional and inexpensive stove for use in the humblest household.

Methanol is manufactured all over the world from natural gas and is shipped in large quantities. It is the most widely available alcohol. It is also the most easily and cheaply produced from biomass. The authors discuss technologies available to gasify biomass for methanol synthesis and, likewise, a technology to manufacture methanol from synthesis gas on a small scale.

The authors argue that methanol from natural gas is the ideal bridge between the current day and the day when methanol can be manufactured from plantation and renewably harvested biomass on a scale large enough to achieve economies and serve significant populations.

The opportunities for developing countries that implement a methanol-based energy economy are discussed. Introduction of the stove and fuel would result in savings per family of 5 tonnes of CO_2 equivalent per year. If carbon credits are sold, this could return money to the family to offset the cost of stove and fuel. Labour savings from not having to gather wood could mean additional hours each day for gainful employment. Local manufacture and distribution of the stove and fuel create the potential for local industry.

The authors note that the use of methanol will not be limited to cooking. Other appliances are under development or already available for refrigeration and lighting. Engines and small direct methanol fuel cells will generate household electricity. Because of the close link between household energy and local enterprise, the availability of adequate energy supplies and the technology to use them will create the opportunity for many wealth-producing activities.

1 Introduction

The solutions to major problems are often far from the most obvious ones on which we tend to concentrate initially. Our natural tendency is to try to improve on existing practices, which may be already obsolete. It would seem, for example, that the way to improve on the use of wood as a domestic fuel is to make a more efficient wood-burning stove and then pipe the decreased but still very significant smoke and fumes out of the house or the courtyard. But this is not the best solution. The best solution is to depart completely from tradition, for example, just as the inventor of the self-cleaning stove oven did. Who would ever have thought that the way to clean an oven was to set it on fire? Yet, that is what the inventor did. He closed the oven with a safety lock and then heated it to the ignition temperature of grease and carbon and held it just above ignition temperature—not too hot—so the grease and carbon would oxidize away in a couple of hours to a little bit of white ash that could be wiped off with a damp rag. Now such ovens are installed on stoves all around the world.

Fig. 1 A one-burner ORIGO® methanol stove.

It is not obvious that the quickest and best way to solve the wood-burning problem is to stop burning wood. Rather than burn wood directly, the answer is to make wood into a clean liquid fuel and burn the liquid fuel. Our purpose here is threefold: (1) to provide a brief explanation of how to accomplish the conversion of wood to a clean liquid fuel, (2) to introduce to the reader existing appropriate technology that is either available today or is being adapted to permit the efficient and economical use of the clean fuel, and (3) to offer a strategy for bridging the gap of time between now and the day when we can actually make biomass into a clean liquid fuel for use in the home.

2 A More "Industrial" Approach

By way of background, let us look at some interesting history. Travelling in the British Isles, one is struck by the lack of forests in a once heavily forested country. Even Iceland, where there is scarcely a tree today, was once well forested. Where did the trees go? They went to heat homes, to cook with, and to make charcoal for the manufacture of iron, as well as to other manufacturing purposes. Had England not discovered coal and how to use it, the population of the entire U. K. today would perhaps be 5 or 10 million people subsisting on agriculture and cooking with biomass. Of course, this is an overstatement. However, it places into relief what has occurred. With the exploitation of coal, the people of the British Isles began to move up the "energy ladder" (UNDP World Energy Assessment, 2000), and away from the direct use of wood as their primary fuel. It lay the foundation for enormous economic and technological expansion. After a time, and with the development of concerted forestry and conservation programs, this enabled communities and nations to begin the regeneration of their forests. Today, as a consequence, there is a respectable degree of reforestation occurring in the British Isles, for example in areas like the Lake District. In quite a few developed countries, forest cover is increasing and has been increasing for decades. The U. S. is also an example. The fundamental reason is always the same: other fuels taken from below the earth have replaced the use of wood.

Similarly, the answer to the use of biomass for domestic fuel is to stop using trees directly as fuel, and to substitute a clean fuel derived from a fossil source as the way to bridge the gap between now and the day when forests can be regrown. This must be accomplished on a very large scale. When we again have adequate forest resources, we must learn to harvest and convert them efficiently, to make the same fuel we will have used in the meantime as our "bridge" to sustainability (Serchuk and Means, 1997). In this way, we will have secured the time needed to get away from burning trees directly. This will necessitate a more centralized, "industrial" approach to solving the environmental problem of burning biomass than the approach of continuing to directly burn biomass in household stoves, but simply more efficiently. There is room for both approaches; indeed, both are mutually supportive and can be joined successfully in a nation's domestic energy policy that seeks to reestablish sustainable biomass reserves as a resource for long-term, sustainable energy production.

Fig. 2 A two-burner ORIGO® methanol stove.

In the past, as with our example of the British Isles, it is in fact industrialization (despite its many impacts) that has enabled the developed nations to begin to reclaim their forests. The managed forests that are now being constantly harvested and regrown in countries with well organized forestry programs rely on the extensive use of fossil fuels for their planting, maintenance and harvesting. The energy for conversion of trees into lumber and pulp is increasingly derived from the wastes from these processes. If we follow this example to its conclusion, we can say that the fossil-derived "bridging" fuel that we will choose to supply domestic (household) needs will eventually not only be made from trees but also will be used as the fuel to operate the machinery that will thin, harvest, transport and process the trees. Thus, in the long run, we could finally achieve an approach where our domestic fuel is derived completely from renewable biomass. We cannot achieve this rapidly. There must be a bridging fuel to take us there, derived from a suitable fossil resource. The fossil fuel is natural gas, and the bridging fuel is methanol from natural gas.

3 The "Energy Ladder"

The concept of the "energy ladder," first suggested by the U. S. Office of Technology Assessment in 1992, ranks household fuels along a spectrum running from simple biomass fuels (dung, crop residues, wood), through fossil fuels (kerosene, LPG and now methanol) to electricity. The fuel-stove combinations that represent rungs in the ladder tend to become cleaner, more efficient, more storable, and more controllable as one moves up the ladder. But capital costs and dependence on centralized fuel cycles increase as one moves up the energy ladder. The cost of constructing, maintaining and operating a power generation plant and electricity grid is perhaps the best example of this.

Methanol could be said to occupy a unique position on the energy ladder since it is a highly improved fuel that can be derived from biomass and fossil fuels alike. It performs with the quality of propane or natural gas, yet requires a delivery infrastructure similar to that of kerosene. Literally, it pours as a liquid but burns as a gas.

4 Methanol as the Bridging Fuel; the ORIGO® Stove Opportunity

Why is methanol the appropriate bridging fuel? The simple answer is that it is also the ultimate fuel for domestic use, a fuel that can be made from fossil fuels or from biomass, and a fuel that burns very cleanly. Its use will eliminate the smoke and soot produced in the household when wood is burned, and will reduce household CO_2 and greenhouse gas (GHG) production by about 5/6 when compared to using non-replaced forests for fuel. (Please see Kirk R. Smith, et al. for a discussion of indoor air pollution and GHG production from the burning of solid fuels.)

The use of methanol as a domestic fuel is not only possible but also desirable for at least three compelling reasons. First, methanol, the simplest alcohol and the one we know how to make most cheaply and efficiently, can readily be made from wood. Indeed, methanol entered commerce over 100 years ago from this source, albeit as a minor byproduct of making chemicals and charcoal from wood, using a very non-selective and inefficient process. Today we can make methanol from any type of biomass far more cheaply and efficiently than we can make ethanol from corn.

Second, methanol is absolutely incapable of forming soot when it burns because its one carbon atom is firmly anchored to one of the two oxygen atoms needed to burn it. An ethanol flame will produce soot. Pots stay bright and clean with a methanol flame. The products of combustion of methanol are carbon dioxide and water vapor.

Fig. 3 The fuel canister for the ORIGO® stove is designed for safety and performance. Filled with an absorbent material and holding 1.2 litres of fuel, it is leak-proof, even when held upside down.

Third, methanol is a splendid cooking fuel, and there has been in use for well over a decade a very efficient stove in which to burn it. Designed originally for ethanol, this stove performs even better with methanol. It is not pressurized; it is safe, controllable, convenient and, when produced and distributed on a large scale, it will be inexpensive to buy. This stove, known as the ORIGO® stove, which was developed and is produced by Dometic AB of Sweden, is pictured in Figs. 1, 2, 4 and 5. These photographs show the stove in its present one- and two-burner models (Figs. 1 and 2), a two-burner model in use in a South African home during a recent pilot study (Fig. 4), and an artist's rendering of the ORIGO® stove in its improved form for low-cost, mass production (Fig. 5). Also shown is its fuel canister (Fig. 3). The fuel canister is packed with a highly porous refractory mass. The methanol is contained within this mass and cannot spill or run out except by the intended capillary action when the surface methanol is burned off.

Methanol, when very pure, has only a faint, pleasant odour. Its boiling point is similar to that of the premium liquid hydrocarbon fuels widely used in boat and camp pressure stoves and lanterns. A methanol flame is easily extinguished by water because methanol is soluble in water in all proportions. Water tends to spread a hydrocarbon flame but in the case of methanol it cools and extinguishes the flame. Methanol is handled as a liquid in non-pressure containers just as for a century or more we have handled kerosene and the gasoline-range hydrocarbon stove and lantern fuels. Indeed, methanol, early in its existence, was often used in upscale restaurants to heat chafing dishes and warming tables in the dining room amidst the guests. This is because it burns cleanly without odours or smoke and because it is easy to handle. Then came the invention of Sterno®, which was ethanol denatured by methanol and gelled by an aluminum compound so that it was, in effect, a solid fuel. This made it even more convenient for waiters and safer for the guests. Sterno® stoves have become a stand-by stove for households all over the world as well as a boon to campers and picnickers. The fuel and stoves are still available. The can of gelled fuel is not refillable. The fuel is used up and the can is thrown away.[1]

Fig. 4 ORIGO® stove with large pot, in a South African home. The ORIGO® stove is being redesigned to be larger, sturdier and more stable, able to handle large pots.

The invention of the ORIGO® stove, by one of the authors of this paper, went several steps farther than the gelled fuel concept. The inventor designed a reusable canister containing a permanent, porous, refractory mass that absorbs and holds liquid (alcohol) fuel so well that it will not spill out of the canister, even when the canister is inverted. In essence, the ORIGO® stove provides for storing of the liquid fuel as though it were solidified, but in a manner that permits convenient fuel replenishment, thus retaining the great advantage of liquid fuel, namely ease of handling. This novel, patented method of holding the fuel makes for a degree of safety and convenience not hitherto seen in a liquid fuel stove and does so without sacrifice of efficiency or heating rate. The inventor also designed a safe, all–stainless-steel stove body to contain the canister, and a burner extremely effective in primary and secondary air mixing.

Methanol performs best of any alcohol in this burner because of its higher volatility and better inherent burning characteristics. As the burner heats, the methanol evaporates from the fuel canister into the burner. This causes the burner to perform like a gas burner, even though the methanol is not under pressure. The burner is fitted with a regulator that controls the surface area from which the methanol is being volatilized. This allows the burner to be regulated like that of a gas stove. The burner must be extinguished before the stove body can be opened to refill the fuel canister(s), a valuable safety feature. An electric element was placed in some stove models to permit the use of electricity, when available, and other models were designed with an oven. The inventor has now redesigned the stove for mass production at relatively low cost and for better performance in a wider range of applications, namely developing-country households.

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[1]A gelled-fuel project is currently under development in Zimbabwe and neighboring countries using ethanol produced from sugar crop waste (Millennium Gelfuel Initiative).

Fig. 5 Artist's rendering of the new, low-cost ORIGO® stove for developing country households. Several prototypes have been developed. The first of these stoves will be ready for production in early 2003.

5 Why Methanol?

Now we have the stove, but what about the fuel? The answer is that methanol is made all over the world from natural gas and in a few places from coal, oil, or from miscellaneous wastes, including municipal wastes. But today virtually all of it is made from natural gas. It can readily be made from biogas. There are several projects that propose to do this in the U. S. from biogas recovered at landfills.[2] Methanol is recovered as a by-product from a coal-to-synthetic-fuel plant in South Africa. It is also made directly from coal in South Africa. Similarly, it is made from coal in the U. S. today. It can be made from any carbonaceous material: wood, bagasse, grasses, agricultural waste, lignite, semi-bituminous coal, bituminous coal or anthracite. Heavy petroleum residues can be used, including the very heavy bitumens from Venezuela and Canada, to name only two sources of this very plentiful material. Several plants have been built to make methanol from heavy oils of this general character.

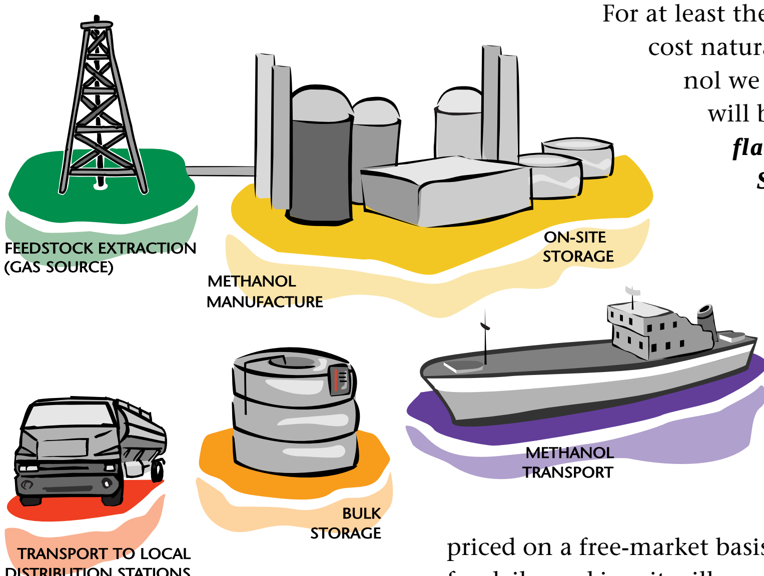

Fig. 6 How imported methanol reaches the market today.

For at least the next 50 years, however, we have plenty of low-cost natural gas, already discovered, to make the methanol we will need for the many fuel uses to which it will be put, including cooking. ***There is enough flared gas in Nigeria to supply every family in Sub-Saharan Africa with methanol for cooking fuel.*** All over the world, methanol is produced from natural gas and transported to the market at very low transportation cost, in the manner depicted in Fig. 6. This is of course the same transportation system used with crude petroleum and its products. Considering the efficiencies obtained in its use, methanol can be delivered on average at a cost comparable to or cheaper than purchased fuel wood, or kerosene and propane when priced on a free-market basis. If the household gathers its 5–10 kg of wood for daily cooking, it will use 2 to 6 hours of labour. Even at a labour value of only U. S. 25 cents/hour, about one hour's labour will buy the daily methanol needed. The other 1 to 5 hours can then be sold into the marketplace for agriculture or manufacturing, if such opportunities are available.

6 The Methanol Economy

Methanol is traded worldwide as a commodity like fuels refined from petroleum. As with any commodity, its price can vary with supply and demand. On average, its real price has been declining for the 75 years since it entered the market as a synthetic product. As the market expands, ever-larger plants, already engineered, using well-proven components, will be built, lowering costs. Already it is transported in ships as large as the largest tanker used to transport gasoline. Its price delivered to seaports all over the world will average about U. S. $130 ± 30 per metric tonne (t) with rare excursions above

[2]An example of this technology is Alcohol Solutions, LLC, of Cleveland, Ohio, USA.

$160/t but with an increasing tendency to sell at a lower average price, perhaps as low as $110 to $120/t. With crude oil at $30 per barrel (0.147 tonnes), a price reached in the year 2000 for a number of months, gasoline sells ex-refinery for as high as $367/t, which is comparable on a heating value basis to methanol at $190/t. Kerosene sells ex-refinery at a price roughly comparable to that of gasoline. With crude oil at $22 to $28, the now widely expected future range, or an average of $25, the methanol equivalent would be $160/t. These figures are given in order to put the cost of methanol in perspective. The consumer cost, as with gasoline, will be higher due to delivery to local distributors and their mark-up. When methanol is eventually made locally, these distribution costs will be much lower and all costs will become wealth created in the local economy, the result we all desire to accomplish eventually (Fig. 7).

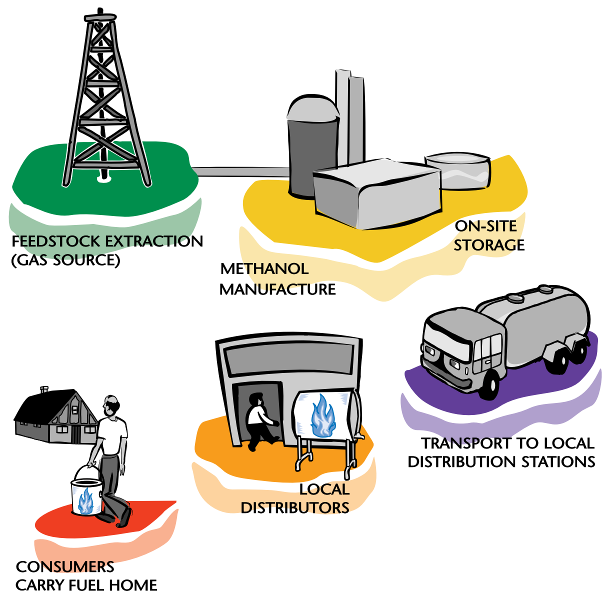

Fig. 7 When methanol is made locally.

If one looks at the CO_2 effect of burning non-replaced wood compared to life-cycle emissions for methanol, one finds that CO_2 emissions from methanol are one-sixth to one-tenth as much as from burning wood. The reduction or elimination of other greenhouse gases by burning methanol in place of wood is even more dramatic. A wood-burning stove produces, in addition to carbon dioxide, methane carbon, carbon monoxide, polyaromatic hydrocarbons and nitrous oxide. As previously noted, a methanol stove produces only carbon dioxide and water vapor. The beneficial effect of reducing the production of greenhouse gases is obvious.

What will it take to get started using methanol to replace fuel wood? In any given market area, the use of a new stove and a new fuel will need to be encouraged with a demonstration or pilot program of perhaps up to 1,000 stoves placed in households in selected communities to allow people to become familiar with them. This phase will have to be subsidized at a cost on the order of tens of thousands to several hundred thousands of dollars, depending on how large the program is, for a year-long pilot study. Credits for the sale of stoves and fuel at subsidized prices (representative of commercial prices after scale-up, when full economies of scale can be achieved) would offset or reduce these costs. The next step would be to assist local entrepreneurs to collaborate with the stove manufacturer and fuel manufacturer or importer to distribute both stove and fuel. The distribution of fuel can and should be in local hands. In some cases, fuel distribution could be accomplished through community cooperatives.

Because methanol is toxic and must not be ingested, the methanol fuel must be clearly marked on its container as toxic and should be coloured with a dye to promote easy identification. A standard colour should be selected for this purpose. Highly effective dyes exist that will colour methanol at a thousandth of a percent by volume. The methanol should also be denatured, preferably with both a smelling and a tasting agent, to render it unpalatable. A standard tasting agent in wide use for just this purpose is Bitrex™ (Denatonium Benzoate NF). This tasting agent is extremely bitter and is very effective in parts per million. Not only will it render a liquid bad tasting, but also it will make it physically intolerable to hold in the mouth. It is in wide use in household products, such as cleaning fluids. A feasible smelling agent is

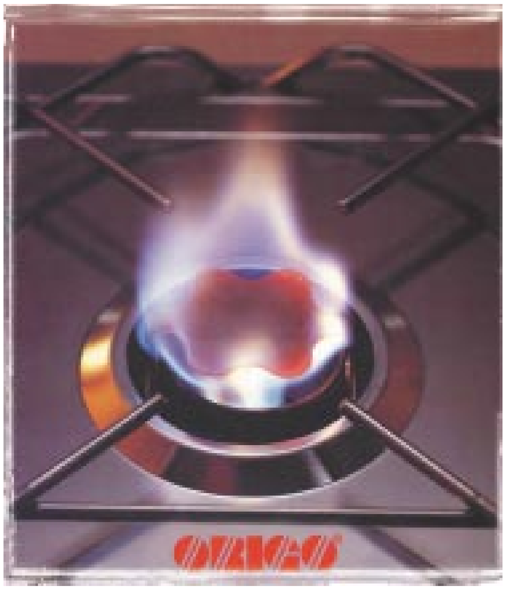

Fig. 8 The ORIGO® burner with blue methanol flame.

methylamine, which will give an unpleasant smell to the liquid methanol, but when the methanol burns, the methylamine will burn cleanly without smell. It also has the added advantage of adding some orange colour to methanol's blue flame (Fig. 8).

Methanol distribution in the modern world resembles the distribution of crude-oil–based petroleum products. In the latter case, however, crude oil is brought close to the market and then refined into products for local distribution, while in the case of methanol, the "refining" (manufacturing) is accomplished at the source of the gas, which is also the source of crude oil, since most gas is "associated." The methanol is then brought in bulk to the local terminal, which is analogous to the petroleum products terminal at the refinery. In each case there is one large, bulk step involving ships of somewhat comparable sizes (Fig. 6).

Imported methanol thus comes by ship to ocean-side terminals. Railroad tank cars or tank trucks will take it inland, depending upon distance and the availability of railroads and roads relative to the market. For fuel distribution, it would be denatured at the terminal and transported directly to the retailer if possible, in an effort to eliminate the need for the middleman. Consumers would transport the denatured methanol fuel themselves from retail dealer to home in easily carried, reusable 5-litre plastic containers weighing, full, about 4 kg (Fig. 7). This is, of course, similar to the way in which kerosene has traditionally been distributed in many countries. Historically, a great benefit of kerosene has been that it can be transported by donkey, by ox-cart or in the same fashion that fuel wood is transported. This is less true for LPG or any pressurized, gaseous fuel because of the limiting effect of the weight of the pressure canisters. In time, 100- to 200-litre methanol tanks could be placed in villages. These tanks would be supplied by a local tank truck service. As methanol supplants the use of kerosene in a given area, it would simply take over the kerosene distribution infrastructure or recreate it.

As noted above, crude oil is delivered to the refinery and refined into kerosene, LPG and other products within tank-car or tank-truck range of the market. In the case of methanol, the plants to make the fuel will be at the gas source. In countries with an oil or gas resource, such as Bangladesh or Nigeria, small package methanol plants using cheap natural gas can be installed at the gas source as soon as a methanol stove and fuel market develops. Consequently, the whole fuel system from oil or gas well to end user will produce wealth within the country, associated gas will be "monetized," and gas flaring will be avoided. The need for hard currency to buy imported fuels will be reduced or eliminated.

In other countries, without fossil fuel resources but with ample biomass, including plantation biomass or biomass grown "on purpose," local biomass-to-methanol plants could be built soon. Critical to building such plants is the development of an adequately sized methanol stove and fuel market that can produce revenues sufficient to justify the financing of such plants. The component parts of a biomass-to-methanol plant already exist and are produced in modular, highly transportable form. Therefore, these plants could be placed far inland or wherever local biomass resources exist that are sufficient in size and reliable in their yield. A concentration of biomass waste (such as piles of sawdust and lumber-mill tailings) can supplement plantation biomass. It is important to stress that such plants will not be built on a purely speculative market. Therefore, the market must be developed first using methanol brought in from natural gas sources outside of the country, when those resources do not exist in-country.

7 Technologies for the Fuel Methanol Industry

Fortunately, we are not dealing with unproven technologies. The ORIGO® stove has been perfected over several decades of use with alcohol fuels. Small-scale methanol plants have been built and are offered commercially with guarantees by HydroChem, Inc. of Holly Springs, Georgia, which is now part of Linde AG, a world-class integrated chemical and industrial gas company. In the U. S. there is a proven Department of Energy (U. S. DOE)–sponsored technology operating to make raw synthesis gas from wood with the gas being burned now for power production. This is the Battelle duel fluid bed pyrolyser-reformer. The technology is owned and offered by FERCO of Atlanta, Georgia. The supplier of the small methanol plant, HydroChem, Inc., can readily adapt its plant to this gas, which is already partially reformed to synthesis gas.

Another biomass gasification process of American provenance that has great promise is the BrightStar Synfuels technology, now owned by Energy Developments, Ltd. of Australia and used to gasify municipal waste for power production. It has its first commercial application in a waste-to-energy plant in Wollongong, Australia. The plant opened in February 2001.

The BrightStar process gasifies wood and other biomass by combining it with steam at high temperature and passing it very rapidly through a low-to-moderate pressure, externally heated, tubular reformer (gasifier). The hot syngas is passed through a heat recovery boiler to cool it. The inorganics in the feedstock (ash) and the small amount of carbon that is not converted to gas are removed by dry filtration. The syngas is then available for power generation and methanol synthesis.

The BrightStar process is continuous and achieves more than 99% conversion of biomass carbon to syngas without using any catalyst. A medium Btu gas is produced. The BrightStar gasifiers are modular in design and can vary in size to accommodate small to medium scale applications. A variety of biomass wastes can be gasified, including sawdust, bark/hogged fuel, sugarcane bagasse, agricultural crop residues, sewage sludge and the cellulosic fraction of municipal solid waste. The syngas produced generates very low levels of NO_X, CO and particulate emissions when combusted. A portion of the syngas can be used as fuel for the gasifiers, enabling a BrightStar plant to operate in a remote location away from the electricity grid or without need of fossil fuels.

Although these component technologies are well developed, a biomass-to-methanol plant does not exist, and the cost to produce methanol from biomass has not been established by experience. Biomass-to-methanol plants will be capital intensive, and conditions will have to be just right to justify a plant. These conditions are, first, a local supply of waste biomass at very low cost, and, second, a proven, freight-sheltered (protected from tariffs, etc.) domestic fuel market for the methanol. Niche projects will be the first to be built, but only after the methanol stove-fuel market is first proven using methanol from more conventional sources.

If there were a local market for methanol and local biomass available at low cost, engineering contractors and entrepreneurs could be found right now to build commercial plants. The Project Gaia team is looking for exactly these opportunities. If the plant needs to be a large one, for example 1000 t/day or larger, the commercial technologies of Winkler (Krupp Uhde) and Kellogg are available to gasify wood or other biomass on this scale.

In the longer range, 10, 20 or 30 years from now, when the growing and harvesting of biomass for energy is better established and cheaper relative to the then cost of fossil fuels, production of methanol from biomass will be undertaken on a larger scale, without the need for niche economic conditions or subsidies.

An important point to note about the high-temperature processing of biomass to methanol synthesis gas is that it can be accomplished without by-products other than wood ash. If such a plant is operated to make methanol and power and to recover low-temperature heat, its overall thermal efficiency can approach 70%, which is about the maximum that can be reached by natural-gas–based methanol technology (or any co-generation technology for that matter).

The other interesting technology that can be used as the first step in the manufacture of methanol is the production of biogas (two-thirds methane and one-third carbon dioxide) by anaerobic digestion of almost any kind of biomass with, of course, by-products. This biogas can readily be made into methanol, and part of the CO_2 is converted to methanol by:

$$3H_2 + CO_2 = \underset{\textit{(methanol)}}{CH_3OH} + H_2O$$

The hydrogen is the excess from methane reforming after the CO made in reforming the methane is converted to methanol.

8 Opportunities for Developing Countries

One can ask, is all this worthwhile just to replace wood as a cooking fuel? To answer, we have only to look at the need to stop forest depletion, on the one hand, and to lower CO_2 emissions, on the other. It is hard to put an exact monetary value today on either, especially on the value of arresting forest depletion. But if CO_2 credits were worth $30/t ($110/t of carbon) as some expect them potentially to be, then the yearly CO_2 credits for a family's use of methanol in place of wood would buy a stove and its methanol supply for an entire year, with money left over. The second year, with the stove purchased, more money would be left over, which could be granted to the family for other uses.

Further, if the labour in gathering wood is valued at 25 cents per hour and can be monetized with employment in local enterprises or agriculture, and 6 hours daily are required to gather wood, then the family could have its methanol supply paid for and $1.25 per day of cash income to spend on food, medicine, and wealth-generating activities.

A single family would save 5 or more tonnes of CO_2 a year. Since upwards of 2 billion people or 400 million families still cook with wood (UNDP World Energy Assessment, 2000), the possible CO_2 reduction from a 20% market penetration of the ORIGO® stove is enormous, on the order of a half-billion tonnes per year.

But methanol's use need not stop with cooking. Today, refrigerators are produced and sold that run on kerosene and propane. These refrigerators have been thoroughly tested on methanol, a fuel they can readily use. New cooling technology, best described as heat-operated refrigeration using adsorption technology, has been developed by Dometic, and can be powered by methanol. This technology will be affordable for, and adaptable to, the developing world. Methanol can fuel a suitable lantern, the heat from which can be recovered for cooking or water heating. This lantern has been developed for Project Gaia by Britelyt, Inc., a U. S. company, and is ready for commercial production. Small generator engines can run on methanol and, in time, small direct methanol fuel cells will be used to generate household electrical energy. Heat can be recovered from engines or fuel cells for the family's hot water. By introducing methanol as a domestic fuel, we are laying the groundwork for a total energy system for the household.

There is an extremely close relationship between household energy and local enterprise. In addition to having more time for work outside the home, the availability of adequate and affordable energy supplies and the right technology to use that energy in the home create the opportunity for commercial activities based on cooking, cooling and the processing and preserving of food. Other activities, such as crafts (sewing, metalworking, etc.) can flourish when there is light to see by and energy to power simple machines. Any gain that can be achieved in the household energy sector will also bring gain to the local economy.

Thus, it can be seen how a carefully selected, clean-burning fossil fuel, ultimately to be sourced from biomass, can help to lift low-income people to a much improved standard of living with significant family health benefits together with local as well as global environmental benefits. We must add to this the opportunity to create, in time, a local, self-sustaining industry based directly upon the new fuel, particularly when it is produced from biomass. Both fuel and stove, and the other appliances designed to run on methanol, will become the basis for industry built, run and sustained in the country where they are used.

The less fortunate people of the world do not benefit proportionally from the world's resources. For example, natural gas cannot reach 2 to 3 billion people today because pipelines cannot be built to them. Mother Nature and modern technology allow us to "package" and transport natural gas as methanol, so that the extensive benefits of natural gas can be distributed far and wide, not just to the more well-off people in cities and towns in the developed countries. The benefits can begin by creating opportunities for people in developing countries to replace inefficiently burned wood gathered at great labour from fast depleting forests with a safe, clean, easy-to-use fuel. These benefits can grow into what will eventually be a complete household energy system used for cooking, cooling, heating, lighting and producing electrical energy. In the end, the revegetated forests, as well as plantation biomass, can become once again the primary fuel source for people all over the world, but this time by means of efficient conversion to a clean liquid fuel, not by direct burning. Perhaps then, the widely sought after goal of energy sustainability can be achieved, at least for communities and nations whose energy requirements do not outstrip their ability to grow, harvest and process biomass.

It is for this reason that we call our project "Gaia," out of respect for the capability of natural systems to provide for the needs of humankind. We will be able to return to the forests for at least a portion of our energy providing we build the right bridges to get there. If we do not build such bridges, we will very possibly run out of energy choices, including the choice to return to nature for sustainable energy from biomass.

References & Additional Reading

The following works have been referenced in this article and are recommended as additional reading.

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