Agrienergy (Agriculture/Energy): What Does the Future Hold?

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It's a pleasure to have the opportunity of sharing some thoughts with you on the single most important problem in the world today, an opportunity, a challenge, which presents an enormous economic possibility to those countries or organizations which have the farsightedness and initiative to exploit this tremendous opportunity: **agrienergy**. Agrienergy is a composite word derived from agriculture and energy. This is a new area of science and technology which I believe has new major potential industrial possibilities for every country in the world.

Figure 1.

I (A.G. MacD) find myself to be particularly fortunate in that I have several laboratories throughout the world dedicated in my name, in addition to the two university laboratories in the United States, the University of Pennsylvania in Philadelphia, Pennsylvania and the University of Texas at Dallas in Richardson, Texas. The first and foremost in other countries is in my home country, New Zealand, the first formed MacDiarmid Institute (for Advanced Materials and Nanotechnology) in Wellington. This was followed by Jilin University in Changchun, China (the largest university in China—100,000 students) and by The MacDiarmid Institute of Innovation and Business of Embrapa, which is the agriculturally related organization of Brazil (forty research laboratories in various parts of Brazil), and also the MacDiarmid Laboratories for Polymer Research in Karnatak University in India and very much more recently the Alan MacDiarmid Energy Research Laboratory in Chonnam National University in Korea.

I might mention that I was born in New Zealand and was educated at Victoria University, which in my day was called Victory University College of the University of New Zealand. I am a New Zealand citizen and also a naturalized American citizen.

Hopefully my comments, based on some worldwide experience, may be of some use to pass on in our present discussion.

Figure 2.

Agrienergy is good for agriculture and for removing dependency on petroleum, coal, natural gas, and fossil carbonaceous fuels. It is good for farmers. Happy farmers help to produce a stable government in any country.

Figure 3.

In a somewhat lighter vein, we could call this, if we wish, "*Back to the Future*" or "*Reinventing the Wheel.*" As one can see, this energy-efficient vehicle runs on oats and on grass. Note the reminder, "Please don't step on the exhaust!" I should explain the background of Figure 3: The Amish people in Lancaster County, just a few miles from Philadelphia in the United States, originally came from a certain part of Germany. They adhere very strongly to their old religious beliefs and do not believe in electricity or automobiles. They are also extremely good farmers and very good businessmen.

Figure 4.

We have in front of us the enormous "land of opportunity" of energy, which is the new frontier to be explored by those who are sufficiently farsighted. But we must remember that with any business, including farming, one must invest money in order to make money. For example, let's imagine we have two farmers, neither of whom has very much money. Each takes some money out of the bank; one uses money to put fertilizer on his farm, the other uses the money to buy a new, very much needed truck. The neighbors of the farmer, who puts on the fertilizer, will not notice any immediate change, but the neighbors of the

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Figure 1.

farmer who has the new truck will say "John Jones must be extremely successful." In one or two years, which farmer will have the greater income? So it is also with energy—we must invest money to make money!

Figure 5.

This is one of the most remarkable photographs ever taken. It is a composite photo of the world at night taken from outer space by NASA. Just one glance at this tells us where, at the present time, we have the greatest amount of energy consumption, and presumably, to support that, the greatest amount of energy production. If we look at a similar picture, 40 to 50 years from now, it will be very different from this; there will either be many more parts of the world which are bright, indicating a greater amount of energy production and use, or there will be larger parts which are dark, indicating a reduction in energy use and production. I would like to see, in the future, that there are larger parts in the world which are bright, except for a few selected areas such as the Amazon, where we would hope the Amazon forest will remain intact for years to come. What the photo will look like 50 years from now depends on what we do today.

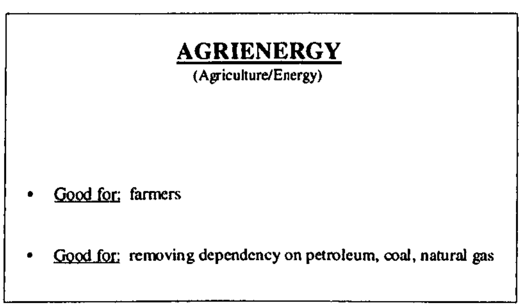

Figure 2.

Figure 3.

Figure 6.

One viewpoint of humanity's top ten problems for the next 50 years is illustrated. At the present projected rate of increase, the world's population will increase from 6.3 billion to 10 billion people. There is insufficient energy to support 10 billion people in the world of tomorrow. If we have sufficient relatively inexpensive energy, we will have more relatively inexpensive water, and if we have relatively inexpensive water, this will result in relatively more inexpensive food. For example, when flying across the barren areas of the U.S.A., one can see circular patches of bright green in arid landscapes. This is due to irrigation. We can make the deserts bloom again! If we have plenty of energy and plenty of water, which we can obtain, for example, from distillation of sea water or recovery of water (as cactus plants do in the desert) from the small amount of water in the atmosphere. If we have plenty of water, energy, and food, this will eliminate not all, but a large number, of the world's major problems today, whatever they might be:

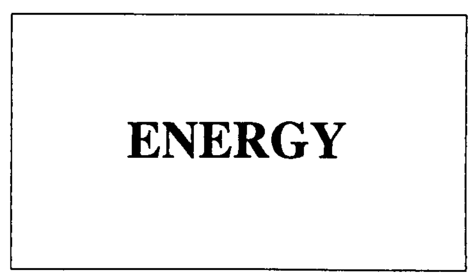

Figure 4.

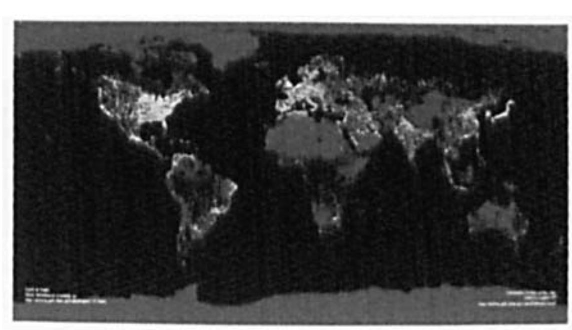

Figure 5.

Humanity's Top Ten Problems for Next 50 Years

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism & war
7. Disease
8. Education
9. Democracy
10. Population

Year 2003: 6.3 Billion People
Year 2050: 10 Billion People

Figure 6.

hunger, poverty, disease, war, terrorism, poor education, and so on.

Figure 7.

We note that the world is using more energy every day and that we are running out of energy; therefore, drastic action must be taken. The world will eventually use all of its **economically** available fossil fuels. I stress **economically** available. One can read many reports, as we all have, which suggest that we still have enormous available stores in the earth of oil, coal, and gas. Undoubtedly many of these predictions are absolutely correct in every way; but I stress **economically** available. For example, quite naturally, oil companies will first take from the earth the most economically recoverable oil. However, in order to recover the last amount of oil, one has to revert to very much more expensive methods. For example, one can imagine pumping down, into an already partly depleted rock or sand formation, water with a detergent in it and then pumping out a mixture of water, detergent, and petroleum, which then must be separated. This will be more expensive than the easily recoverable oil of today. In any case, if we continue using oil, coal, and gas, we will create major problems, because when the oil, coal, and gas are burned, carbon dioxide will be released, which will result, as far as we know, in global climate changes. It is difficult to say when

- **The world is using more energy every day**
- **We are running out of energy – drastic effects in every country!!**
- **The world will eventually use up all its economically available fossil fuels:**
  - **oil**
  - **coal**
  - **gas**

... and ... in so doing will create problems (global climate changes)

When?

Many experts believe before the end of this century*
*See for example:
"*Out of gas*", by D. Goodstein, Vice Provost and Professor of Physics, Cal. Int.Technology; Norton Co., New York, (2004)

Figure 7.

STATE OF THE UNION ADDRESS
January 31, 2006
by
George W. Bush
President of the USA

... we have a serious problem: America is addicted to oil ... The best way to break this addiction is through technology... We'll also fund additional research in cutting-edge methods of producing ethanol, not just from corn, but from wood chips and stalks, or switch grass. Our goal is to make this new kind of ethanol practical and competitive within six years... Breakthroughs on this and other new technologies will help us... to replace more than 75 percent of our (USA) oil imports from the Middle East by 2025. ... this country (USA) can dramatically improve our environment, move beyond a petroleum-based economy, and make our dependence on Middle Eastern oil a thing of the past.

... support for breakthrough technologies, such as cellulosic ethanol, an alternative fuel made from plant fibers ... (*Philadelphia Inquirer*, February 6, 2006)

Figure 8.

these effects will take place. Many experts believe it will be before the end of this century.

Figure 8.

It is interesting to note that earlier this year, President Bush of the United States, in his State of the Union message to the citizens of the United States, came out with some very remarkable statements, which were undoubtedly based on opinions of his various advisors. Just to mention a few of these, he said "We'll also find additional research in cutting-edge methods of producing ethanol, not just from corn, but from wood chips and switch grass." (A type of grass which grows very quickly in certain climatic and soil conditions.) "Our goal is to make this new kind of ethanol practical and competitive within six years. So time is running out. We can dramatically improve our [the USA's] environment and move beyond a petroleum-based economy and make our dependence on Middle Eastern oil a thing of the past." He also supported breakthrough technologies, such as cellulosic ethanol, which I will mention a little later—an alternative fuel, made from agricultural waste.

Figure 9.

We have alternative forms of renewable energy to carbonaceous materials. We have generators of electricity from wind (windmill farms) and hydroelectric (which is used extensively throughout the world); we have solar photovoltaic cells and also solar photoelectrolysis of water; geothermal (which has been developed in New Zealand for many years); making use of ocean and river currents; ocean tides; nuclear, which is a very interesting and controversial subject. It would be great if we can ever develop nuclear fusion! With nuclear fission, one of the problems is how to get rid of the radioactive byproducts which have very long radioactive half-lives. The hydrogen economy is of concern as to whether it is really renewable. We will discuss this later; it depends on how you make the hydrogen. Biofuels

ALTERNATIVE FORMS OF RENEWABLE ENERGY

- Wind
- Hydroelectric
- Solar (photo-voltaic and photo-electrolysis of water)
- Geothermal
- Ocean currents, ocean tides and rivers
- Nuclear (fusion; fission)
- Hydrogen (renewable?)
- Bio- fuels (solar power)

Many different forms will be used by different countries in the future, depending on climate, geography, soil, etc.

Figure 9.

derived from plant growing are based on solar power, sunlight absorbed by the leaves of plants, trees, etc. The important thing to remember is that in the future, many different forms of renewable energy will be used by different countries depending on the climate, geography, soil conditions and governments of the countries. I firmly believe that no **one** alternate form of renewable energy will be used in the world in the future; indeed, many different forms of alternative energy may be used in every country, depending on climate and soil conditions in different parts of the country.

Figure 10.

Economic factors are of extreme importance in looking at alternative forms of energy to fossil fuels, i.e., petroleum, coal, and natural gas. As shown, the use of alternate forms of energy depends extremely heavily on the price of oil, coal, and natural gas and on social factors such as environment, wars, terrorism, natural disasters, plagues, etc. The present cost of oil internationally is about $(US) 60/barrel; if the price of oil falls to its value of a year or so ago (~$(US) 40/barrel), there will be a decreasing stress on renewable energy. If the price of oil increases, as is highly likely, there will then be an increasing stress on renewable energy, since the higher the cost of petroleum, the more financially profitable it will be to invest in renewable, nonpolluting forms of energy. It is often stated in Brazil that the cost of driving 100 km using bioalcohol is less than driving 100 km using gasoline. If purchase of both bioalcohol and gasoline is available at a gas station, then the sales (and hence the price) will be largely determined by the consumer.

Figure 11.

It is also possible that agrienergy may be helpful in reducing drug use, crime, etc., worldwide. It would seem highly probable, if farmers currently producing drug crops find that the growing of energy crops is better economically and socially; this would be a real inducement to change from drug crops to energy crops. There are, of course, many factors involved in this, but it is an interesting possible beneficial side effect of switching to agrienergy crops.

Figure 12.

Highlighted are the real fundamental important points of involving biofuel, that is, fuel which is 100% renewable energy from plants, etc. Frequently, the very great difference between the two forms of biofuel, namely, bioalcohol and biodiesel, is confused. Bioalcohol results from a process involving fermentation, from, for example, sugarcane or

AGRIENERGY – Helpful in reducing drug use, crime, *etc* world-wide.

If farmers presently producing drug crops should find that the growing of energy crops is better for them economically and socially, there is a real inducement to change drug crops to energy crops.

Figure 11.

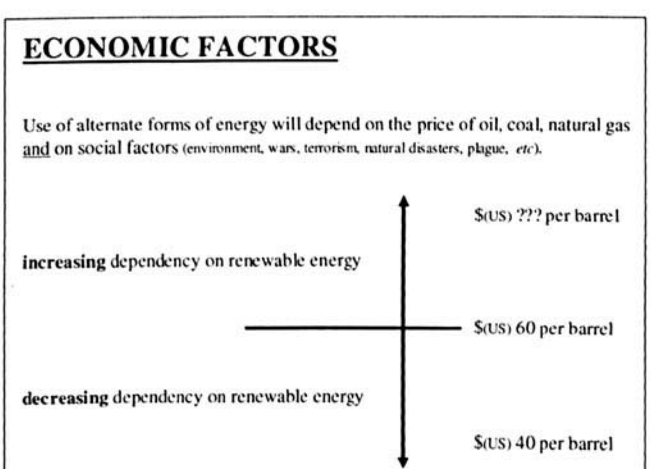

Figure 10.

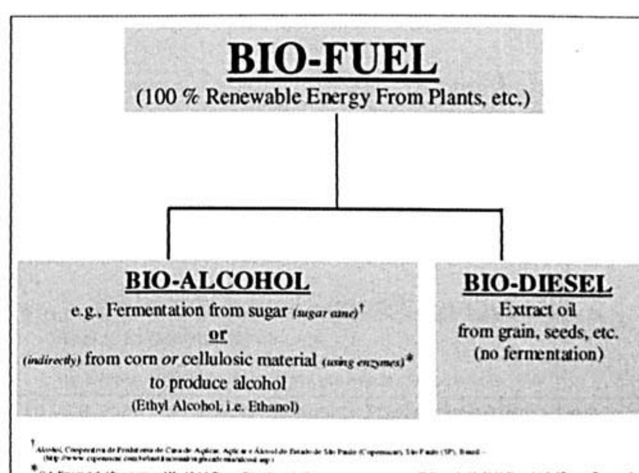

Figure 12.

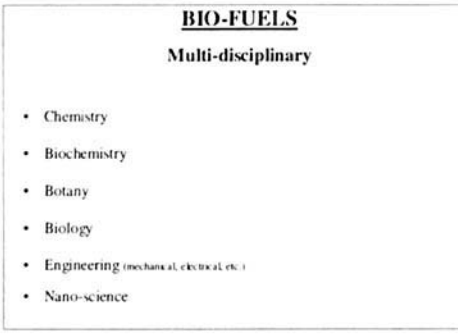

Figure 13.

corn; we hope in the future that more bioalcohol will be made using cellulosic materials, which we will discuss later. Ethyl alcohol, ethanol, and bioalcohol, in our discussions, are synonymous terms. Biodiesel is completely different from bioalcohol in that no fermentation process is necessary. Biodiesel is obtainable by extracting oil from grain, seeds, etc. This will be discussed later.

Figure 13.

Working with biofuels involves a multidisciplinary area of scientific and technological study. It is very widely based; it involves chemistry, biochemistry, botany, and bioengineering in various forms—mechanical, electrical, and so on—and it also involves nanoscience in certain various important ways to be discussed later.

Figure 14.

Biofuels are an excellent substitute for petroleum. As we know, petroleum is also a very special and useful source

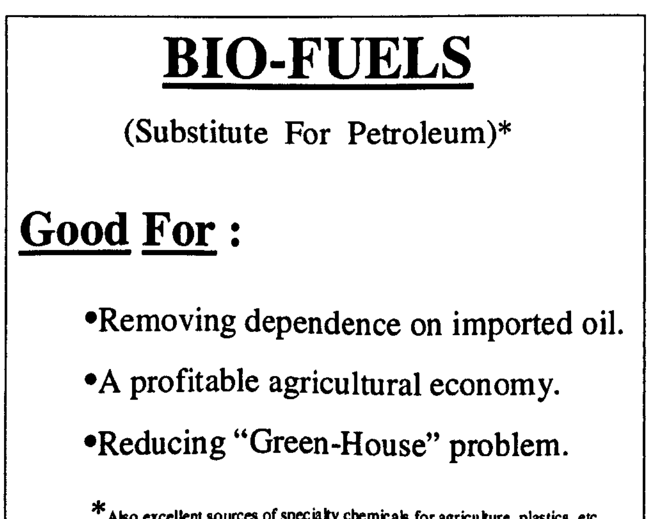

Figure 14.

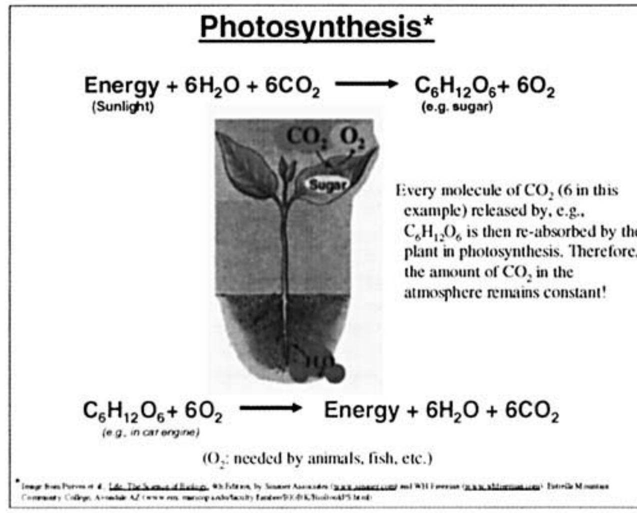

Figure 15.

for specialty chemicals for agriculture, plastics, medicine, and so on. Biofuels also have the potential for being a very rich source for these same specialty chemicals. And biofuels, of course, are good for removing dependency on imported petroleum, and at the same time present a very potentially profitable area for agriculture as well as reducing the "greenhouse problem" which results from the worldwide production of carbon dioxide from the use of fossil fuels such as petroleum, coal, and natural gas. As we know, the "greenhouse effect" is caused primarily by carbon dioxide.

Figure 15.

Photosynthesis is the essential basis of biofuels. It involves several fundamental concepts involving energy (in the form of sunlight falling on the leaves of plants), plus water from the soil, plus carbon dioxide from the atmosphere, which is then converted to various types of organic substances, such as sugar, which is then stored in the leaves and the stems of plants and the wood of trees. At the same time, oxygen is liberated. In other words, we now simultaneously supply oxygen, which is needed by animals and fish. It is very important to remember that when we take substances produced in plants and trees and burn them, or cause them to react with the oxygen in the air by fuel cells, we'll get energy as well as carbon dioxide. The amount of carbon dioxide that is liberated by using the bioderived fuel is equal to the amount of carbon dioxide which is removed from the atmosphere by the photosynthetic process. Therefore, we have a completely closed cycle in which no "new" carbon dioxide is added to the atmosphere and the carbon dioxide is constantly removed from the atmosphere and is converted into material in plants. We must remind ourselves that oil, coal, and natural gas are derived from forests that lived on the face of the earth several million years ago. When we burn such materials we are converting the carbon

Farms For:

- **Food**
  [We no longer hunt in the forests for animals, plants and fruit.]
- **Fuel**
  [Now, not necessary to hunt for fossil fuel buried in the forests of several million years ago.]

Figure 16.

in these materials to carbon dioxide. This is carbon dioxide that had been removed by plants millions of years ago. When this "new" carbon dioxide is added to the atmosphere, there is no comparable process to remove every molecule produced by using fossil fuels. There are insufficient plants and trees in the world today to constantly remove the carbon dioxide produced from the fossil forests of several million years ago!

Figure 16.

"Farms for Food." In the past, mankind needed to hunt haphazardly for plants and animals and berries in order to eat. Now we have become more civilized. We breed our animals and cultivate plants. There is today no need to "hunt" (explore) for fuel derived from forests buried millions of years ago. We can now make use of our new technologies and grow our fuel, just as we are growing our food today.

Figure 17.

We find that Brazil has been, and indeed still is, the world leader in developing biofuels and also their use in automobiles such as Flex cars, which run either on bioalcohol or on gasoline. We will talk more about this later. The world is catching up fast—very fast. The question is: will another country overtake Brazil and become the world leader in the biofuel area? And, if so, which country will this be?

Bio-Fuels

Brazil has been, and still is, the world leader in developing bio-fuels and their use in automobiles (eg. "Flex" cars)

But

The world is catching up! Fast!

- Will other countries overtake Brazil and become the world leader in the bio-fuel area?

Figure 17.

Other countries are rapidly developing wood, paper waste, switch grass, etc. as a source for their bio-alcohol.

- Who will be the world leader in this field?
- Who will be a follower?

Figure 18.

Figure 18.

Where do we stand today? Other countries are rapidly developing wood, paper waste, for example, and other crops such as switch grass, etc., as sources for biofuels. We ask ourselves, "Who will be the world leader in this field in the future and who will be the follower?" Undoubtedly some country and farsighted individuals will see the enormous economic benefits to be derived from being the leader in this field. Other countries and organizations will be content with being followers. What is going to happen?

Figure 19.

We stress that today Brazil leads the world. Brazil represents a great success story. Brazil's national alcohol program dates back to 1975, when the Brazilian government first introduced the policy as a measure to reduce its dependence on petrol imports and enable the country to produce renewable and environmentally friendly energy. From 1985 to 1990, nearly 90% of all automobiles manufactured in Brazil were powered by ethanol. That's an amazing figure. To date, more than 6 million ethanol and flexible fuel vehicles have been manufactured in Brazil. So Brazil is certainly the leader in producing and economically using biofuels and producing vehicles operating on these fuels. By Flex vehicles, we mean cars that can run either on pure ethanol or gasoline. The term "gasoline," as used in

TODAY, BRAZIL LEADS THE WORLD

Brazil represents a great success story, as the country's National Alcohol Program dates back to 1975, when the Brazilian government first introduced the policy as a measure to reduce its dependence on petrol imports and enable the country to produce renewable and environmentally friendly energy.

From 1985 to 1990, around 90% of all automobiles manufactured in Brazil were powered by ethanol.

To date, more than 6 million ethanol and flexible fuel vehicles have been manufactured in Brazil.*

* Ford Motor Company, USA, May 10, 2005. (http://media.ford.com/print_doc.cfm?article_id=20825)

Figure 19.

Brazil, actually refers to a mixture of 78% gasoline and 22% bioalcohol. You can drive into a gas station, as I have done many times in Brazil, and can buy bioethanol or gasoline. There are sensors in the engines and gas tanks of cars which determine the relative amount of bioethanol and gasoline in the gas tank and adjust the engine accordingly. Brazil has led and is leading the world at the present time. The question is, who will be the future leaders of the world?

Figure 20.

We highlight a statement by the Ford Motor Company from their web site in 2005. We can see that Ford is strengthening its leadership in bioethanol cars in Europe for producing environmentally advanced bioethanol powered vehicles, including Flexi-fuel cars in France, with similar pilot projects underway in the United Kingdom, Ireland, and Spain. Flexi-fuel has also been available for retail purchase in Germany since August 2005. Indeed, 40% of all Ford sales in Europe are Flexi-fuel vehicles. Other European countries are expected to follow. As stated by Ford, "The future belongs to those who have the guts, the grit and the new ideas to get there first. In many ways, innovation is the very essence of the American spirit. Increasingly, innovation will define and distinguish Ford in the marketplace as we make it the compass that directs our decision-asking and leads our company into the future." We should remind ourselves that Ford very wisely saw the economic advantage in pursuing this direction and building on what had been worked out in Brazil during the last thirty years or so.

Figure 21.

This same thought is again shown in a statement by Bill Ford of the Ford Motor Company, viz., "Starting next year (2006) we will have the same number of vehicles (1/4 of a million) that will be ethanol capable. You can have them running on gasoline, ethanol, or other biofuels. We will be getting this country to be less dependent on foreign oil." Shown are two advertisement pictures taken from television in Philadelphia a few months ago.

Ford Strengthens Leadership in Bio-Ethanol Cars for Europe

- Ford strengthens its leadership position as producer of environmentally advanced bio-ethanol-powered vehicles in Europe
- New Focus Flexi-Fuel and Focus C-MAX Flexi-Fuel ready for market introduction in France
- Multi-stakeholder pilot projects underway in the UK, Ireland and Spain
- Focus and Focus C-MAX Flexi-Fuel also available as retail purchase in Germany since August 2005
- 40 percent of all Ford sales in Sweden are Flexi-Fuel vehicles (FFVs)
- Other European markets expected to follow

"Driving American Innovation, the theme of the campaign, reflects our belief that the future belongs to those who have the guts, the grit and the new ideas to get there first," says Mark Fields, Ford Motor Company executive vice president. *"In many ways, innovation is the very essence of the American spirit. Increasingly, innovation will define and distinguish Ford in the marketplace as we make it the compass that steers our decision-asking and leads our company into the future."* *

* Ford Motor Company, USA, October 20, 2005. (http://media.ford.com/print_doc.cfm?article_id=21846)

Figure 20.

Figure 21.

Figure 22.

We might recall that Dick Branson is a private entrepreneur who sees further into the future than many of us. He was the person who started the new transatlantic airline between North America and Europe, Virgin Airlines. As we can see, at the end of the year 2005 he stated that he was tired of skyrocketing jet fuel prices and that he plans to turn his back on hydrocarbons and use plant waste to power his fleet. He now has four different airlines of about 100 planes. "We are looking for alternate fuel sources. We plan to start building cellulosic alcohol factories to make fuel that is derived from waste products of plants." (I will shortly discuss cellulosic bioalcohol.) "It is 100 percent environmentally friendly and I believe it's the future of fuel." Branson believes that in the next 20 or 30 years it will replace conventional fuels. He thinks that cellulosic ethanol (which is the byproduct you get from the waste product of plants) and the bits left in the field that get burned up may be a key thing. Using organic waste, or biomass, could be essentially cheaper than using corn or sugar by fermentation processes, since such waste is not a primary product but

Virgin Airways boss eyes plants for fleet fuel

Branson: 'I believe it's the future' and can replace fossil fuel in 30 years

DUBAI, United Arab Emirates - Tired of skyrocketing jet fuel prices, Virgin Atlantic Airways boss Richard Branson said on Wednesday he plans to turn his back on hydrocarbons and use plant waste to power his fleet.

"We are looking for alternative fuel sources. We are going to start building cellulosic ethanol plants (to make) fuel that is derived from the waste product of the plant," he told Reuters in an interview.

"It is 100 percent environmentally friendly and I believe it's the future of fuel, and over the next 20 or 30 years I think it actually will replace the conventional fuel that you get out of the ground."

He said cellulosic ethanol "is the byproduct you get from the waste product (of plants), the bits in the field that get burned up," as opposed to traditional ethanol, which is produced mainly from corn or sugar cane.

Using organic waste, or biomass, could be substantially cheaper than corn or sugar cane since that waste is not a primary product but simply residue from other agriculture or logging.

The ethanol idea is part of Branson's broader plans to cut Virgin's fuel bill. In September, he said he was looking at building a conventional oil refinery in a bid to ease a global shortage of refined fuel, including jet fuel.

The company operates four airlines with almost 100 aircraft.

"We use around 700 million gallons of fuel a year between the four airlines," Branson said. "I hope that over the next five to six years we can replace some or all of that" with plant-based ethanol.

Figure 22.

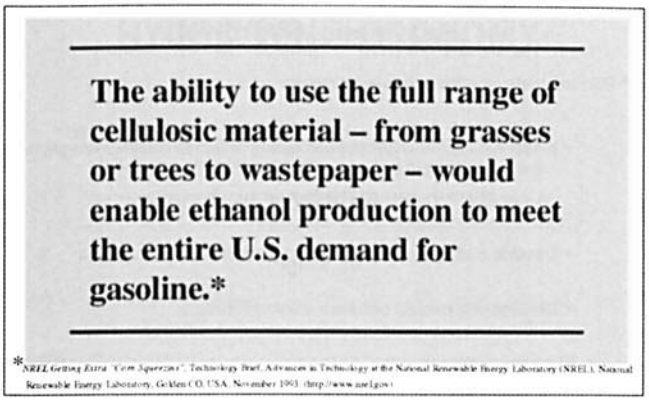

Figure 23.

simply a residue from agriculture or logging. Branson's goal is to cut his airline fuel bill. He is considering building a conventional oil refinery in order to ease global shortage of flying fuel, including jet fuel. Here we have a private entrepreneur who has already shown that his pioneering concepts have paid off. Remember, Brazil already has an airplane flying on biodiesel fuel. The question is: is there another organization or another country or a combination of countries that can think in a similar way into the future?

Figure 23.

The United States Department of Energy report is rather mind-boggling. "The ability to use the full range of cellulosic material, from grasses or trees to waste paper would enable ethanol production to meet the entire US demand for gasoline"! Ah! Food for thought: are they right, are they wrong, or partly right and partly wrong? Who is going to find out?

Figure 24.

Figure 24 repeats Figure 12. Going back to biofuel, we have up to this point been discussing bioalcohol; now we want to turn to the other chief type of biofuel, that is, biodiesel.

Figure 25.

We list a few examples of various types of seeds and grain which contain large amounts of oil and from which oil can be extracted by simple processes to give what is called "biodiesel oil". One can see by looking at the list that, for example, castor beans are 50% by weight castor oil. If we run down the list to soya beans, these types of beans can grow in a variety of different types of environments, climate-wise and soil-wise. This is highlighted graphically in Figure 26. What happens after we squeeze out, for example, 10% of the oil from soya beans? We are left with 90% of the material. At the present time, this "waste" material is used in feeding cattle or feeding chickens; it is not a value-added part of the crop. However, as we will

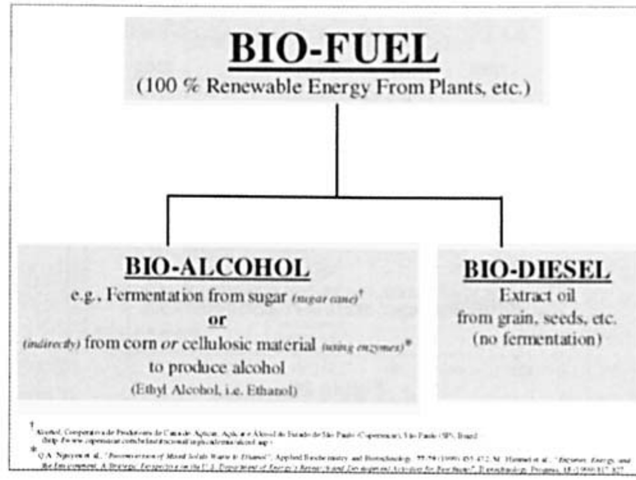

Figure 24.

show later, by using cellulosic methods, it is possible to convert this "waste" product to a very valuable part of the crop to make bioethanol.

Figure 26.

This is extremely important. Brazil is, today, the second largest world producer of soya bean. The United States is the world's largest producer. However, this has not always been the case. In Brazil, as you can see, in 1960 relatively small parts of the country were used to produce soya bean. This area increased very greatly, as one can see, to 2002. Why is this? Brazil has developed, by careful agricultural selection 396 different varieties of soya bean which can grow in very different climatic and soil conditions. These soya beans can convert nitrogen from the air into useful organic nitrogen-containing fertilizers; they also have particular resistance to pests and disease. The very interesting question arises: of the various types of biograin that can produce biodiesel, can we find adaptive types of grain and seed that will grow in climatic and soil conditions that today are not able to grow such materials? We have some very interesting agricultural challenges facing us. Just

Selected Examples of Bio-Diesel Sources

Brazilian grains potential

Grain types	Oil content† (wt. %)	Productivity (kg/ha.year)*	Bio-diesel production (kg/ha.year)
Castor bean	50	1,500	750
Sunflower	42	1,600	672
Peanut	39	1,800	702
Sesame	39	1,000	390
Canola	38	1,800	684
Palm	20	10,000	2,000
Soybean	10	2,200	396
Cotton	15	1,800	270
Babassu (Braz. Palm)	16	12,000	720

* 1 hectare = 10,000 m^2 = 2.47 acres

† Convert cellulosic material (remaining after oil extraction) to bio-ethanol

Figure 25.

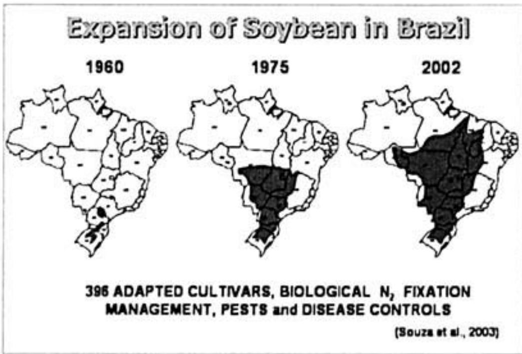

Figure 26.

from the somewhat humorous side, we can ask ourselves, what is New Zealand's best, easiest, most prolific crop? It is gorse! Gorse grows just about everywhere, and it is very hardy. A silly question arises: could New Zealand exploit the country's gorse-growing capabilities and convert gorse into bioalcohol by methods we will show?

Figure 27.

Let's take a closer look at cellulosic materials. The vast bulk of plant material consists of cellulosic materials. We need to develop further biomass technology, which has already reached a certain degree of sophisticated advancement. Biorefineries that produce an array of valuable chemicals and products together with bulk biofuels? It is desirable to lower the cost of the known technology which breaks cellulose and hemi-cellulose down into their component sugars using enzymatic methods. Fermentation methods are then used to convert the sugars into bioalcohol.

Figure 28.

We look at enzymatic hydrolysis—I stress that this is a known method; it is already being done. It needs further work in order to bring it into a commercial stage. It is desirable to reduce the cost of using cellulose enzymes. At the present time, an additional cost of enzyme treatment of cellulosic material ranges from about 8 to 13 cents (U.S. dollars) per liter of ethanol produced. In other words, if we make bioethanol from cellulosic materials, at the present time this adds an additional 8 to 13 cents per liter. The objective is to bring this additional cost of using cellulosic material down to about 1.3 cents per liter to the cost of the ethanol. We must develop industries to produce these results and to engineer appropriate cellulosic enzymatic processes. Who is going to be the leader in doing this?

Figure 29.

Considerable work has already been done on cellulosic materials processing. I will not go into this in detail except to point out that if using waste from the timber industry or agricultural waste, it is first necessary to grind down the starting material, to make it smaller so that it will react more

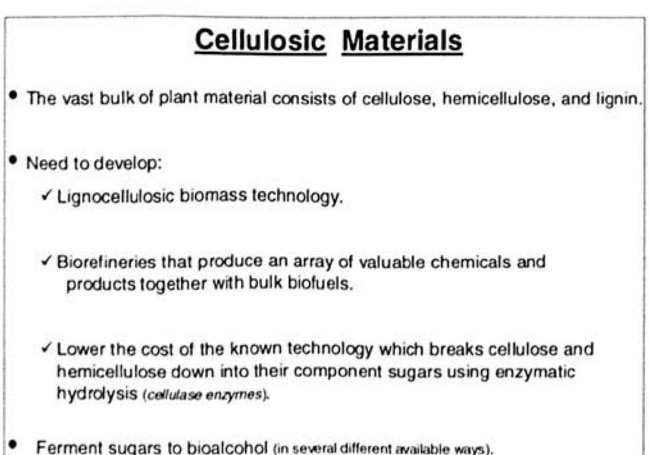

Figure 27.

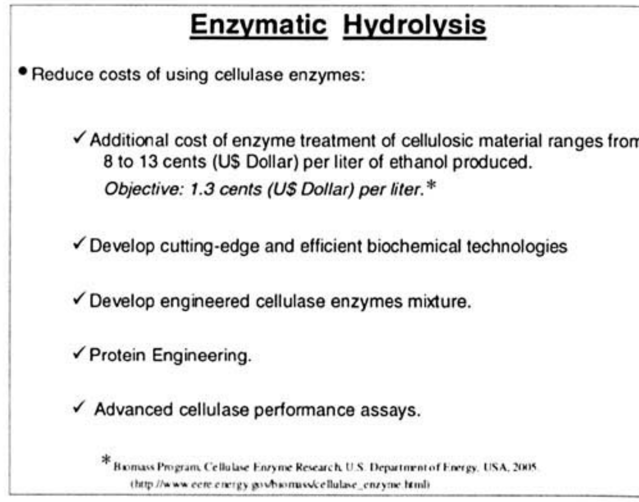

Figure 28.

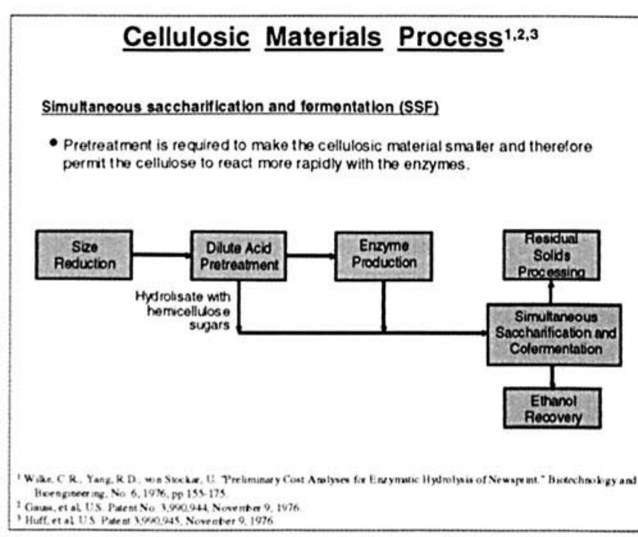

Figure 29.

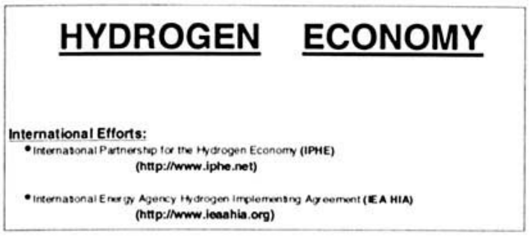

Figure 30.

readily. Some company, organization, or country will jump on this in the future, hopefully very soon.

Figure 30.

We turn to the hydrogen economy. The hydrogen economy was supported very strongly by U.S. President Bush in his State of the Union message, 2003. The hydrogen economy has developed into a worldwide scientific technology challenge. A few months ago, I was at an international meeting on the hydrogen economy in Italy. It had representatives from many countries. The basic concept is that automobiles of the future will be run just by hydrogen gas, stored in one way or another in the car, using fuel cells that combine the hydrogen and oxygen (from the air) to produce electricity. The only substance that would come out of the tailpipe of the automobile, therefore, would be water vapor. This approach would reduce air pollution very greatly in cities. But the unanswered question is: "Where does the hydrogen come from?" Does the hydrogen come from a carbon dioxide polluting process? Or does it come from a (biomass) source?

Figure 31.

This figure gives various methods of producing hydrogen gas. The most profitable and the most promising method at the present time is to combine natural gas, coal, or petroleum, or even gasoline, with water to produce hydrogen. Such methods will produce unwanted carbon dioxide, since they use carbonaceous starting materials. However, we ourselves are actually working on the use of bioethanol to

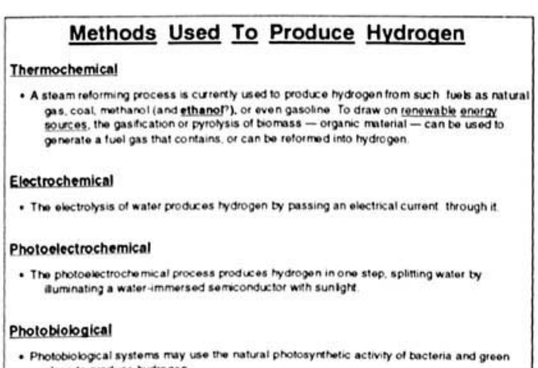

Figure 31.

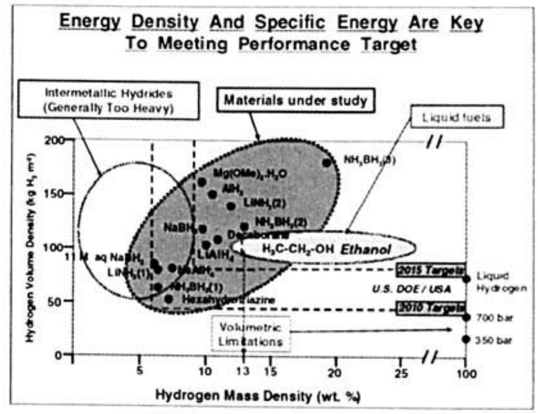

Figure 32.

combine with water as starting materials. The CO_2 produced goes into the atmosphere, but it came from the air originally, since it is bioalcohol. The hydrogen economy could, depending on how the hydrogen is produced, be an excellent useful future method for pollution-free transportation.

Figure 32.

This figure summarizes the properties of different hydrogen storage materials. This figure was actually presented at the World Hydrogen Conference in Lucca, Italy in June 2005. It can be seen that ethanol is considered, from both its hydrogen volumetric and its gravimetric density, to be a very interesting serious source of transportable biofuel. Indeed, its properties at the moment exceed the properties set by the International Hydrogen Economy as their target for the year of 2015. We are also working actively in this area to find cheap, convenient, clean methods for converting bioethanol to electricity for use in movable vehicles.

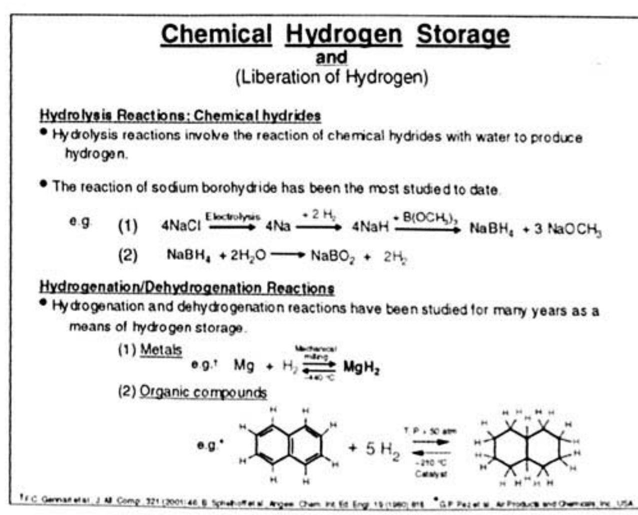

Figure 33.

Figure 33.

A variety of chemical methods being studied are summarized for storing hydrogen in solid or liquid materials in a moving vehicle. I will not go into a discussion of these various methods here, except to point out that metal/hydrogen compounds are being studied intensively, and also hydrogenation/dehydrogenation reactions involving metals or selected organic compounds. Of course, the key question that must always be answered is: where does the starting material that you put into the automobile or truck come from? How is this starting material made; what is the cost; and what is the effect, if any, on polluting the atmosphere?

Figure 34.

The fuel cell area is an extremely important area in which increasing work is being done worldwide. Of particular interest is how we can convert bioalcohol and biodiesel directly into electrical energy by reacting them only with the oxygen in air. In general, fuel cells work best when the electroactive material and/or catalyst is very small, for example, in the nano- or microsize range. My prediction is that in the future automobiles will be powered by electricity obtained from fuel cells using only air and bioalcohol or biodiesel. As we all know, a few decades ago mechanical watches had reached a very high degree of perfection. They were masterpieces of micromachinery. Then along came liquid-crystal, battery-operated watches, and immediately the market gave way to cheap liquid-crystal-display, battery-operated watches. In my opinion, the same thing will happen to automobiles. At the beginning of the 21st century, we have developed automobiles throughout the world which are absolute masterpieces of highly tuned mechanical reciprocating engines. We will have a rapid change from mechanical reciprocating engines to electric motors. The electric motors will be driven by fuel cells in which we use air as one component of the fuel and a bioalcohol or a biodiesel as the other component. These will run on nonpolluting renewable energy-saving sources such as bioalcohol and biodiesel.

Figure 35.

This illustrates the basic thermodynamics of an air/organic compound fuel cell. "Any substance which burns in air is thermodynamically unstable in air"; that is, thermodynamically it wants to change to carbon dioxide and, for exampe, water and energy. For example, if we use oxygen from the air and hydrogen, as in the hydrogen economy, then what is consumed goes to water and some sort of energy: heat, light, or electricity. In a fuel cell most of the energy given out is in the form of electricity. Many of us are looking at the same thing with bioalcohol, for example, alcohol will certainly burn in air, giving out heat and light. What we are working on is to find out how the alcohol can be coaxed to react with air in a fuel cell, giving out most of the energy in the form of electricity. More work will be done in the future throughout the world on fuel cells.

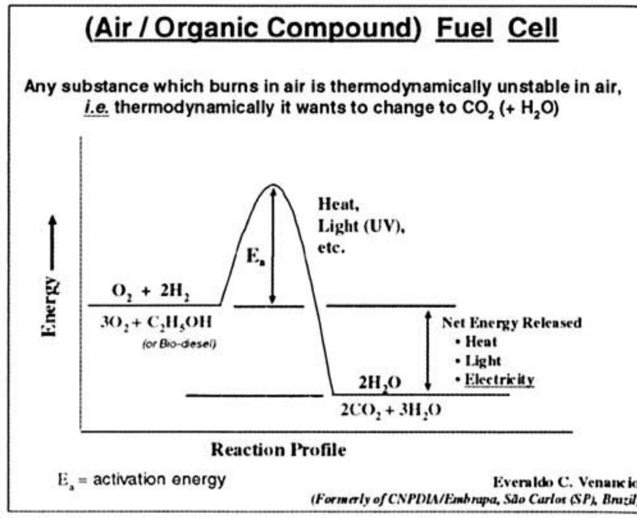

Figure 35.

Figure 36.

What we need very badly at this time is a "crash program" similar to the space exploration programs now being carried out in many countries. Such a program would not have different organizations and different countries in competition with each other, but would proceed by partnership between different countries, different businesses, different agricultures, different petroleum companies, different electric companies, different governments, and different universities. This would result in the mutual commercial benefit of each organization. It is much better to

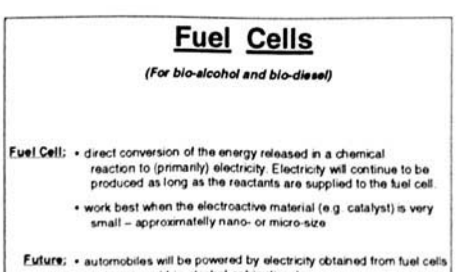

Figure 34.

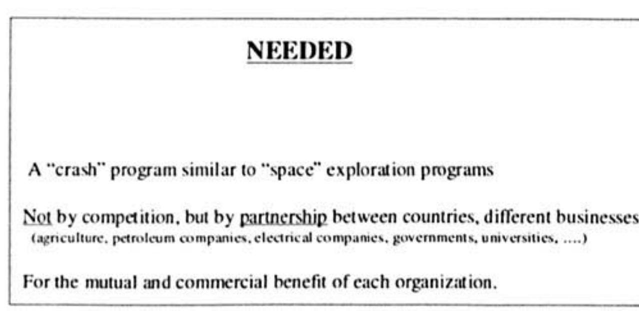

Figure 36.

Summary

- Brazil has been, and still is, the world leader in renewable energy e.g., bio-ethanol and bio-diesel (and "Flex" cars).
- But, the world is rapidly catching up!
- Therefore, Brazil must always keep one step ahead of the world!
- What country will take the leadership role away from Brazil?
- How will this be done?
  - ✓Develop the best and least expensive science/technology for converting cellulostic materials to bio-alcohol.
  - ✓Develop bio-diesel from seeds and grains which can be grown in different climates and soils in various parts of the world (***good*** for farmers and ***good*** for independence from imported petroleum and ***good*** for new materials for chemical industry – pharmacological, plastics, etc. – and ***good*** for reducing greenhouse problems).
  - ✓ Develop efficient and inexpensive methods for converting bio-alcohol and bio-diesel to gaseous hydrogen (for hydrogen economy) and for developing air/bio-ethanol and air/bio-diesel fuel cells.

Figure 37.

become involved in partnerships rather than in competition. How do we go about this?

Figure 37.

In summary, Brazil has been and still is the world leader in renewable energy and in Flex cars. But the world is catching up. Therefore, Brazil must always keep one step ahead if it is going to continue to be the world leader. What country will take the leadership role away from Brazil, and how will this be done? One must develop the best and least expensive science and technology for converting cellulosic material to bioalcohol and develop biodiesel from seeds and grains which can be grown in different climates and soils in various parts of the world. To stress again, this is good for farmers and good for independence from imported petroleum. It is also good for new materials for the chemical industry, such as the pharmacological and plastics industries, and it is very good for reducing global warming and associated climate-change problems. We must develop efficient and inexpensive methods for converting bioalcohol and biodiesel to gaseous hydrogen for the hydrogen economy and for developing air-bioethanol and biodiesel fuel cells. Some interesting challenges—but the technologies are already being developed. Some of these, first developed in Brazil, are being exploited in other parts of the world today. Also, there are new emerging technologies. We will see who will be the leader in these areas.

Figure 38.

As a reminder to ourselves, science and technology "is people." New laboratories and beautiful buildings do not create new science and new technologies. It is the people inside the buildings who do the creating. We must bear this in mind when we proceed into this new economically, scientifically, technologically, and sociologically challenging part of the 21st century.

SCIENCE IS PEOPLE

Figure 38.

Figure 39.

I summarize a proposed, very specific plan of action; I will go over each of these points individually in order to stress their importance. We need to have, in some part of the world, a working meeting—not a meeting where we sit back and discuss things very pleasantly and then go back home to our respective organizations on Monday morning and do exactly what we had been doing before the meeting. We must ask ourselves, "What will we do differently on Monday because of the meeting?" Needed is a small number of enthusiastic expert persons from various organizations and countries who want to develop an immediate specific plan, which would be of much benefit economically. It is very important NOT to "reinvent the wheel"; firstly, we should find out what has already been done worldwide and to advance from that point. We must go into any future study with complete knowledge as to what has been done before. And we must develop agricultural exploitation of alternate energy crops, such as switch grass, certain fast-growing trees and bushes for conversion to bioalcohol and for biodiesel, and conversion of cellulosic material from wood waste, agricultural waste to bioethanol. Let's also not forget to discuss the disadvantages of biofuels, corrosion of automobile engines and pipelines using bioalcohol, and the status of worldwide development of ethanol and air fuel cells. We want to take into account also the financial risks and advantages for "payback" time for certain projects (the time we start to get money/profits from a given project). Partnership is much better than competition: partnership with agricultural industries, conventional petroleum companies, transportation industries,

PROPOSED SPECIFIC PLAN OF ACTION

(1) A working meeting involving a small number of expert persons from the USA, Brazil, New Zealand and other possibly interested countries, *e.g.* Korea, India, Indonesia, Malaysia, *etc* who want to develop an immediate specific plan.

(2) Let's not "rediscover the wheel"! First find out what has already been done world-wide and advance from that point.

(3) Agricultural exploitation of alternate energy crops, such as switch grass, certain fast-growing trees, *etc.* for conversion to bio-alcohol and bio-diesel.

(4) Conversion of cellulosic material from wood waste material, agricultural cellulose material to bio-ethanol.

(5) Disadvantages of bio-fuels *eg*, corrosion of automobile engines and pipe-lines related to bio-alcohol.

(6) The status of world-wide development of bio-ethanol/air fuel cells.

(7) Financial risks and advantages for "pay-back" time for certain projects.

(8) Partnership with agricultural industries, conventional petroleum companies, transportation industries, airlines, (e.g. [illegible] airlines), trucking, railroad, etc.

(9) Use of bio-ethanol as an excellent source of gaseous hydrogen for the Hydrogen Economy.

Figure 39.

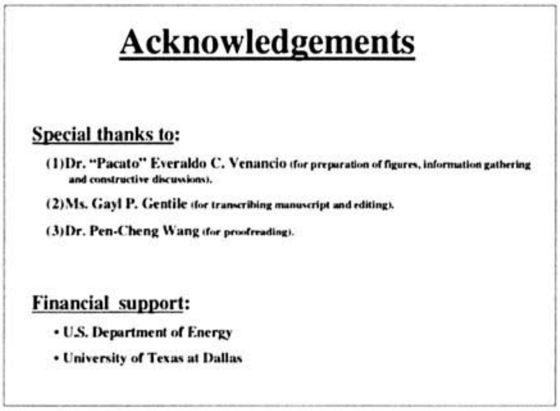

Figure 40.

airlines (not forgetting, for example, Branson-owned airlines), trucking companies, railroads, etc. The use of bioethanol is an excellent potential source of gaseous hydrogen, for the hydrogen economy.

Every country, large or small, at this very moment in time has a magnificent opportunity to scientifically, technologically, and economically exploit these concepts to improve the world and its many people and to become a world leader as we enter the beginning of this scientifically/technologically oriented 21st century.

Figure 40.

I wish to give my special thanks to those who helped in preparing this manuscript.

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