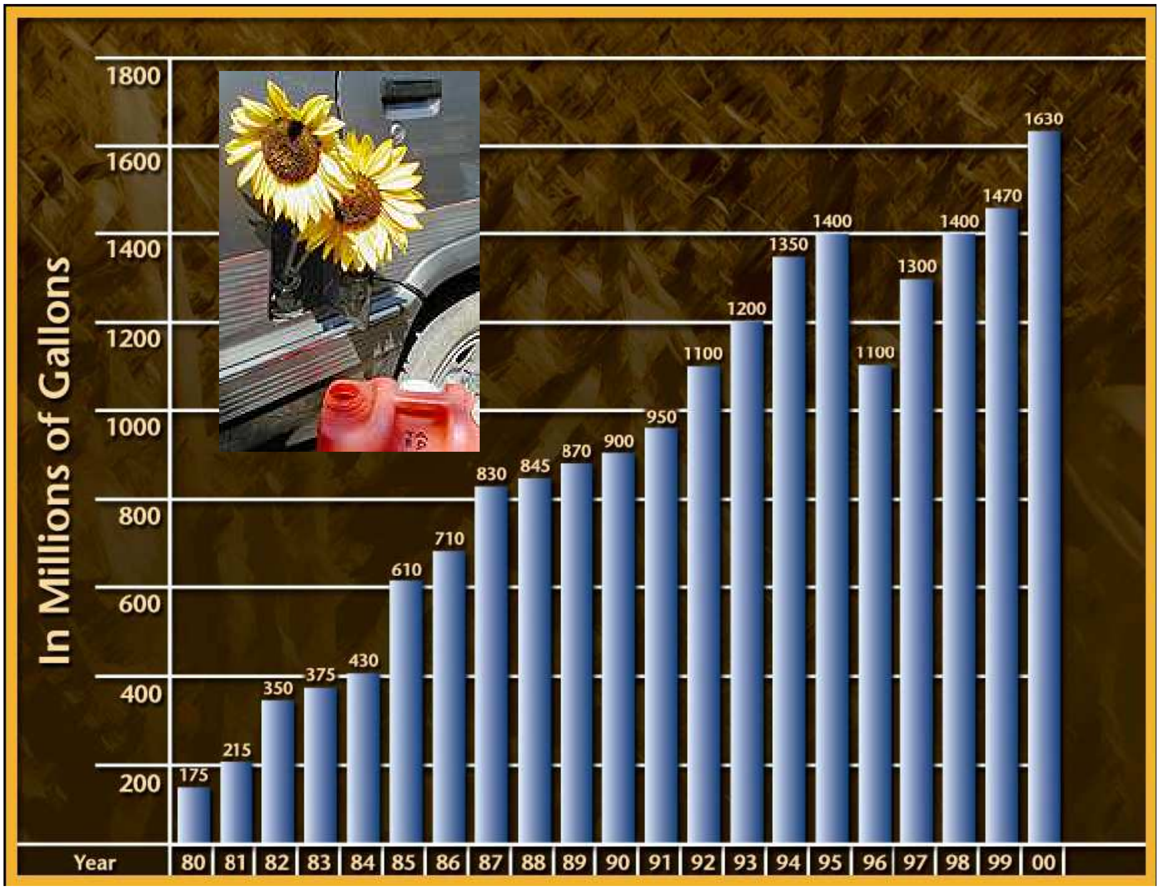
The Future of Bio-fuels: A Blend of Hope and Concerns

by

Richard S. Courtney



Growth in U.S. fuel ethanol production.
source: Energy Information Administration/
Renewable Fuels Association

The Center for Science and Public Policy
Washington, D.C.
Robert Ferguson, Exc. Dir.
202-454-5249
http://www.scienceandpolicy.org
bferguson@ff.org

August, 2006

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Synopsis

Biomass is biological material used as fuel, and biofuel is biomass that has been converted into a form that makes it useful as a displacement for a fossil fuel; for example, petroleum. Biomass is solar energy collected by photosynthesis over a small area and a few growing seasons in plants that are not compressed and not dried. Simple calculations of the solar energy collection at the Earth's surface demonstrate that no developments of biomass can provide significant amounts of energy because the energy required to farm and harvest it is a substantial proportion of the collected solar energy. And biomass cannot be economic because the net amount of energy harvested can only be small. Indeed, governments would not need to subsidise bio-mass if it were an economically competitive fuel. But the production of biomass has potential for environmental damage by reducing biodiversity, and reliance on the use of biomass threatens energy security.

1. Biomass and Biofuels

Like wind power, bio-mass is an ancient idea which has recently again found favour. Simply, bio-mass consists of harvesting crops for use as – or conversion to – fuel. Coppicing and charcoal manufacture were standard forms of bio-mass use throughout much of Europe for centuries. But – also like wind power – biomass lost favour when the high energy intensity in fossil fuels became available by use of the steam engine.

Biomass is solar energy collected by photosynthesis over a small area and a few growing seasons in plants that are not compressed and not dried. Fossil fuels are solar energy collected by photosynthesis in plants over large areas and very many years that is in a compressed and dried form.

Energy is consumed by farming, harvesting and transporting the bio-mass to its point of use. There is a net loss if the farming, harvest and transport consume as much energy as the use of the bio-mass provides. This sets a limit on the area of bio-mass which can be grown for profitable use in any one place.

The term ‘biofuel’ is applied to biomass that has been converted into a form that makes it useful as a displacement for a fossil fuel; for example, petroleum. But, in principle, all biomass is biofuel when it is burned to obtain heat.

Some countries have increasing concern at their need to import fuels, especially oil, and are promoting the use of biomass as an alternative to such imports. Also, the use of bio-mass circulates carbon through the carbon cycle while the use of fossil fuels returns carbon to the cycle. Hence, concerns at anthropogenic global warming (AGW) have induced some people to call for use of bio-mass to displace use of fossil fuels. This paper explains that any such displacement could only be very small.

Additionally, the use of biomass has been advocated in response to calls for ‘sustainable development’. But this paper explains why such ‘sustainable development’ is not possible.

2. The natures of Energy, Sustainable Energy and Fuels

Energy

Energy is the ability to do work. All usable energy derives from the "big bang" which initiated the universe. It cannot be created or destroyed.

Energy flows from regions where it is in high concentration to regions where its concentration is lower. For example, heat flows from hot to cold areas, and water runs downhill not up. Ultimately, the universe will be filled with a uniform distribution of energy and everything will cease. Scientists call this ultimate end of everything "the heat death of the universe".

The flow of energy can be reversed in localised regions; for example, water can be heated to make steam. But the net effect of a system which concentrates energy in one place is to increase the overall distribution of energy (scientists call this "increasing entropy").

The natural flow of energy from a high concentration to a lower concentration may be used to conduct work. This is demonstrated by all energy systems from log fires to nuclear power stations. But the original state of higher energy concentration can never be replaced: it is lost for ever. In other words, no source of energy can be replenished once it is used.

Only three processes provide energy flows which can be sampled by humanity. They are

- the residual energy which was concentrated in ancient - now dead - stars,
- the residual energy from the formation of the solar system, and
- the energy flowing from the sun.

Processes which initiated during the lives of ancient stars have generated radioactive substances notably uranium. Amounts of these substances were part of the material which accreted to form the Earth, and they may be utilised as fuel in nuclear power plants.

Residual energy from the formation of the solar system is observed in the power of the tides and geothermal forces. Indeed, it can be argued that the Earth and Moon system is still forming because these processes still continue.

Energy flowing from the sun consists of radiations and particles. To date, only sunlight and solar heat have been used as energy sources by humans. Biomass is one of the ways that solar energy is used.

Sustainable Energy

It has become fashionable to promote "sustainable development". The media in the developed western countries have accepted that it is a desirable objective. Indeed, in 1992 at the Rio Summit, several governments committed themselves to encourage it.

But – despite the noises from the environmentalist lobby – sustainable development is not possible for energy.

There are over 100 definitions of sustainable development [(1)] but most can be summarized to be ***the restriction of the use of resources to the rate at which those resources are replenished***. This implies that energy sources should be replaced as fast as they are used. The laws of physics decree that – in absolute terms – this is not possible for energy because all energy was created at the 'Big Bang' and no more can be created. Hence, those who talk about sustainable development in energy usually mean ***the restriction of the removal of energy from a place to the rate at which energy arrives at that place*** [2]. This may seem pedantic, but it is very important when considering the use of biomass.

Biomass is a method to collect solar energy. The energy available for collection is limited by the rate at which photosynthesis can collect it.

Biomass is one of the ways used to collect solar energy

Bio-mass is a renewable energy source when the annual crop which is harvested is not more than the annual crop which is grown. The harvesting of wood for fuel in much of the third world is not a renewable source because the harvest is depleting the stock of trees. This demonstrates the severe limits to the energy available from biomass without severe damage to the environment.

Fuels

Fuels are stores of energy. They are commodities which can be stored, transported when and where desired, and used as required. Thus, they can be used to provide energy which can be distributed as electricity when and where it is wanted.

3. Theoretically Available Energy from Biomass

The various common sources for biomass are summarised in Figure 1. Ristinen & Kraushaar [3] consider the energy available from biomass in terms of a ratio they call the 'biomass efficiency' (ε): ε = [biomass energy/m^2/day] / [solar energy / m^2 / day].

Clearly, the collected solar energy will depend on the crops that are grown for fuel and the geographical location. Ristinen & Kraushaar calculate several cases. One of their cases is provided here as illustration because it provides an estimate of the maximum available energy from biomass crops.

Ristinen & Kraushaar derive an estimate of the biomass energy /m^2 / day of 20 grams / m^2 / day from measurements of dry mass produced in a corn field in mid summer in Indiana. The solar intensity in Bloomington in summer is 262 watts/m^2. Hence, for this case, they determined that biomass energy /m^2 / day = [20 gms/m^2/day] * [674 Kcal] = 74.9 Kcal/ (m^2*day)
[180 gms].

And, the solar energy /m^2 /day is: Solar Energy /m^2 / day = [262 W/m^2] * [86,400 sec] * [1 Kcal] = 5408 Kcal/(m^2*day) [1 day] [4186 J].

The summer corn-field efficiency is then: ε = 74.9/5408 = ~1.5%.

This illustration is used here because it provides an example of very high collection efficiency. The paper by Ristinen & Kraushaar provides a number of solar efficiencies for other crops. A pine forest, for example, has an efficiency of 0.5%.

It is important to note that the high estimate of ~1.5% collection efficiency is very high. It estimates the daily collection of solar energy by a crop with high collection efficiency in Summer (i.e. the growing season). Thus, a very, very high estimate for the maximum available energy obtainable from a crop could utilize this value as being obtainable for every day of the year.

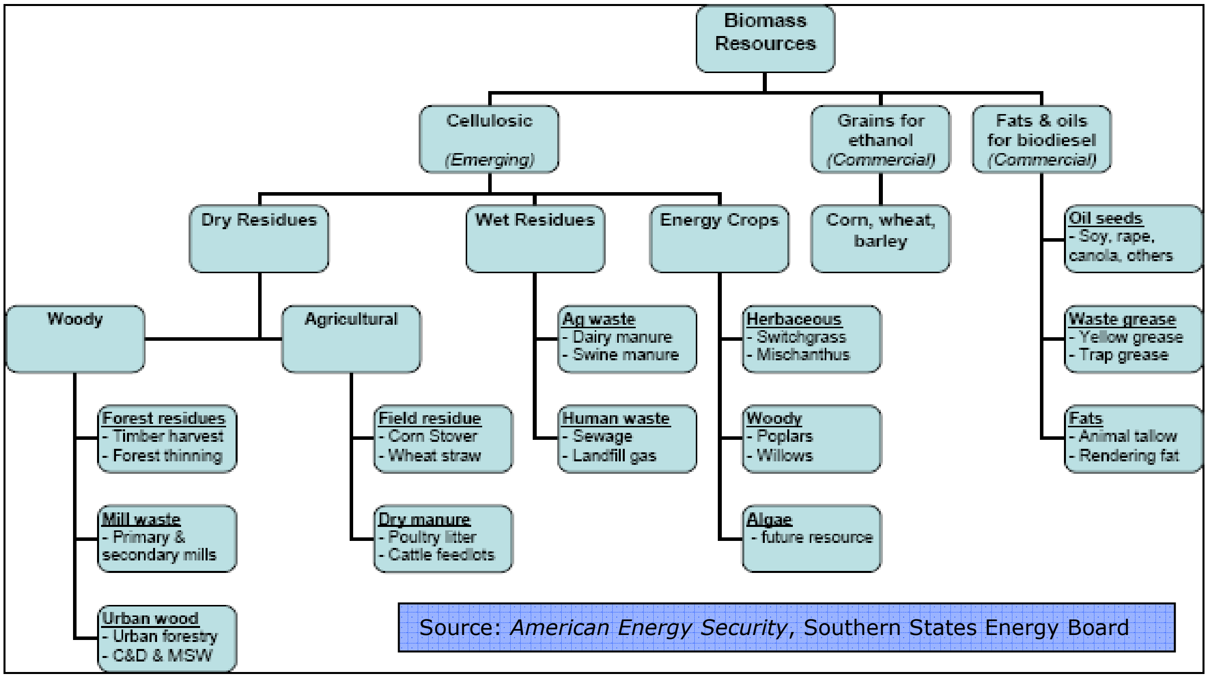

Figure 1. Summary of common biomass feedstocks.

Adopting this indication as the maximum available energy obtainable from biomass per year gives [5408 Kcal/(m^2*day)] = [5408 Kcal/(m^2*day) * 365] = 1,970 Mcal/(m^2*year) = 8.27 x 10^3 MJ/(m^2*year). But a hectare is 10 km^2, so this equates to 8.27 x 10^7 MJ/(hectare*year).

Put another way, the 1.5 collection efficiency for solar energy provides a maximum available energy from biomass of (262 W/m^2 * 1.5%) = 3.93 W/m^2. And a hectare is 10 km^2. So, very optimistically it can be estimated that the maximum available energy from biomass is 40 kW/hectare and in a year this would total (40 * 365 * 24) kWh/hectare = 350 MWh/hectare.

Of course, this indication ignores energy losses due to farming, harvesting and transporting the biomass. Expending more than 8.27 x 10^7 MJ of energy on the farming, harvesting and transporting of the biomass from a m^2 of land in a year would result in a net loss of energy. Also, the collected solar energy is in wet plant material and energy would be used to dry this material when the biomass was used. The US Department of Energy provides one of the most optimistic estimates of these energy losses: it estimates that only 71% of the collected energy would be lost. Furthermore, converting the biomass, for example, to transport fuel would consume additional energy.

However, this indication of the maximum limit to available energy from biomass is so extremely high that there is no possibility of it being reasonably disputed.

Converting 10% of US agricultural production to biomass production would provide less than 10% of US energy needs.

The US is the most productive agricultural producing country. The US Department of Agriculture estimates that in year 2000 the total agricultural land in the US was 943 million acres which equates to 382 million hectares. As estimated above, the maximum available energy obtainable from biomass per year is very optimistically 8.27 x 10^7 MJ/(hectare*year). Hence the maximum possible available energy from biomass as a result of conversion of all US agricultural land to production of biomass is 780 quadrillion J.

This seems much. According to the EIA the US total energy consumption was 94.27 quadrillion BTU in 1998 with 36.57 quadrillion BTU of this being oil. This equates to US total energy consumption in 1998 of 89.4 quadrillion J with 34.7 quadrillion J of this being oil. Hence, total conversion of US agricultural production to biomass production could provide more than 8 times US energy needs. But it is important to note that this estimate of the maximum available biomass energy collection in the US is very optimistic. It ignores energy losses from farming, harvesting, transporting, drying and converting the biofuel while assuming the energy collection efficiency is ~1.5% (although it would probably be less than half that), and assumes the collected solar energy would be at summer levels all year. In practice, less than a tenth of this hypothetical maximum is likely to be achieved. If a tenth of this hypothetical maximum were achieved, then these figures indicate that conversion of 10% of US agricultural production to biomass production would provide less than 10% of US energy needs.

This conclusion agrees with European experience. The European Union (EU) Environment Commissioner, Stavros Dimas, says the EU would have to use 14-27% of its agricultural land to reach its target for replacing 5.75% of its fossil fuel usage with bio-fuels (see Section 5).

4. Special uses of Biomass

It is not possible for bio-mass on its own to compete economically with oil, coal or nuclear power because they are fuels containing high concentrations of energy. Indeed, some governments are encouraging use of biomass by use of subsidies that would not be needed if biomass were economically competitive. However, waste biomass can be a profitable fuel in some cases because the waste has disposal costs. For example, wood chippings from saw mills can be burned as a no-cost fuel for the mill and this also obviates their disposal cost.

The European Commission has advocated use of bio-mass as an alternative to paying farmers for producing nothing under the "Set-Aside" scheme of the Common Agricultural Policy [(4)]. However, on its own this would be very uneconomic.

The Set-Aside Scheme does provide a special case for bio-mass in the European Union (EU). The large capital cost of a power station cannot be justified for the returns from use of bio-mass. But bio-mass from very near to an operating power station would be a small amount of cheap fuel. Hence, a power station could increase its profitability if it could substitute bio-mass for some of its fuel at the height of the harvest season. The fluidised bed combustion (FBC) technologies and air blown gasification combined cycle (ABGC) for making electricity from coal, and the liquid solvent extraction (LSE) process for making oil from coal have sufficient fuel flexibility to do this. The economics of one of these systems would be improved by substitution of the small amount of bio-mass which was cheaper than its coal feed, but the benefit would be very modest.

5. Developing problems with desired use of Biofuel

Some countries are concerned at their need to import oil for transport fuel and have governments that desire to reduce this need by growing biomass for conversion to transport fuel. Indeed, the production of ethanol from sugar cane for use as a transport fuel is a major industry in Brazil.

The EU 'Biomass Action Plan' published December 2005 [(5)] set a target for the EU to replace 5.75% of its fossil fuel usage with bio-fuels by 2010. At their annual spring summit in March 2006, EU heads of states and governments suggested that this target could be increased to 8% by 2015, pending further impact analysis. The stated intention of this target is to reduce carbon dioxide emissions as part of a policy to avoid AGW in accordance with the Kyoto Protocol. According to the EU-sponsored *Well to Wheels* study [(6)], Europe would have to use 14-27% of its agricultural land to reach this 5.75% target. The study concludes that this amount of agricultural land is too large for the target to be met by domestically produced biofuels alone. Hence, meeting the target would require significant imports from countries like Brazil and Indonesia.

The EU 'Biomass Action Plan' has worried some environmentalists. They are concerned that the reduction to carbon emissions will be negligible and that rainforests will be replaced by mononcultures for efficient production of biomass. Imports could cause not only shipping and land transport emissions but also destroy the rainforest to make way for plantations, thus reducing the carbon sink that rainforests provide.

Environmentalists are worried at the possible effects of the EU Biomass Action Plans.

Non-Governmental Organisations (NGOs) are not alone in voicing these concerns. On 7 June 2006 at a biofuels conference organised by three leading environmental NGOs in Brussels, the EU Environment Commissioner, Stavros Dimas, said a balanced solution needs to be found in developing biofuels. "The Commission needs to consider carefully how policies can best increase use of biomass without damaging the environment, and this must also cover biofuels," Dimas said, conceding that the Commission's policy in this field is "still very much under development". Dimas said the current techniques used in biofuels production, which are mainly derived from agricultural crops (so-called 'first generation' biofuels), means the EU will likely not meet its 5.75% target. "So-called 'second generation biofuels' seem to have much lower overall greenhouse gas emissions and other environmental impacts than the first generation biofuels that dominate production in the EU today," Dimas said. "They also offer higher potential for production and cost reductions, as they can be based on biowaste with fewer competing end-uses".

While Dimas' comments may have pleased the environmentalists at the Conference, they point to an innate problem with biofuels. The so-called 'second generation biofuels' are merely the profitable disposal of waste material by using it as fuel. There is not much suitable waste available for its conversion – in gasifiers and liquifiers – to enable its use in internal combustion engines, and the conversion would have very high cost.

Importantly, Dimas stated the obvious in his speech when he said of energy derived from biomass (whether in the form of waste, wood or energy crop), "Using biomass for heating and electricity is cheaper and provides far greater avoidance of fossil energy and CO_2 (carbon dioxide) than converting biomass to biofuels". But, at the same time, he said more biofuels should be called for to help the transport sector out of its "oil addiction". "The EU stands to become almost 90%

dependent on imported oil in 2030. The present target of 5.75% biofuels by 2010 ensures a basis for development efforts in this sector," Dimas said.

Imports of biomass to the EU from large producing countries like the US or Brazil will be needed while the EU waits for a significant contribution of second generation biofuels to the EU's transport sector needs. These imports have potential for longer-term problems. The governments of the potential supplying countries are also promoting use of biomass, and they can be expected to put priority on their internal supply. Hence, a growing EU dependence on imports from these countries would threaten EU energy security.

The low solar collection efficiency of biomass provides similar problems of energy security to any country that adopts significant use of biomass. Little fuel can be grown within any country (see Section 3) and, therefore, imports of biomass would be required.

Large use of biomass by any country would require imports of biomass.

In addition, growth of biofuels could drive up food prices by diverting crop yields to produce fuel, and this could make it more difficult to feed urban poor. This is especially true for developing countries.

6. Environmental Effects of Biofuel

As stated in Section 5, environmentalists are becoming concerned at the potential effects of biomass use although environmentalist desires for 'sustainable development' were among the original reasons for a return to use of biomass. However, as explained in Section 3, there is little energy available from biomass unless the crop has good solar collection efficiency and it is farmed very efficiently. These efficiency requirements require large areas of land to be turned over to monoculture if useful amounts of biomass are to be obtained, and the monoculture would reduce biodiversity. Alternatively, the need for efficient farming may be avoided by using cheap, natural biomass – for example, rainforest – with resulting damage to the natural environment. Environmentalists desire reduction to use of fossil fuels because they fear AGW, but the possible destruction of biodiversity and the natural environment also worries them.

Reduced Biodiversity

BirdLife International is an NGO with concern for bird species. It has welcomed the EU Commission's 'Action Plan' for promoting use of biomass as a step forward in the fight against climate change, but has expressed serious concerns about its delivery 'on the ground'. The EU proposals acknowledge the threats posed by the development of biomass to biodiversity but fail to outline a clear strategy to address them. BirdLife is asking the European Commission to set clear environmental standards to ensure that biomass production results in a significant decrease in greenhouse gas emissions while preventing harmful impacts on biodiversity. The desire for significant decrease in greenhouse gas emissions is forlorn because biomass cannot provide significant displacement of fossil fuel usage (see Section 3), but the effects on biodiversity would inevitably be significant where biomass is farmed.

BirdLife wants an accreditation system that traces how biomass and biofuels have been produced and screens them against environmental standards. But this is meeting strong resistance from Europe's farm lobby. Clairie Papazoglou, BirdLife's Head of European Division, said: "We are concerned that the new proposals remain too generic to offer real guarantees that wildlife will not be harmed. The EU can ensure it doesn't go this way by putting in place a strong system of safeguards. These proposals provide a step in the right direction, but only the bare bones of environmental protection are currently there."

Reasons for the conflict between European environmentalists and farmers are obvious. BirdLife recently conducted an assessment of the overall status of birds in Europe. According to this survey, 43% of all bird species are declining and the decline worsened between 1995 and 2005. Farmland birds in the EU-15 countries have fared particularly badly and experienced a decline of 32% between 1980 and 2002. Many common farmland birds such as Corn Bunting *Milaria calandra*, Yellowhammer *Emberizia citrinella*, Barn Swallow *Hirundo rustica* and Tree Sparrow *Passer montanus* have experienced a severe decline in the EU largely as a result of the intensification of agriculture [(7)].

Dedicated biomass crops for use in Europe include short-rotation willow-coppice, unusual grasses and forestry products. The current rapid expansion of biomass crops in Europe often utilizes set-aside land that had been withdrawn from production under the 'Set-Aside' Scheme of the Common Agricultural Policy. Farmers are paid a subsidy to provide set-aside land, and these pockets of natural land have become important for the survival of some birds and other wildlife. Set-aside land has become almost the only remaining habitat for many grassland-dependent species in several areas of intensive agriculture. For example, in France the Little Bustard *Tetrax tetrax* is breeding almost exclusively on pockets of habitat provided by set-aside land. But the EU 'Biomass Action Plan' allows farmers to grow energy crops on set-aside land, and if further incentives are given to do this, Europe could lose hundreds of thousands of hectares of wildlife habitat within a few years.

The EU Biomass Action Plan could result in the destruction of thousands of hectares of wildlife habitat within a few years.

Rainforest Loss

As explained in Section 5, the net energy provision from biomass is so small that even the use of all set-aside land would not meet the EU Action Plan's target of 5.75% biofuels by 2010. Meeting that target would need conversion of between 14% and 27% of all the UK's agricultural land to biomass production (this range depends on the chosen biomass crops and the region in which they are farmed). But the EU Commission recognizes that such conversion is not feasible technically or economically. Hence, meeting the target requires the import of biomass. The imported biomass would probably be from the cheapest sources willing to supply them, and that means material harvested from rainforest areas. This prospect horrifies environmentalists.

Aat Peterse of Transport and Environment (T&E) has said: "For transport, improving energy efficiency of vehicles should be the first priority. If biofuels are to be part of the energy solution, the EU must ensure that those produced by clearing rainforests and protected habitats will never be sold in Europe."

A report published by the 'Worldwatch Institute', a Washington-based advocacy group, and commissioned by a German agricultural agency says fields of soybeans and palm are encroaching on tropical forests In Brazil and Asia [(8)]. The oils from soybeans and palm can be converted to biodiesel.

"The most problematic and serious risk (of biofuels) is of spreading into wild areas and impacting biodiversity," Christopher Flavin, president of Worldwatch, said, "That is going to require more stringent laws than currently exist in most countries."

Other Environmental damage

Direct use of biomass as a fuel has significant potential for release of pollutants including toxic emissions. Biomass contains much moisture and everything that accumulates on and in the growing biomass. Severe control of its combustion is needed to avoid emissions of dust, polyaromatic hydrocarbons, nitrous oxides and dioxins. Such control requires use of advanced combustion technology because the biomass is – by its nature – variable material.

The report published by the 'Worldwatch Institute' also says that traditional ethanol crops, such as corn in the United States and sugar in Brazil, could increase erosion and deplete aquifers. The top five ethanol producer countries are shown in Figure 2.

And, the 'Worldwatch Institute' report says that if biofuels are produced from crops which take high inputs of products derived from fossil fuel, such as fertilizer, the process of growing, making and burning the fuel could create more greenhouse gas emissions than oil does. However, it claims that no-till crop techniques and the use of advanced biofuels, such as cellulosic ethanol, can cut carbon dioxide emissions below those from fossil fuels. Cellulosic ethanol uses microbes to break down the woody bits of plants. The advanced biofuel can be made from low-imput perennial crops, such as switchgrass, that grow on marginal lands. The cellulosic ethanol industry is in its infancyand at present there is only one such plant in North America. It is operated by the Canadian company Iogen, with investments from Royal Dutch Shell and Goldman Sachs & Co.

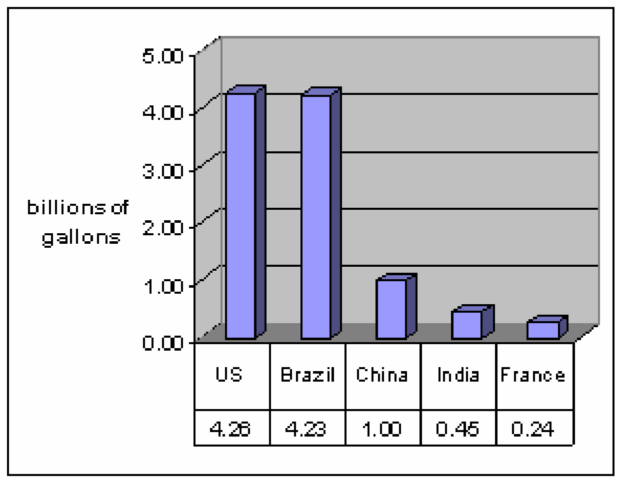

Figure 2. The five major ethanol producer countries.

These assertions that use of biomass may increase or reduce carbon dioxide emissions are probably true, but neither effect would be significant because the displacement of oil by such biofuels can only be insignificant (see Section 3).

7. Economics of Biofuel

Advocates of biofuels are bullish. A recent report from 'Biofuels for Transportation' titled 'The market for biofuels' said that the market for biofuels, including ethanol and biodiesel, is small but growing rapidly. Between 2000 and 2005, ethanol production doubled while biodiesel output quadrupled although it started from a smaller production base. In 2005 the global ethanol supply fueled a little less than 1 percent of the world's transport vehicles but, according to that report, biofuels could provide 37% of US transport fuel within the next 25 years. A report published by the 'Worldwatch Institute' claims that biofuels could replace 20% to 30% percent of oil-based fuel in the European Union within the next 25 years. Neither report points out that this would require massive imports of biomass (see Sections 3 and 5).

In addition, growth of biofuels could drive up food prices by diverting crop yields to produce fuel, which could make it more difficult to feed urban poor especially in developing countries, according to the Worldwatch report.

The Worldwatch report also says production of biofuels is a source of jobs. The ethanol industry provides 200,000 jobs in the United States and 500,000 jobs in Brazil (which produces slightly more ethanol than the United States). This may be true, but the report does not say how many of those jobs would have been in agriculture that has been displaced by the ethanol production. And ethanol is a less efficient transport fuel than petroleum. If the produced ethanol is being used to displace transport fuel then the reduced transport efficiency may have the overall effect of reduced economic efficiency with the result of fewer jobs. The report does not address this issue.

There is a clear need for an analysis of the total economic effects of reduced transport efficiency from use of ethanol and biodiesel. These effects will be dependent on the economy of each individual country and, therefore, are beyond the scope of this paper.

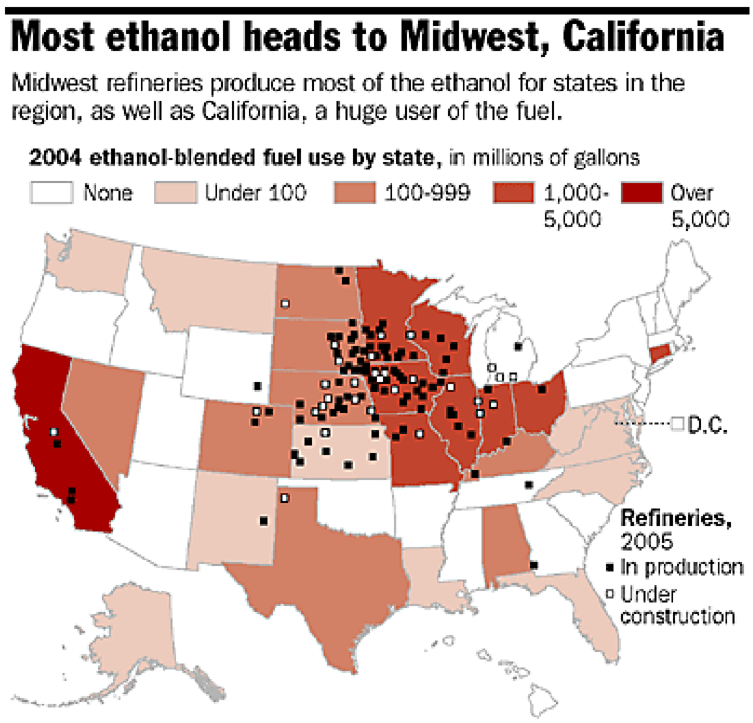

Figure 3. Ethanol production and consumption in US States

But use of ethanol as transport fuel has direct economic effects because it is more expensive than petroleum (called gasoline in the US). The US use of ethanol for transport fuel is shown in Figure 3. President Bush and others have suggested that biofuels such as ethanol could reduce the need for the US to import oil. As explained in Section 3, biofuels cannot provide a significant reduction to the imports. However, ethanol is being used throughout the U.S. as an additive of 10% blended with gasoline. The result has been increased fuel costs for US drivers. In the two months following introduction of this additive at the start of May 2006, demand for ethanol caused its price to rise about 65% to around \$4.50 a gallon in U.S. spot markets, according to the Oil Price Information Service. This is much more expensive than gasoline which costs about \$2.90 a gallon at the pump so the direct effect is to raise the price at the pump to \$3.06 (a price rise of 16%) without taking into consideration costs of transporting and blending the ethanol. The Wall Street Journal commented, 19 June 2006, “Analysts say this has set up a lesson straight out of the Economics 101 textbook: If you add an ingredient to a product that is pricier than the product itself, in effect, you're driving up the price of the product”.

8. Recent Biofuel Developments

The US is enforcing adoption of ethanol as transport fuel (see Section 7), and in June 2006 developments of biofuels were announced in many other places.

France has set itself a target of 7% biofuel use by 2010 and 10% by 2015. On 1 June 2006 the French government launched an experimental scheme in the Marne region to run a fleet of seven Ford Focus cars running on 85% ethanol (E85). The so-called flex-fuel is currently not authorised in France but its use is already widespread in Brazil and Sweden. Industry minister François Loos said France was aiming for the approval of E85 early next year with the fuel expected to become widely available by 2010. Loos has said, "Our objective is simple: we want, by the end of the decade, the market to offer cars that can drive equally with gasoline or with a biofuel that is almost pure". On 7 June 2006, the French government set up a biofuels working group steered by former F1 champion Alain Prost. Called 'Flex fuel 2010', the group brings together the oil industry, farmers, carmakers and consumers and aims to draw-up a biofuels action plan by September 2006. Renault has said it will make half of its cars flex-fuel capable by mid-2009.

Also in June 2006, the Indonesian Government announced plans to clear three million hectares of forest to create palm oil plantations dedicated to biodiesel production. Environmentalists complained that losing such large areas of habitat risk extinction of threatened bird species like the Sumatran Ground-cuckoo *Carpococcyx viridis* and also threatened mammal species such as the Orang-utan *Pongo pygmaeus* (see also Section 6.1).

3,000,000 hectares of Indonesian rainforest are already planned for clearance to grow biomass for biofuel production.

China is the world's third-largest ethanol producer, after the United States and Brazil. It has four government-sponsored ethanol plants that use corn or wheat as their raw material and have a combined annual capacity of 1.02 million tonnes. But worried over food security, Beijing has said it intends to use non-grain raw materials for fuel ethanol as part of its effort to cut dependence on imported oil. China imported 127 million tonnes of crude oil in 2005. The Guangxi region is to build ethanol plants with a combined annual capacity of 1.0 million tonnes to deal with a fuel shortage according to Xinhua news agency. The plants will process Cassava to make the ethanol, and Guangxi provides more than 60% of China's cassava output, producing 8 million tonnes annually. Xinhua reports that the region is to encourage cassava planting to guarantee supplies for the ethanol plants. Sen Yang, a professor from China Agricultural University, said in April 2006 that cassava alone could supply as much as 4 million tonnes of fuel ethanol in China.

Thailand, the world's top cassava producer, already converts some of the vegetable into fuel ethanol.

On 20 June 2006, DuPont Co and BP Plc announced they had formed a 50:50 partnership to develop transportation biofuels [(9)]. They will work with British Sugar, a subsidiary of Associated British Foods plc, to convert its ethanol fermentation facility in Wissington, eastern England, using sugar beet to produce 30,000 tonnes of biobutanol annually. And a larger second phase of development work will have been completed in 2010. DuPont officials claimed biobutanol can be made from a range of common crops, such as sugar cane or sugar beet, corn, wheat, or cassava, and has the potential to be blended into gasoline at higher concentrations than existing biofuels without the need to retrofit vehicles. It can be used in existing fuel distribution pipelines, offers lower emissions and would give consumers more miles per gallon. Thomas Connelly, DuPont's chief innovation officer, said the companies projected that its new biofuel would be competitive without subsidies with oil in the range of $30 to $40 per barrel. Also, DuPont had formed a business unit in April 2006 specifically aimed at development of biofuels and said it had a bio-based product pipeline valued at $3 billion.

The announcement by DuPont Co and BP Plc came seven months after the oil company BP formed BP Alternative Energy that is a dedicated alternative energy business. And their announcement coincided with BP launcheing a new biofuels business unit with plans to invest $500 million over the next decade in a new Energy Bioscience Institute to fund long-term biofuels research.

Environmental Defense President Fred Krupp issued a statement applauding the partnership and calling for further actions to address not only problems associated with oil dependency but also global warming concerns.

Construction of a 13.8 MWe power plant to burn biomass started in Wales at Longlands Lane in Margam, Port Talbot during June 2006 [(10)]. It will supply electricity to the UK grid. In a joint venture Cardiff-based renewable energy company Eco2 and Western Log Group are leading the project which will burn wood from sustainable forestry sources. All its fuel will be wood material from managed forests and saw mills. Hence, this project is an example of profitable use of waste by disposing of it as biomass. However, it does displace fossil fueled power and the operation of the plant will employ 30 people. The project is being funded by Englefield capital and the Bank of Tokyo Mitsubishi.

The announcements listed above demonstrate a remarkable change in the fortunes of biofuel especially for transport. This is clearly shown by the changed circumstances in Brazil [(11)].

In June 2005, analysts were saying the Brazilian government's biodiesel program – based on castorbean oil production to benefit poor family farms – was a charitable thought but not viable. A year later, the small castorbean farm component still appeared to be inadequate for the demands of Brazil’s biofuel plans but the entry of large players like the state-run oil and gas company Petrobras had revolutionized the propects for biofuels in Brazil.

In 2008 a 2% blend of biodiesel becomes mandatory in all diesel sold in Brazil, and new biodiesel plants and retail outlets via the distribution arm of Petrobras seem to make this possible. Petrobras already offers biodiesel at 500 of its filling stations and plans to sell it in 7,000 stations in 2007. Miguel Biegai is a biofuels specialist at local analysts Safras e Mercado and he says, “Brazil is forecast to need 800 million liters of biodiesel by January 2008 and, as it looks now, output will reach and surpass that with plenty to spare”.

Brazil is in the lead as large and small economies seek alternatives to high priced oil imports. Brazil has the world’s most advanced biofuel industry that produces ethanol from sugar cane. There are over 30,000 filling stations across the country selling ethanol to motorists and this fuel accounts for 40% of all fuel consumed by Brazil's light vehicles.

Brazil went from a net oil importer to a net exporter in 2006. This was due in part to increased production of deep water crude after Brazil opened exploration and production to international firms. But Brazil still needs to import lighter petroleum products that its predominantly heavy crude output lacks.

Brazil's large but failing vegetable oils industry is likely to be the direct beneficiary of Brazil's biofuels plans. Norberto Freund, biodiesel specialist at Vision Grain says, "This could help support the soy crushing industry, especially in the center-west, which is the only oil producer of sufficient scale to match a national biodiesel program". Brazil's soy industry has been moving to Argentina where there arere favorable market conditions and so may benefit in the short term, but more efficient oil yielding crops such as palm, sunseed and canola will probably displace soy if the demand for biofuels continues.

Repar refinery, in Araucaria, Parana, Brazil's top grain state, uses a state of the art refining process to produce high quality diesel using 10 percent vegetable oil called H-Bio diesel. H-Bio has not yet been produced commercially and should not be confused with Brazil's conventional biodiesel production. Petrobras has applied for a patent on the process. Brazil's President, Jose Sergio Gabrielli, has said of the process, "In developing this technology, we are allowing a great advancement in the energy independence of Brazil". Petrobras says H-Bio is cheaper to produce than high quality petroleum diesel because the vegetable oil is blended in with petroleum in the refining process. H-Bio could be used by city bus fleets to improve urban air quality because of its low sulfur content that is about 10% less than that of normal diesel. Brazil consumes 40 billion liters of petroleum diesel a year and most is imported at what it considers a high cost, but the quality of domestically produced diesel is poor and polluting. Petrobras said the H-Bio program alone will allow Brazil to quit importing 250 million liters of diesel in 2006 and reduce 2007 imports by 450 million liters. This would consolidate Brazil as the world leader in biofuel production.

The greatest economic benefit from biomass is the economic disposal of waste.

Clearly, the greatest economic benefit from biomass is the economic disposal of waste. Hence, cellulosic ethanol has greatest potential for transport fuels from biomass because it can be produced from any part of a plant. Straw, stalks and corn husks are waste rich in cellulose that can be converted into sugar, and then ethanol. Also, equipment to produce cellosic ethanol from plant material could use wild plants harvested without cultivation (indeed, this is a fear of environmentalists; see Section 6.2).

However, economic production of cellulosic ethanol from plant material is expected to require the breaking down the cellulose into sugars by use of enzymes that have yet to be developed. The most promising methods are still at the laboratory stage, and the first commercial enzymes aren't expected until 2009 at the earliest. For example, the University of California at Berkeley is attempting to use an enzyme derived from a cotton-eating fungus and it shows much promise but is only in the laboratory as yet. More long-term developments include the work of the geneticist Craig Venter who has raised $31 million in venture-capital funding to make genetically modified plants and plant-eating enzymes using his company Synthetic Genomics [(12)].

It remains to be seen if conventional chemical techniques for breaking down the cellulose into sugars can be an economic method for production of celluosic ethanol. Despite this, a Canadian company called Iogen is building the world's first cellulose-to-ethanol factory that is intended to produce ethanol from switchgrass. In May 2006 Goldman Sachs invested $27 million in this project.

And cellulosic ethanol is attracting other notable investors, for example Bill Gates, Chairman of Microsoft, has purchased 25% of Pacific Ethanol, a Fresno, Calif. company that is planning to build several ethanol refineries in the U.S. Those refineries would be able to adapt to whichever ethanol production method is used.

But all these developments have high risk for developed countries. As explained in Section 3, it is extremely difficult – and probably physically impossible – for production of ethanol from indigenous crops to provide a substantial proportion of the energy needs of a country with an advanced economy. And ethanol has high cost relative to that of petroleum. The demand for ethanol as a blend addition in transport fuels is politically driven and this demand could cease if the political drive were to change.

9. Conclusions

Biomass has some significant uses to provide economic waste disposal, but it has little potential as a primary energy source. For example, the European Commission admits that achieving its target of 5.75% of its transport fuels by use of biomass will require substantial imports of biomass despite turning more than 14% of EU agriculture over to biomass production.

The limits to biomass for primary energy supply are set by physical laws and, therefore, cannot be overcome.

Biomass is solar energy collected by photosynthesis over a small area and a few growing seasons in plants that are not compressed and not dried. The energy available for collection is limited by the rate at which photosynthesis can collect it. And farming, harvesting, transporting and drying biomass consume most of the collected energy. Furthermore, converting the biomass, for example, to transport fuel would consume additional energy. These factors limit the potential use of biomass; for example, conversion of 10% of US agricultural production to biomass production would provide less than 10% of US energy needs.

However, the production of biomass has potential for environmental damage by reducing biodiversity and reliance on the use of biomass threatens energy security. These problems are causing concern to environmentalists in Europe.

The use of biofuels for transportation increases transportation costs. But biomass and biofuels, especially for transport fuels, are attracting investors. These investments have high risk because the demand for biofuels is politically driven and this demand could cease if the political drive were to change.

The political drive is induced by desire to reduce fuel imports and to reduce carbon dioxide emissions. Any such reductions would be insignificant to a developed economy.

The economic effects of the costs of substantial biomass deserve analysis. However, these costs will depend on the national economy of the country using the biomass and, therefore, are beyond the scope of this paper.

References

1. http://www.gdrc.org/sustdev/definitions.html

2. http://webapps01.un.org/dsd/partnerships/public/partnerships/180.html

3. Ristinen, RA & Kraushaar, JP, ‘Energy and the Environment’, Chapter 5, Wiley (2006)

4. EEC Commission, ref. P/91/67, 25.9.91

5. EU Commission, Biomass Action Plan, Dec. 2005.

6. EU Commission, Well to Wheels, 16 May 2006 available at http://ies.jrc.cec.eu.int/wtw.html

7. Birdlife, World Birdlife Magazine, March 2006

8. World Watch Institute, ‘Biofuels for Transportation: Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century’, (2006)

9. Gillam C, ‘DuPont, BP link up for biofuels production’, Reuters, 20 June 2006

10. Barry S, Western Mail, 14 June 2006

11. Ewing R, Reuters, 21 June 2006

12. Taylor C, ‘Grain alcohol is seen as the new gasoline. But which recipe is the one for investors to bet on?’, Business 2.0 Magazine, 23 June 2006

About Richard S Courtney

Richard S Courtney is a Member of the European Science and Environment Forum (ESEF) and acts as a technical advisor to several UK MPs and mostly-UK MEPs. He is Chairman of the Southern Region of a Trade Union (BACM-TEAM) affiliated to the UK's Trades Union Congress. He was the Vice-President of BACM-TEAM from 1995 until May 2000, and he was also a Member of the Executive of the Federation of European Energy Industry Executives throughout that time. Having been the contributing Technical Editor of *CoalTrans International,* he is now on the Editorial Board of *Energy* & *Environment.* His present work mostly consists of providing commissioned advice to national governments, although he has recently conducted research studies of energy interactions at sea surface.

Richard is a respected authority on energy issues, especially clean coal technology. He has been the Senior Materials Scientist of the UK's Coal Research Establishment, has served as a Technical Advisor to the European Coal and Steel Community (ECSC), possesses several patents, and has published papers in many journals including *Nature, Microscopy* and *Filtration.* He is the author of the chapter on coal in *Kempes Engineers Yearbook.*

His scientific achievements have obtained much recognition. The British Association for the Advancement of Science appointed him as a Member of the Association of British Science Writers in recognition of his "clear presentation of scientific information to politicians". The UK's Royal Society for Arts and Commerce appointed him as a Life Fellow in recognition of his "services to British industry". PZZK (the management association of Poland's mining industry) gave him an award in recognition of his "services to Europe's industry". He has broadcast on radio and TV around the world in response to requests from several media companies, notably the BBC, and he lectures around Europe.

His knowledge of energy and environment issues is widely respected. He has been called as an expert witness by the UK Parliament's House of Commons Select Committee on Energy and also House of Lords Select Committee on the Environment. UNESCO commissioned a paper from him on Coal Liquefaction. An Expert Peer Reviewer for the UN Intergovernmental Panel on Climate Change (IPCC), in November 1997 he chaired the Plenary Session of the Climate Conference in Bonn at the joint request of the European Academy of Science, the Science and Environment Project (USA), and the Europaische Akedemie fur Umweltfragen e.v. (Germany). In June 2000 he was one of 15 scientists invited from around the world to give a briefing on climate change at the US Congress in Washington DC, and he then chaired one of the three briefing sessions.

Richard is also an Accredited Methodist Preacher. He is a founding Member of the Christ and the Cosmos Initiative that explores the interactions of religious and scientific ideas. The Initiative started in the UK but became active in 28 countries.

Richard avoids confusion about him in his scientific and religious activities by rarely citing his academic achievements, but his material science qualifications include a DipPhil (Cambridge), a BA (Open) and a Diploma (Bath). He may be contacted at:

Address: 88 Longfield
Falmouth
Cornwall
TR11 4SL
United Kingdom

Tel.Fax.: +44 (0) 1326 211849
Mobile (UK): 07720 759268

Email: RichardSCourtney@aol.com