Revista Virtual REDESMA
marzo 2008

A Biofuels Manifesto: Why biofuels industry creation should be 'Priority Number One' for the World Bank and for developing countries

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Abstract

Traditional industrial development pathways, that did not take into explicit consideration the issue of energy technologies to be utilized, now imperil development prospects around the world. As oil supplies approach their peak globally, and energy security becomes a major issue, so developing countries have everything to lose by simply following fossil-fuel based industrialization, and everything to gain by recasting their development strategies around the prospects for renewable energies and biofuels. This is now a feasible prospect, as shown dramatically by the Brazilian experience, now being replicated in many developing countries, including most notably in India and China. These three countries – the BICs – are now leading the developing world to a new energy future and a new pathway of industrial development. This paper argues that the time is therefore ripe for developing countries, and development agencies such as the World Bank, to re-evaluate their stance on biofuels. The paper argues that a swing behind biofuels can unlock a chain reaction of favorable developmental processes – provided developing countries seize the initiative and set in place renewable energy industry creation projects before the developed world has managed to shake itself out of its fossil fuel dependence.

"China and India will soon be the main source of [greenhouse gas] emissions, and to avoid a hot and uncomfortable world, there is no sensible alternative to nuclear energy."
James Lovelock, author of the Gaia hypothesis

"All renewables suffer from low areal densities… photosynthesis has too low a power density (~0.6 W/m^2) for biofuels to contribute significantly to climate stabilization."
M.I. Hoffert et al, Advanced technology paths to global climate stability: Energy for a greenhouse planet, *Science*, 298 (Nov 2002), p 984

"The biodiesel industry has accidentally invented the world's most carbon-intensive fuel."
George Monbiot, "Worse than fossil fuel", *The Guardian*, 6 December 2005

The world is finally having the debate over greenhouse gas emissions and what to do about them that we should have been having a long time ago. But many of the most prestigious and revered contributors to the debate are getting things round the wrong way. Many, if not all commentators, see China and India as becoming the worst offenders in terms of greenhouse gas emissions, and thereby imply – or are explicit – that they must be stopped to protect the rest of us. Others simply assert, albeit in the refereed pages of Science, that biofuels cannot substitute for fossil fuels, although considering evidence that, on closer inspection, leaves out potentially vast resources in the developing world. But actually there is a quite different perspective, one that sees the three main developing countries today – Brazil, India and China – as the vanguard countries in the search for renewable energies. From this perspective, it is the conjunction of concerns over the peaking of oil supplies, combined with the pressing concerns to reduce greenhouse gas emissions, that is leading Brazil, India and China to develop a totally novel approach to the issue of renewable fuels, and biofuels in particular. By so doing they are driving their own industrial development, in a way that offers exciting prospects for the rest of the developing world today. Far from being source of the world's environmental problems, the developing countries, led by Brazil, India and China, could instead be leading the world to a practicable solution.

The world is on the verge of a vast and dramatic surge in investment in biofuels – starting with ethanol, and then moving rapidly to biodiesel and a range of other biologically produced liquid fuels. While some companies in the US, Europe and Japan are already deeply involved in biofuels and renewable energies generally, and while the oil and automotive industries dither over their responses to these developments, the fact is that this is one technological

paradigm shift where the lead can be taken by the developing world. Governments and entrepreneurs in China, India and Brazil in particular understand better than anyone else that that they cannot hope to achieve full industrialization by simply following the same unsustainable fossil fuel pathway pursued by the developed world. If they burn coal, oil and gas at the same rate as the developed world has done, they will kill us all. More to the point, they well understand that they would be prevented by military threat – and by outright war – from attempting to do so. Renewable energy options for these countries therefore represent a compelling option.

Until recently, it was the conventional wisdom that renewable energies would be a marginal and costly alternative, that might make some headway over a century or more as technologies improved. But the case of Brazil and China and India shows that renewables – led by biofuels and in particular ethanol – are competitive here and now, and what's more represent an exceedingly attractive option for developing countries.

The advantages for developing countries of ethanol and biodiesel over their fossil fuel counterparts as transport fuels are many, and include the facts that:

- they are cheaper than oil;
- they provide energy security as opposed to dependence on imports from unstable oil regimes;
- they burn more cleanly;
- they generate fewer greenhouse gases;
- they promote rural development;
- they can generate new export industries for developing countries;
- even countries with a low level of science and technology can get a start with biofuels; and
- they promote South-South cooperation, led by cooperation and investment between Brazil, India and China.

Strategizing around renewable energy is fundamentally different from securing strategic supplies of fossil fuels, in particular oil. To engage in global strategic games (with their deadly consequences in the form of resource wars) in pursuit of security of oil supplies is one thing – and China, India and Brazil are all playing that game, with increasing sophistication and success, to the consternation of the US and its western allies. The key issues here are military strength, international political and military alliances, and diplomatic maneuvering.

But to strategize around renewable energy sources calls for calculations of a quite different kind. This calls for interventionist industry policies to kick-start new renewable energy industries, such as those based on growing and distilling biofuels; or on capturing solar energy; or building wind farms and kick-starting domestic industries to produce PV solar cells and wind turbines. But more than this it calls for sophisticated design of the institutional settings in which a transition to utilization of renewable energy may be effected – from mandating the use of ethanol-petrol blends in motor vehicles, and extending such mandates to diesel-powered machines, to mandating rising proportions of electric power generation from renewable sources; to sophisticated tax measures that offer incentives to move towards energy conservation and efficient fuel usage and disincentives to inefficient fuel use (such as indiscriminate use of SUVs in cities). The point is that strategizing around renewables goes to the heart of an industrial development strategy – and one that is, moreover, tuned to the fundamentals of energy supply and demand, rather than being framed in purely monetary terms.

Brazil has taken an early lead in biofuels, driven by its huge domestic ethanol program that has seen its use as a blended fuel mandated by the federal government, backed by early subsidies to sugar producers to enable them to produce ethanol as well as sugar. Now Brazil has a thriving export industry for biofuels, with firms operating bioreactors at its core. In these reactors a decision to produce sugar or ethanol can be taken on a daily basis, at the flick of a switch, depending on current world prices. In 2005 Brazil started to replicate its success with bioethanol through a biodiesel program. Already by late 2006 this program had generated 100,000 jobs in the north-east of the country, producing biodiesel from oil crops such as castor oil and palm oil. The Brazilian

national energy company, Petrobras, introduced a new biodiesel product, dubbed H-Bio, produced at the refinery, in 2006, the first in the world to do so. In the words of Brazil's minister of agriculture, Roberto Rodrigues, “Renewable fuel has been a fantastic solution for us. And it offers a way out of the fossil fuel trap for others as well."

China and India are Brazil’s largest export markets for ethanol, and are themselves rising fast as producers, now as 3rd and 4th largest ethanol producers in the world, and rising fast in the biodiesel stakes as well. Many other tropical developing countries, in Asia and in Central America, are also becoming active in biofuels. In promoting renewable energy futures, in their own interests, developing countries can thereby create a new agenda for solving the wider problems of global warming. While many economists and policy specialists have addressed themselves to this issue, most see the developing world blindly following in the footsteps of the polluting developed countries; few if any see developing countries as part of the solution. Herein lies the attractiveness of developing countries, and development agencies like the World Bank, in getting behind biofuels and renewable energies. By doing so, they take the lead in moving the world to its destined future independence from fossil fuels – as envisaged by numerous scholars, and captured most effectively by the IIASA/ WEC study, Global Energy Perspectives, published in 1998, as shown in Chart 1.

The era when industrial development strategies could be formulated without reference to energy sources, is over. When we look just at the developing countries, of the world’s 47 poorest, no fewer than 38 are net oil importers, and 25 are completely dependent on oil imports – victims of commitments made during the times when the price of oil was seen as low forever. Yet these are the countries that generally have favorable circumstances for producing biofuels.

If the argument of this paper is sound, then it means that renewable energies – starting with biofuels – represent a unique and irreplaceable opportunity that must not be missed. It means that organizations such as the World Bank should be getting behind the renewables option – and in particular biofuels – with huge and massive assistance, making it their top priority. For developing countries generally, biofuels

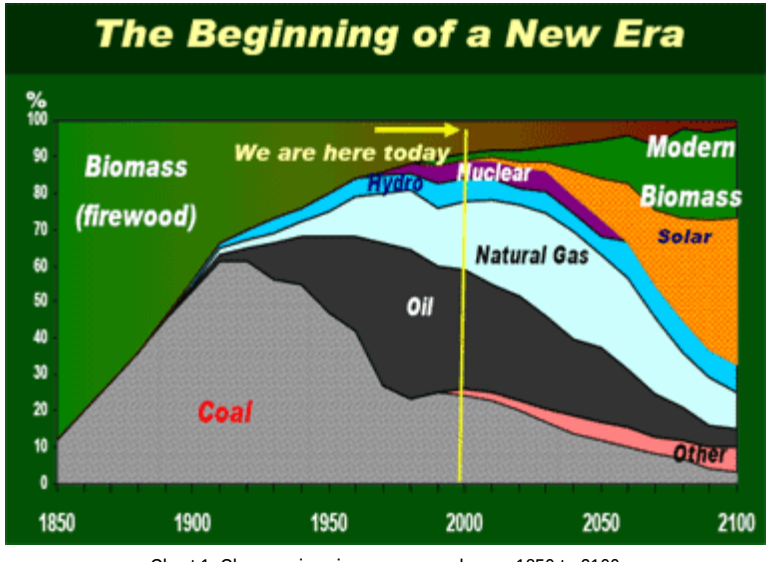

Chart 1. Changes in primary energy shares, 1850 to 2100
Source: Nakicenovic et al (1995) Fig. 5.7 Scenario C1

are pressing to be considered as Number One priority because of their multiple benefits and multiplier effect they induce.

The case of Brazil

Brazil has emerged as the world's leading producer of biofuels, encompassing ethanol and biodiesel. It has built this leadership position through distinctive crops that maximize its advantages as a tropical country, deriving ethanol from sugarcane, and biodiesel from a variety of oilseeds. Some of these, like castor oil, are being grown as a deliberate strategy on degraded and arid lands in the impoverished northeast, thereby giving a major fillip to social development in the region.

Brazil has become the world's largest producer and exporter of ethanol. In 2005, production of sugar and ethanol in Brazil totaled 28.7 million metric tons and 4.8 billion gallons (18.17 billion liters, or 18,170 ML), which are record levels. The industry is highly decentralized, but it also includes national lead firms like Petrobras, which is rapidly morphing from an oil producer to an energy producer, with a focus on ethanol and biodiesel. The industry has really taken off in the 2000s as the unsubsidized price of ethanol has fallen below that of oil – as shown in Chart 2.

Brazil grows sugar cane crops on five million hectares, a fifth of its land under cultivation. In Brazil there are around 60,000 crop suppliers (farmers and farmer coops) supplying over 340 industrial units producing ethanol (bioreactors and distilleries), with a further 50 such units under construction. The ethanol industry supports an estimated 500,000 jobs in the countryside, and a further 500,000 jobs in indirectly related employment.

In Brazil many of the ethanol plants are in fact dual plants, running with technology that allows them to produce either sugar or ethanol, at the flick of a switch – depending on the world price of each. In fact some plants are now built as triple integrated plants, involving sugar, ethanol and biodiesel.7 The share of sugarcane used in ethanol production is expected to rise substantially in coming years.

Brazilian ethanol is far more competitive than that produced in the U.S. from corn or in Europe from

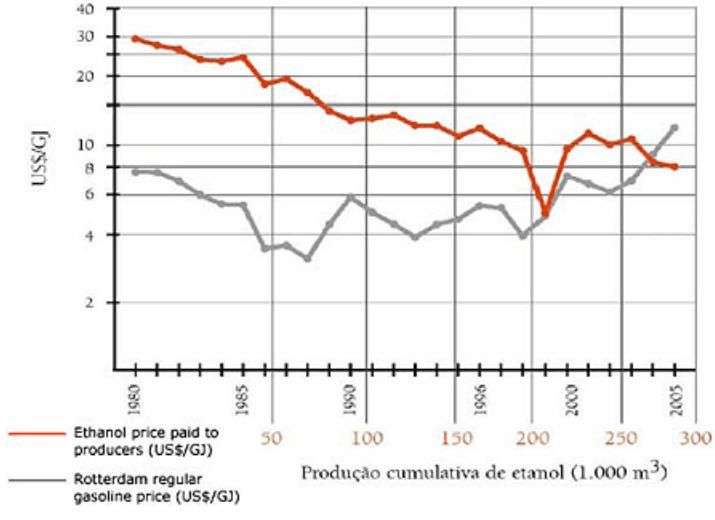

Chart 2. Price paid to ethanol producers and gasoline cost
Source: UNICA (Brazil)

sugar beet, because of shorter processing times (the starch in corn or beet has to be rendered into sugars first), lower labor costs, lower transport costs and input costs. *The energy derived from sugarcane is roughly eight times that derived from northern hemisphere crops such as corn*. But there are also subtle factors at work as well. In Brazil a massive R&D effort has been devoted to unlocking the biological secrets of sugar and ethanol. At the Centro de Tecnologia Canavieira (Cane Technology Centre), an R&D facility funded largely by the sugarcane industry the genome of sugar cane has been decoded, and used to select varieties that are more resistant to drought and pests and that yield higher sugar content. The Centre has developed some 140 varieties of sugar, which has helped to drive costs down by 1% a year, and allowed the country to avoid the pests and diseases that can ravage monoculture.

This is a latecomer advantage – the capacity to focus R&D exclusively on a topic of national economic significance, rather than across the board. Brazil has done this to a refined degree with sugar and alcohol, and results speak for themselves. No wonder successive delegations from India and China have been visiting Brazil over the past year.

Brazil's success with ethanol goes back to the 1970s, when the country's military leaders reacted to the 1973 oil crisis with a drastic push towards ethanol. Brazil in the 1970s was 80% dependent on oil imports, and 40% of its foreign exchange earnings were used to import oil. The country slid into recession, and by the mid- 1970s was facing bankruptcy. In these circumstances the military government issued a directive requiring that the country's gasoline should be blended with 10% (E10) ethanol – a level that Brazil raised steadily over the next five years to 25% (E25). To facilitate the shift, the government provided sugarcane companies low interest loans to build ethanol plants, as well as funding indigenous efforts to produce a car that would run on pure alcohol – which was achieved at a Brazilian Air Force laboratory, leading to a 5,000 mile trip embarked on by the cars, with banners announcing "Powered by Alcohol."

Then after the 1979 Iranian revolution, and a further rise in oil prices, the Brazilian government implemented the National Alcohol Program, or Proalcool program, under which the ethanol blend targets were raised; further subsidies and low-interest loans were made to sugar companies to raise ethanol production; tax breaks were offered to car companies to build ethanol-powered vehicles; and the national oil company, Petrobras, was ordered to make ethanol available at filling stations. By the end of 1979, Fiat was offering an ethanol-only vehicle for sale in Brazil. All told, Brazil spent a total of $16 billion from 1979 until the mid-1990s on the Proalcool program – with savings in oil imports amounting to at least US$120 billion.

The program dipped in the mid-1980s, as oil prices fell to record lows. But it was never entirely discontinued, and meantime Brazilian sugar producers were

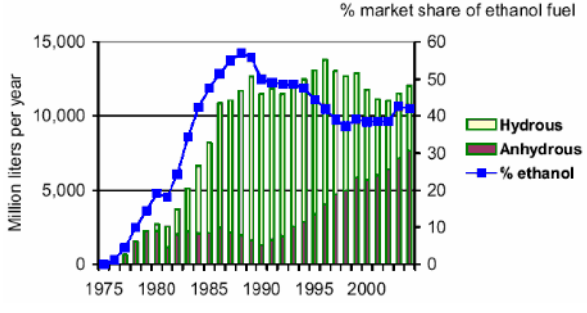

Chart 1. Changes in primary energy shares, 1850 to 2100
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raising their productivity. By the mid-1990s, Brazil had discontinued its subsidies for the sugar industry, forcing producers to be world competitive. As oil prices rose again in the 2000s, so the program came back into fashion, this time under a civilian administration, and this time building on the competence base established by the Proalcool program. Brazil now mandates a fuel blend of E25 nationally. But ethanol has become so popular that it now accounts for at least 40% of all vehicle fuel, and rising. Brazil is estimated to save $50 billion per annum in terms of petroleum imports – one of the most significant of the side-effects of moving to biofuels.

The critical breakthrough in the recent period has been the idea of flex-fuel vehicles (FFVs) – an institutional innovation riding on the back of a simple technological innovation. Flex-fuel vehicles, introduced in Brazil in 2003 and their sales have increased dramatically since, by 585% in 2005, so that the share of flex-fuel vehicles (FFVs) in the total vehicle fleet reached 22% in 2004. It is expected to reach 60% in 2006.

The flex-fuel vehicle is an ordinary vehicle fitted with a sensor, to detect the oilethanol blend at any given moment in the petrol tank; an on-board computer programmed to adjust the engine mechanism to the current fuel mix; and a simple adjustment of the engine firing systems to accommodate pure ethanol. The total package can cost as little as US$80.

It was Brazilian innovation that came up with the device. Although Ford had offered a flex-fuel system in a few of its vehicles, dating back to 1991, the Brazilians thought the device clumsy. A designer at the Italian parts company, Magneti Morelli in Brazil, Fernando Damasceno, created the current Brazilian system by programming a standard car computer to do the job. In 2002 the company licensed the device to VW, who introduced its first flex-fuel vehicle, the Gol, in 2003. It took off like the proverbial rocket, and nothing has been the same in Brazil since. Brazil is now turning to ethanol as aviation fuel as well, to complement its success in aviation exports, e.g. through Embraer. Small planes, like crop dusters, are reported to be switching to ethanol because it is cheaper and more widely available. They are thinking along the same lines as Richard Branson, who has been reported to have invested heavily in ethanol production systems for his Virgin Atlantic and Virgin Blue airlines.

Biodiesel in Brazil

Brazil is also taking steps towards biodiesel, as the second phase of its planned development of biofuels. The pieces were put in place as early as 2003 when a special strategy workshop was held by the newly elected Lula administration. Then in 2005 the National Biodiesel Production Program was launched, as a total program, encompassing phased introduction of biodiesel blends, and the encouragement of supplies, their standardization and quality assurance, and the active promotion of small family farms in the

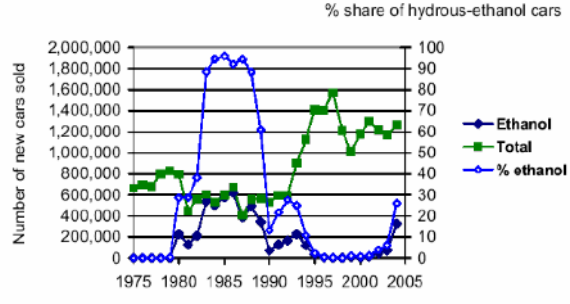

Chart 4. Historical market share of ethanol-fueled cars in Brazil
Source: Fig. 2.4, ESMAP 2005 (ANFAVEA 2005)

impoverished north-east as suppliers. The Biodiesel program is focused on the cultivation of a variety of oilseeds, including such well known staples as soybean and palm oil, and including newer varieties that are non edible, such as castor oil, which cannot therefore be viewed as competing with foodstuffs. The phased blends involve a voluntary blending of up to 2% initially, moving to a mandated 2% blend by 2008, and rising to a mandated 5% blend (B5) by 2013 at the latest. As discussed below, the Brazilian biodiesel program is a carefully thought through initiative, involving institutional innovations such as the use of a special "Seal of Social Responsibility" which can be awarded to biodiesel producers if they source their oilseeds from small, family-owned farms in the impoverished north-east. The variety of crops utilized is shown in Table 1.

By September 2006, when the program was no more than 18 months old, already 20,000 such farms had been enrolled in the program, creating up to 100,000 new rural jobs in the cultivation of oilseeds for biofuels. Thus the Biodiesel program is being carefully crafted in Brazil, in conscious imitation of the country's successful Proalcool Program. Several plants are now being constructed or are in operation, using advanced technology supplied by leading oil companies such as the Belgian giant DeSmet Ballestra, which has licensed its technology to the major Brazilian supplier of biodiesel and ethanol plant equipment, Dedini. Brazilian agroindustrial producers now include such national firms as Granol (one of the largest conglomerates in Brazil, with its own industrial units, warehousing and purchasing operations, and port terminals), Usina Barralcool, and Grupo Bertin.

There is also homegrown technological innovation helping to drive the Brazilian biodiesel program. In mid-2006, the Brazilian national energy company, Petrobras, announced that it had developed a hydrogenated vegetable oil/mineral oil mix, dubbed H-Bio, to be its lead biodiesel product in coming years. As opposed to the current method of choice (transesterification) to produce biodiesel, H-Bio is produced by catalytic hydrogenation of a vegetable oil/mineral oil mix. The hydrogenation is carried out at a refinery, where hydrogen is produced as a by-product from petroleum refining processes. H-Bio represents a revolutionary new approach to production of biodiesel, and puts Petrobras in the world lead in this emerging market. It enables Petrobras to benefit from the wide variety of oil-crops currently grown in Brazil, as shown in Table 1.

Petrobras has announced that it plans to utilize 256 million liters of soy oil in the first year (10% of the total of soy oil exported by Brazil) and that this will represent a saving of 15% in diesel imports, amounting to a saving of US$145 million in the first year, and US$240 million in the medium-term. Brazil currently imports 10% of its diesel fuel needs. While soy oil is being used for H-Bio at first, it is expected that other oils, such as castor, sunflower, palm and cotton oils will be used in oil blends in the future. According to Petrobras, investments needed to modify the refineries are small, of the order of US$38 million. As of 2008, the company has announced plans to spread the process to two more refineries, with a fur-

	castor oil	sunflower	soy	palm	cotton
crop yield (kg/ha)	1500	1500	3000	20000	30000
oil contents (%)	47%	42%	18%	20%	15%
oil yield (kg/ha)	705	630	540	4000	450
2005 production in Brazil (thousands of cubic meters per year)	90	23	5600	151	315

Table 1. Brazilian biodiesel and vegetable oil sources
Source: Petrobras

ther US$23 million in investments. By then, the company will be processing 425 million liters of oil, representing a 25% reduction in the need for imported diesel.

China, India and others are following close behind

China and India are also taking their own steps to becoming significant producers of biofuels and of renewable energy sources generally. India, like Brazil, has large tracts of land under cane cultivation. Both the Chinese and Indian governments are extending tax incentives to make biofuels economically feasible. China is reported to be considering making an E10 blend mandatory before the 2008 Chinese Olympics in Beijing, to do something about the air pollution.

China has become the world's third largest ethanol producer after Brazil and the US, according to an announcement from the National Development and Reform Commission (NDRC), the state economic planner, in March 2006. China has ambitious plans to make biofuels account for 15% of the nation's transport fuels by the year 2020. The Chinese Ministry of Finance is reportedly developing a risk sharing mechanism to cover biomass producers, and give them a buffer in case oil prices plunge again. E10 blends have been made mandatory in five Chinese provinces that account for 16 percent of the nation's passenger transport. China actually introduced a trial ethanol program in five cities in 2002, and expanded it to seven additional provinces in 2004.

Under the 10th five-year plan (2001-2005), China mandated the construction of four bioethanol plants. Annual production of ethanol has increased to 1.02 million tons per year, thanks to direct funding from the Finance Ministry, preferential tax policies and subsidies. Fuel ethanol is produced in Northeastern China, central China's Henan province, northern China's Hebei province and eastern China's Anhui, Shandong and Jiangsu provinces.

So far in China, mainly corn (maize) and wheat have been used as raw materials to make fuel ethanol, and the ethanol has been purchased and mixed with gasoline by the country's state-owned oil producers, including Sinopec. The Finance Ministry has allocated 2 billion yuan (US$250 million) for ethanol projects over the past five years. They were launched mainly to solve the problem of corn surpluses in the northeast, China's major corn-producing area. The corn-for-ethanol projects increased the market demand for corn, and the market prices of corn have been increasing gradually in the past several years. For example, the China National Cereals, Oils and Foodstuffs Corporation (COFCO), the country's main fuel ethanol producer, announced plans to build a 300,000-ton-per-annum fuel ethanol plant in Hengshui, Hebei Province, in July 2006. The plant is expected to start supplying ethanol to Sinopec and CNPC, the top two state oil companies, once it is completed at the end of 2007. In addition to its own land, China is also extending its ethanol cultivation into neighboring Laos. China's Henan Tianguan Group has entered into a contract with the government of Laos to lease 15 square kilometers of land for the production of cassava-based ethanol. China itself is home to the world's largest ethanol plant, at Jilin, operated by the Jilin Tianhe Ethanol Distillery.

India already has a Ministry of Non-Conventional Energy Sources which is an institutional means of consolidating all of the country's renewable energy policies. For example in 2006 the Government of India announced that it would make ethanol blending mandatory as from October 2006 – initially with a 5% blend (E5) and rising to a 10% blend (E10) within a further year, and E20 subsequently. This follows several state-level programs that have already made a big difference. India is moving on all three fronts – biofuels, solar energy and wind power – in a determined way. On biofuels it has companies at the leading edge of bioreactor technology, such as Praj, which has world-wide license rights to the advanced bioreactor technology of the US firm Delta-T, and which is using this technological lead to become one of the strongest technology firms in the biofuels

industry. India is mandating alcohol blended fuels in several states.

India has at least 120 ethanol plants in operation, using either molasses or sugar cane as raw material. Major companies involved include Bajaj Hindusthan and Balrampur Chinni, as well as new entrants such as Reliance Industries, which is developing *Jatropha* plantations in Andhra Pradesh. The US venture capitalist Vinod Khosla has taken a 10% stake in the Indian ethanol technology company, Praj Industries, in an indication of where smart investors are putting their money. Likewise BP is investing in a 10-year project to produce biodiesel from *Jatropha*, with the aim of producing 9 million liters of biodiesel each year.

Elsewhere in Asia, Thailand has promoted a cassava-based ethanol program, and mandated E10 for passenger transport starting in 2007. Malaysia also has plans to become a major producer of biodiesel utilizing palm oil. According to the Deputy Prime Minister, Najib Razak. "All efforts will be carried out by the government to promote the development of biodiesel in the country to reach the target of becoming the world's biggest producer of biodiesel," he told reporters. Najib said it would be a mistake if Malaysia, as a major palm oil producer, did not tap the huge potential in the biodiesel market particularly in meeting the demand in Europe and the United States. “We, as a big palm oil producer, logically can become the largest biodiesel producer and this effort will be coordinated by the government with the collaboration of all parties," he said.

In Malaysia, there has been an investment stampede into palm oil production for biodiesel. The Prime Minister, Abdullah Ahmad Badawi announced in July that licenses had been issued for 52 biodiesel plants with a combined capacity of 5 million tons per year; if all these came to fruition it would make Malaysia by far the most significant biodiesel producer in the world. Malaysia is starting its program with a 5% blend (B5) to be available at pumps in October 2006. The program is designed to enhance the economic welfare of the country’s small-scale plantation holders – but it also threatens to accelerate virgin rainforest clearing for palm plantations.

Likewise in Indonesia, the government launched a major bioenergy crash program in 2006, with investments of up to Euro 17.5 billion up to 2010. A National Team for Bioenergy Development has been formed, under the chairmanship of former Manpower Planning Minister, Al Hillal Mamdi. The program envisages construction of 11 biofuel plants, with capacity of 1.3 GL by 2010, or 3% of the country’s fuel consumption of 41 GL this year. This would involve setting aside 6.5 million hectares for cultivation of biofuels. The Indonesian government is moving to develop *Jatropha* plantations and biodiesel as a means of displacing oil and petrol consumption (and at the same time, reduce the subsidies that the government pays out to keep petrol prices below world market prices). *Jatropha* plantations were created by the Japanese during World War II to fuel aircraft and tanks, but after the war they were allowed to fall into disuse. Now they are being revived.

In promoting renewable sources of energy, all these tropical developing countries are utilizing their latecomer advantages, which enable them to leapfrog to advanced technologies while utilizing their comparative advantages in low costs and abundant sunshine. At the same time they are developing institutional innovations, particularly in their tax regimes, designed to provide incentives for fuel efficiencies and energy conservation.

The arguments in favor of a fossil fuel-independent development strategy

The conventional wisdom has it that the developing countries will have to replicate the energy steps of the developed world. The conventional wisdom has always been that the developing countries would eventually catch-up with the developed world, through emulating their pathways of development. This implied that China and India, for example, would be forced to follow in the footsteps of the developed world. But as they did so, they would create

planetary problems of pollution and resource depletion that the sustainability of the system as a whole was placed in question. This was the 'Limits to Growth' nightmare, usually translated into implicit or even explicit threats against the developing countries that promised to upset things with their energy demands and the exhausts of their activities.

But what the conventional wisdom failed to foresee was that perhaps India and China would find an alternative pathway – one not based on fossil fuels and extreme dependence on oil imports, but on a different trajectory, namely one of energy independence and in particular independence from fossil fuels. Unlike Russia, which is playing strategic games with its vast oil and gas reserves, Brazil, India and China (the countries we can christen the 'BICs') are strategizing around how they can build energy independence through a variety of renewable fuels and energy sources – starting with liquid biofuels, since this is where their vulnerability to balance of payments disasters caused by rising oil import bills would be most pronounced.

The arguments in favor of developing countries moving vigorously towards promotion of biofuels industries may be rehearsed under ten headings, encompassing the following issues:

- Energy security and the peaking of oil supplies globally;
- Biofuels as tested substitutes for fossil fuels;
- Abundance of land for producing energy crops in tropical countries;
- Biofuels' potential to reduce fuel import bills and fossil fuel dependence;
- Biofuels production is a rural industry and can promote social inclusion;
- Countries with even low levels of science and technology can get a start in biofuels, and they can create thereby a 'development bloc' that can drive industrial development;
- Biofuels are greenhouse gas neutral and can earn countries carbon credits;
- Developing countries can develop their own distinctive latecomer institutional innovations to capture benefits
- Biofuels promote South-South cooperation; and
- Biofuels represent simply the first step on a clean technology development trajectory.

1. Energy security and the peaking of oil supplies globally

The relentlessly rising costs of oil, which exceeded $70 per barrel in 2006, and which in inflation-adjusted terms is approaching the all-time high of the mid-1970s, now poses a major brake on industrializing efforts by developing countries. The price is one effect; the other is the possibility of being held to ransom by either Middle Eastern oil regimes or by oil companies looking to allocate ever scarcer supplies. In the developing world, only Brazil has achieved oil independence; when its national oil company, Petrobras, opened a new off-shore rig, the P-50, in April 2006. Petrobras said the huge P-50 rig would boost national oil production to an average of 1.9 million barrels a day in 2006, more than average consumption of 1.85 million barrels a day – thus making Brazil completely independent of fossil fuel imports. Contrast this with the situation in the 1970s, Brazil had to import 85% of its oil needs, and it was badly rocked by the 1973 OPEC oil price increase. Petrobras forecasts that by 2010, its production will exceed Brazil's needs by 300,000 barrels a day.

Looking at the global picture, we see a relentless buildup of production; but the discovery of new fields is in steep decline. Indeed new discoveries peaked in the 1960s. Production must fall following these declines; but of course everyone keeps showing mindless predictions of ever-rising production to keep up with ever-rising consumption. But a gap has to open – as shown in Chart 5.

Here we see how the US peaked in 1970; then Russia emerged as a source, now declining; and how Europe – largely through the North Sea – also had its time in the sun, now rapidly fading. Other sources such as in Latin America, West Africa and now Central Asia have also come to play a role – but they will see steep decline even as early as 2010. The Middle East

has reached the limit of its capacity, and is already embarked on an inexorable decline. The immediate impact will be that Saudi Arabia will no longer be able to play the role of swing producer – producer of last resort. Non-conventional sources of oil and gas – such as tar sands -- will simply not be able to pick up the slack, because of high costs, or technical difficulties, or political resistance, as in the case of drilling in Arctic areas. Thus there is no alternative to renewable energy options, especially for developing countries where rising oil import prices would wreck industrialization plans.

As an indication of the plausibility of the peaking of oil supplies, the world's largest user of fossil fuels, the US Armed Forces, is in process of switching to biofuels. In July 2006, the Defense Advanced Research Projects Agency (DARPA) released a solicitation calling for the exploration of energy alternatives and fuel efficiency efforts in a bid to reduce the military's reliance on traditional fuel for aircraft. DARPA announced that it is looking for processes that will efficiently produce alternative nonpetroleum based military jet fuel from agriculture or aquaculture crops. Current commercial processes do not produce alternative fuels that meet the higher energy density and wide operating temperature range necessary for military aviation uses. The program is currently outlined in a recently issued broad agency announcement and is known as The BioFuels program.

2. Biofuels as tested substitutes for fossil fuels

There is a conventional wisdom based on developed country perspectives that biofuels cannot possibly pick up the full burden of transport fuel supplies. As noted in the epigraph above, the opinion of Professor Hoffert and his colleagues, writing in the premier journal *Science*, is that "All renewables suffer from low areal densities." Hoffert et al go on to comment: "… photosynthesis has too low a power density (~0.6 W/m^2) for biofuels to contribute significantly to climate stabilization. PV and wind energy (~15 W/m^2) need less land, but other materials can be limiting" (2002: 984). These illustrious authors, having dismissed so cavalierly in a couple of lines the

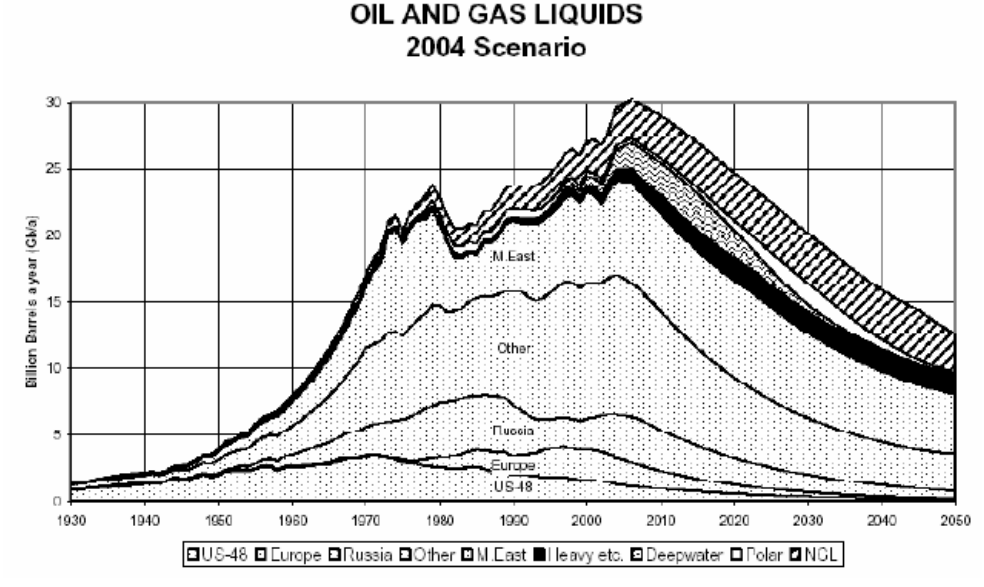

Chart 5. Peaking of global oil supplies
Source: http://www.peakoil.net

terrestrial efforts to make up for fossil fuel deficiencies with biofuels, solar and wind energy, then go on to devote paragraphs to an untried and speculative description of a space-based solar array as part of a star wars initiative.

The reality is rather different, especially for developing countries where sunshine and desolate landscapes are not in short supply. In India for example there are now several major investment programs underway in ethanol and biodiesel production, utilizing vast areas of degraded or under-utilized land. These projects can also capture latecomer advantages through utilizing the latest in biorefinery technology – as recognized in a more recent article in *Science*.

While the issue may be posed in terms of land for food vs. land for fuel in the developed world, this is most definitely not the case in developing countries. There are vast tracts of degraded and semi-arid land that can be utilized for fuel crops such as sugar cane, cassava or castor beans (for biodiesel) – not to mention the prospects for semi-arid cultivation of *Jatropha curcus*. China has vast wastelands in the Yellow River and Huaihe River basins that would be suitable for biofuel cultivation.

There is a huge literature hostile to biofuels, accusing them of being energy intensive in cultivation; taking land from food crops; and enhancing monoculture. But these are largely arguments stemming from developed countries and describing developed country conditions – particularly in US and northern Europe. But the situation in developing countries is quite different. Brazil produces ethanol with an energy gain of up to 8:1, because of the favorable conditions in which the fuel is produced.

All the technologies needed by developing countries already exist. They only have to be harnessed and put to use. Brazil is closely focused in its R&D efforts on improving yields and efficiency of ethanol production. The Cane Technology Centre has developed some 140 varieties of sugar, which has helped to drive costs down by 1% a year. Other improvements include using remains of processed cane (bagasse) to power the sugar/ethanol plants (making them energy independent) and using industrial waste from ethanol production (vinasse) as fertilizer for cane fields. The Centre is using satellite imagery to map the location of all cane fields in the country (largely concentrated in the SE, in the state of Sao Paulo) to help researchers discover which varieties grow best in which localities. These improvements mean a dramatic increase in the productivity of Brazilian sugar cane: 1 hectare which used to produce 2,000 liters of ethanol now produces three times that amount, or 6,000 liters.

There is a role for both very large and for very small firms in developing countries in building biofuels industries. In Brazil for example, Petrobras is already leading the way to becoming a biofuel company over and above its efforts to make Brazil independent of oil imports. Petrobras is now emerging as an energy company in its own right; in December 2005 the company announced that it was forming a JV in Japan, to be called Brazil-Japan Ethanol, which will have as its main object the creation of an ethanol market in Japan through supplies from Brazil. In neighboring Venezuela, the country's State-owned oil company has recently embarked on ethanol production, through a tie-up with Brazilian equipment supplier, Dedini – as mentioned below.

3. Abundance of land for producing energy crops in tropical countries

Tropical developing countries are not as limited in their choice of feedstocks as temperate, developed countries. They have the options of using sugar cane itself, as well as a variety of starchy inputs such as cassava and, for biodiesel, any of a variety of oilseeds that have traditionally been viewed purely as foodstuffs. Indeed many of the oilseeds now being cultivated for biodiesel are in fact inedible – such as castor oil and, in India, the wonder oilseed, Jatropha (that is also being investigated in Brazil – and so there is no question of their competing with food supplies. Indeed one of the most intensive areas for R&D in biofuels in developing countries needs to be an investigation of the potential of existing and little known plants for biofuel production. These options are being explored by Chinese, Indian and Brazilian

ethanol and energy producers in tropical countries. For example, China National Offshore Oil Corp (CNOOC) signed a memorandum of understanding with Malaysia's Bio Sweet Sdn Bhd to develop palm oil-based biodiesel plants in Hainan Island, Shanghai, Guangzhou and Malaysia. The agreement was signed in July 2006 between CNOOC's subsidiary, Oil Base Group Ltd, and Bio Sweet Sdn Bhd of Malaysia which specializes in biodiesel research and development.

The pattern of development of renewable energy sources in developing countries will follow its own 'latecomer effect' logic. While in the developed world, dependence on biofuels is an expensive option (because of intensive land use and need for fertilizers for fuel crops) in the developing world, such as Brazil, biofuels can be produced at much lower unit costs. And the developing countries have much larger land resources to devote to raising energy – from biofuels, from sun (PV cells) and from wind. The developing world can adopt an 'agricultural model' to cultivating renewable energy sources – or what might be called an *ergocultural* model. The 21st century is likely to see major scientific and technical advances in both use of land for food (agriculture) and for energy (ergoculture), with the developing world taking the lead in both.

But of course land can be misused in the pursuit of biofuel crops, and clearances of rain forest in the Amazon and in SouthEast Asia (e.g. in Borneo and Sarawak) represent the front line of such concerns. Countries that allow unchecked clearances are defeating the very conditions that give them a developmental advantage – and creating opportunities for the promotion of global scandals such as the fear that the habitat of apes such as the orangutan are being threatened. And if developed countries can be given an excuse to block imports of biodiesel from tropical countries on the grounds that it is derived from mass clearance of rainforest, then clearly the whole biodiesel enterprise is imperiled.

4. Biofuels' potential to reduce fuel import bills and fossil fuel dependence

For a developing country, it is all the more perverse to neglect the biofuel option while imports of oil are placing an ever-increasing burden on the country's balance of payments. Brazil has estimated the savings on its fuel import bills since the launch of the Proalcool program to be of the order of $50 billion per year – which is far larger than the country has spent in promoting ethanol. Likewise the savings for China and India in foregone oil imports will be of the order of hundreds of billions of dollars – the difference between success and catastrophe in their development efforts. Since indebtedness problems are a major barrier to industrialization, the relief of debt through displacement of fossil fuel imports represents a major strategic shift. China's own domestic supplies of oil peaked in the early 1990s, and so the country became dependent on oil imports – just like the USA 20 years before. The imports of oil needed by China have been rising inexorably ever since – as

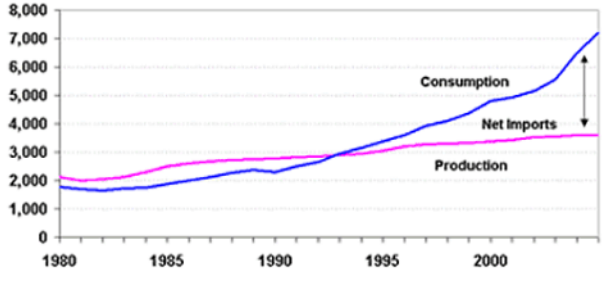

Chart 6. China's oil production and consumption, 1980-2005
Source: personally elaborated

revealed in Chart 6. The situation is even worse in India, as shown in Table 2, where imports are expected to reach 75% of the country's requirements by 2005. This is why an alternative solution has to be put in place by these countries.

5. Biofuels production is a rural industry and can promote social inclusion

Brazil sees biofuels production as a way to promote rural industry and to curb the flight to the cities from the countryside. Biodiesel produced from castor beans in Brazil's arid northeast *sertão*, for example, is promoted not just for the biodiesel but also for the fact that it creates thousands of jobs in this otherwise impoverished region. Promotion is through fiscal incentives, such as tax breaks offered to families producing the raw materials needed for biodiesel production. The more the production of castor beans for biodiesel and sugar cane for ethanol production spreads, the greater are the rural employment generating possibilities, which help to curb migration to the big cities. In India the production of biodiesel from Jatropha is also explicitly promoted as a rural industry capable of generating village-based enterprises and local employment. Indian national firms like Reliance Industries, already a player in the oil business, are now moving into production of biodiesel from plantations established in Andhra Pradesh.

6. Countries with even low levels of science and technology can get a start in biofuels – and go on to build biofuel 'development blocs'

Biofuels in tropical countries can be grown with scarcely more input than seed, land, sunshine – and labor. If the country has a comparative advantage in low costs, then it can start at a low level of sophistication – and move up from there. Brazil is demonstrating how this can be done, through its ethanol program involving sugar cane, and now its biodiesel program involving vegetable oil seeds such as castor and soybean crops. In the words of the country's president, Luiz Inacio Lula da Silva ('Lula') this program had by July 2006 already generated 100,000 new jobs in growing soybeans and other oil crops in the NorthEast of Brazil. The president made the claim that the biodiesel program has been designed as much with social goals as with fuel supply goals. The point is that a country in Africa can emulate this example, and devote large tracts of land to fuel crop production. Domestic consumption can provide an initial market, since the fuel produced can displace expensive oil imports. As sophistication is acquired, and export markets are opened up, so the agricultural practices can be improved, and advanced distillation systems installed, and technological knowhow in the country can be enhanced. This will then have spillover effects in other sectors.

year	production (Mt)	import (Mt)	total (Mt)	import as % of total	import value (USD billion)
1971	6.8	11.7	18.5	63%	0.024
1981	10.5	16.2	26.7	61%	0.744
1991	33.0	20.7	53.7	39%	1.360
2000	32.0	57.9	89.9	64%	6.821
2003-2004	33.4	90.4	123.8	73%	18.000
2004-2005 (forecast)	33.4	100.0	133.4	75%	27.000

Table 2. Production and import of crude oil in India
Source: Ministry of Petroleum and Natural Gas, India

As a biofuel industry becomes established, so it will drive industrial development through linkages and complementarities. Biofuels and renewable energies sector promises to play the role of a critical 'development bloc' for Brazil, India and China in the first instance, and for wider swathes of developing countries through the tropics more generally. The category of development bloc was introduced and defined by the Swedish development economist, Erik Dahmén in 1950, based on his studies of entrepreneurship in the Swedish economy. He defined it as "sequences of complementarities which by way of a series of structural tensions, i.e. disequilibria, may result in a balanced situation" (1989: 111). Such a suprafirm system provides a striking description of how firms may collectively strategize in the context of a disequilibrium economy, and build on each others' efforts to improve their own prospects. Carlsson and Eliasson (2003) have taken up the concept and renamed it competence bloc – to emphasize that such a collective capability is needed to support and sustain technological innovation. If the technological system represents the supply side of industrial dynamics, then the development bloc or competence bloc represents the demand side. The competence bloc captures the notion that if new technologies are to be taken up, or absorbed, then firms must have the requisite capabilities, and the product ranges, to be able to make use of the technologies. It is the blockages due to such inadequacies and bottlenecks that accounts for poor uptake of new technologies, rather than unwillingness or conservatism on the part of managements. Thus a development bloc represents the systemic counterpart to the consideration of market demand as well as supplier competence in the microdynamics of technological trajectories. It generates the forward and backward linkages that can drive industrial development.

7. Biofuels are greenhouse gas neutral and can earn countries carbon credits

Biofuels like ethanol are greenhouse gas neutral, in the sense that every carbon atom burned is simply replacing a carbon atom taken by the plant during photosynthesis. This is by far their most appealing feature from a long-term environmental perspective. Of course this neutrality has to be qualified by the fact that fossil fuels are consumed along the value chain producing the ethanol – but again much of the concern that is voiced on this issue emanates from a developed country perspective and is much less relevant in a developing country. For example the Washington Post ran a story in July 2006 captioned "The false hope of biofuels" in which the main charge was that the energy gain is little after deducting amounts involved in fertilizer, harvesting, transport, processing etc. These considerations change dramatically when considered in the context of a low-cost developing country, where input resources including land and sunshine are abundant. The greenhouse gas emission abatements can then serve to generate carbon credits under the Kyoto protocol.

But again indiscriminate clearance of forest to plant energy crops defeats the gains in greenhouse gas emissions that are potentially there for the taking. It is to curb such behavior and hold governments to a standard of accountability that is one of the principal arguments for global institutions like the World Bank to become more directly involved in promotion (and to some extent regulation) of the development of biofuels.

8. Developing countries can create their own distinctive latecomer institutional innovations to capture benefits

Brazil had to do it the hard way – but having accomplished a successful biofuels industry, it shows other countries how it can be done. In the 1970s it suffered under a military dictatorship, but out of that experience came an understanding as to how the country could benefit from its comparative advantages in sugar cane growing and processing, turning these into competitive advantages. In the most recent period, Brazil has seen its use of biofuels leap ahead under the twin impact of FFVs (flex-fuel vehicles) and the mandated provision by fuel companies of ethanol blends (from E25 to E85) all across the country.

Other developing countries can learn from this example, without having to go through all the painful epi-

sodes of Brazil's history of the past 40 years. They can accelerate their uptake of biofuels, with all the advantages that this can bring (in terms of energy security, savings from oil imports avoided, rural development and cleaner city air), to create new and vibrant export industries, simply through the double expedient of:

1) mandating supply of flex-fuel vehicles (directed at the automotive industry); and

2) mandating provision of ethanol-petrol blends (starting with E10 and moving to E25) within a few years.

It is predictable, based on Brazil's experience, that these two measures will have the desired effect of putting the developing country on a new energy trajectory, leading away from dependence on fossil fuels. The billionaire venture capitalist, Vinod Khosla, has proposed these two measures as being sufficient to take the US similarly onto an ethanol-based new energy trajectory. He adds, for good measure, a third, namely a "contingent tax" which comes into play only if the price of oil drops below $40 a barrel. Khosla adds this third provision in the full knowledge that in some parts of the world, the oil industry giants might try to undermine an ethanol program by drastically lowering oil prices, even to below cost (think of Enron and the manipulation of the California electricity market). The contingent tax would be a way of guaranteeing a floor price for fuels for investors in ethanol production and distribution systems, and thus a way of ensuring that finance will be made available for such ventures.

The key: demand-side initiatives

So much of the discussion of the past decade on renewable fuels has been driven by supply-side considerations – namely costs and technologies. But the key to getting these new industries off the ground – as in every successful case of deliberate industry creation – is to influence demand – in this case, the demand from the automotive industry for cars that run on ethanol blends, and demand from the motoring public for such ethanol blends.

As noted above, the key to the Brazilian success has been an institutional innovation riding on the back of a simple technological innovation. The key is flex-fuel vehicles, introduced in Brazil in 2003 and whose sales have increased dramatically since, by 585% in 2005, so that the share of flex-fuel vehicles (FFVs) in the total vehicle fleet reached 22% in 2004, and is expected to reach 60% in 2006.

So any developing country today can benefit from this experience, and move to establish a biofuels industry with relative certainty as to the outcomes. The key is to start with ethanol blends ('gasohol') rather than seeking to jump straight into pure ethanol or other biofuels, and to do so at a measured pace, building demand for the ethanol blend by drawing the automotive sector and oil sector along with the program. The three steps advocated by Khosla are probably sufficient to get any developing country onto an alternative biofuel trajectory. But this unleashes a chain reaction of processes that make the trajectory sustainable and fuel the country's further industrial development.

The institutions established to drive the uptake of biofuels will likely have a knock-on effect, facilitating the appearance of other industrial sectors, formed initially as support sectors for the biofuel industry. Good institutions develop during an economic activity. When a committed government engages in a partnership with a proactive private sector, they jointly begin to design and implement appropriate institutions. So while institutions are the key, the causation may be from the start of an activity in response to a government trigger (tax break for example), to the unfolding of institutions that help to trouble shoot as the process rolls along. Of course, the process will be highly inefficient in the beginning, as countries learn to make these institutions work more effectively. This is best illustrated in Brazil's own follow-up to the ethanol program, namely its Biodiesel program.

Brazil's biodiesel program – a successful late-comer strategy

This latest biofuel initiative from Brazil shows just what can be achieved by a developing country that

focuses its institutional innovations on capturing its latecomer effects. The Brazilian biodiesel program, which is now just 18 months old, is just phenomenally well crafted and executed. We can identify at least four latecomer institutional features to the program that have not been widely recognized.

First, it is a carefully incremental program, moving through three phases that have been widely discussed in Brazil - a first, voluntary phase, bringing the country up to a level of 2% biodiesel when blended (following the example of the Proalcool Program). By 2008 this 2% minimum becomes mandatory, and rises to 5% minimum blend by 2013. (Although the success of the program in its first 18 months means that it is widely anticipated that the mandatory 5% blend (B5) will take effect at an earlier date, possibly as early as 2010.) Thus the country as a whole is being brought to a position where by 2013 at the latest (and possibly as early as 2010) it will be producing 5% of all diesel requirements from vegetable oils, making it the world #1 by far. The program is overseen by the Ministry of Mines and Energy.

Secondly, the capacity of the country is being ramped up in the initial, voluntary stage, by the smart expedient of staging national auctions for biodiesel. Four such auctions have been staged so far, by the ANP, the motor fuel standards agency. These auctions have encouraged bids from potential suppliers who are thereby induced into the market. The auctions have also served as a means of setting guideline prices for biodiesel, with each auction setting a lower price at which quantities of biodiesel are sold. The state-owned oil company, Petrobras, acts as the buyer of last resort, thereby ensuring that the auctions bear some relationship to market reality.

Third, there is a distinct and explicit social goal to the biodiesel program - again, learning from the experience of the pro-alcohol program. The Ministry of Agrarian Development (which is pro-small farmers) has shaped the biodiesel program with its 'seal of social responsibility' meaning that small farmers have to contribute over 50% to a large trader's or distributor's biodiesel. It is only with such a seal that large companies receive tax credits and are allowed to bid at the auctions. The impact has been dramatic, even in just 18 months. The President, Lula, who backs this program as the central initiative of his presidency, claims that 100,000 jobs have been created in Brazil's impoverished NorthEast through growing oilseeds (mainly castor oil). This is backed by data from the Ministry (MDA) showing that since the launch of the program, just over 200,000 small family-owned farms have been induced into growing oilseeds. Moreover the favored oilseeds are castor oilseed (Port: Manona) and palm oil (from a variety of native Brazilian species), rather than soybeans that are grown in the centre and southeast of the country. (This is in addition to the 500,000 rural jobs maintained by the Proalcool Program, plus the 500,000 jobs indirectly linked to rural alcohol production.)

Fourth, Brazil is backing a wide variety of oilseeds in these early stages of the program, to see which ones turn out to be best in a tropical country (and bearing in mind that European experience is confined exclusively to rapeseed and US experience to soybean). Certainly output is currently dominated by soybean and palm-oil, but cottonseed and castor oil are also picking up, under the influence of the MDA's social inclusion or rural smallholder development strategies. New candidates are coming on to the scene, such as the wonder oilseed *Jatropha curcus*, widely utilized for biodiesel in India (it grows under harsh conditions; it is a perennial that can be harvested regularly; and above all it is inedible, meaning that its cultivation will never be seen as a threat to food supplies). There are as well conventional but underutilized sources such as beef tallow, obtained from slaughterhouses. The broader Brazil's scope of oilseed culture, the more it is able to take advantage of changes in world prices for these vegetable oil commodities, switching between one and the other. Thus it is a smart latecomer strategy to invest in variety at this early stage of the biodiesel industry.

Note that these four central features of the program are driven by four Ministries, all in the pursuit of highly creative latecomer strategies - the Ministry of Mines and Energy, backing renewable energies generally; the ANP, to safeguard standards and conduct the auctions; the MDA, which is essentially launch-

ing a new land reform program with the biodiesel projects, in its direct appeal to 'social inclusion' as a national goal of the program; and the Ministry of Agriculture, which is promoting a wide variety of oilseed crops and not just soybean. The success of the program to date indicates also successful collaboration between these four ministries.

9. Biofuels promote South-South cooperation

Brazil, India and China are already leading the world in the extent and depth of their cross-linkages driven by biofuels. These are all important examples of South-South cooperation. Amongst agreements reported recently, consider:

- India's largest sugar corporation Bajaj Hindustan Ltd (BHL), announced in June 2006 that it was looking to invest somewhere between US$250 and 500 million in a Brazilian ethanol production facility, raising the company's industrial alcohol capacity from 320 ML to 800 ML. This is just one of several India-Brazilian cooperation initiatives.
- A Chinese investment delegation visited Brazil in July 2006, specifically in the inland Goias state, to discuss ethanol and soybean-based biodiesel projects – the latest in a series of such visits. China's Kuok, a diversified conglomerate, has a JV with Cosan, Brazil's largest ethanol producer (operating 16 distillation plants).
- In July 2006 the Brazilian equipment maker Dedini SA Industrias de Base sold a complete ethanol plant with a capacity to produce 8.5 ML of ethanol a year to Venezuela's state-owned oil firm Petroleos de Venezuela SA (PDVSA). The plant, to be set up in Tocuyo, will produce ethanol from molasses. Venezuela reported that it is currently experimenting with E-10 blends in the eastern part of the country, importing 1,000 barrels a day from Brazil.
- Strong ties are being established between Brazilian and African countries through the Biopact established between European and African countries. Much of this cooperation will take the form of technology assistance from Brazil to African countries, particularly those which share its Portuguese heritage such as Angola and Mozambique.
- Likewise ties are being established across Central America. For example, Jamaica announced in May 2006 that it would receive a US$100 million loan facility from Brazil to be used for purchase machinery and agricultural equipment to overhaul the country's sugar industry and to produce ethanol, official sources said. The Jamaican government revealed plans to introduce E-15 blends within the next five years, in imitation of the Brazilian success.
- Malaysia and Indonesia, world numbers #1 and 2 in the world in palm oil production, announced an agreement in July 2006 in which 40 percent of their crude palm oil output would be dedicated to the biodiesel industry. "Both countries agreed to commit a targeted amount of six million tons of crude palm oil each annually as feedstock for the production of biofuels and biodiesel," the Plantation Industries and Commodities ministry said in a statement.

These South-South investment tie-ups and joint ventures have a number of strategic advantages. They are taking place in advance of such JVs being put in place by the advanced countries. They facilitate the diffusion and uptake of ethanol and biodiesel technologies by developing countries in tropical parts of the world, independent of its uptake by the developed world. It encourages the formation of a global market for bioethanol and eventually biodiesel, which will make it harder for countries such as the US to defend its current tariff imposed against Brazilian ethanol imports. Development agencies such as UNCTAD can promote South-South investment, one of its major strategic goals, through support for biofuels.

Because Brazil, India and China have moved so far ahead, they are now in a position to engage in South-South transfers of technology from the BICs to other countries for the development of the biofuels indus-

try, a phenomenon that has not taken off in technology adaptation thus far. This should be particularly appealing for countries that have strong agricultural sectors but weak industrial sectors.

10. Biofuels represent simply the first step on a clean technology development trajectory

Finally, the point needs to be made that biofuels are not an end in themselves, and will necessarily lead a country along a trajectory that will involve many more biofuels innovations and clean technologies. Brazil for example started with ethanol, and now since 2005 it has launched a biodiesel program that promises to rapidly take the country to world leadership in biodiesel. All developing countries can expect to pass through the same two phases, probably in more concentrated form. Within the next decade, a third phase can be expected to become significant, namely the use of biomass generally (such as through forest plantations, or municipal waste) as feedstock for general bioreactors. This phase will depend on the development of enzyme packages that are currently in the test stage in R&D companies such as Iogen. But it is highly likely that this stage will be accelerated through innovations developed in Brazil, India and China, given their track record.

The time for the developing countries to make their mark as leaders in biofuels may well be limited by looming technological developments. There are innovations pending such as the design of synthetic bacteria optimized for the production of ethanol, to be grown in bioreactors located next to power stations and fed carbon dioxide as raw material. If such developments come to pass, they will impose crushing technological competition on the cultivation of energy crops by developing countries. Hence the urgency of these deliberations.

Will the developed world allow a global biofuels market to emerge?

This is the biggest issue of all. Already there is substantial momentum behind the enactment of subsidies to encourage production of ethanol in northern temperate climates – from corn in the US and from sugar beet in Northern Europe – where the costs of producing the final product are far higher (two to three times) than in India or Brazil. It would make so much more sense for the developed world to produce ethanol on a small scale for their own energy security, and import the bulk of their supplies from tropical countries in Asia, Africa and Central and South America. The US, for example, operates a tariff of $0.54c per gallon against ethanol imports, at the behest of corn-belt ethanol producers, in addition to the substantial subsidies paid by state and federal gov-

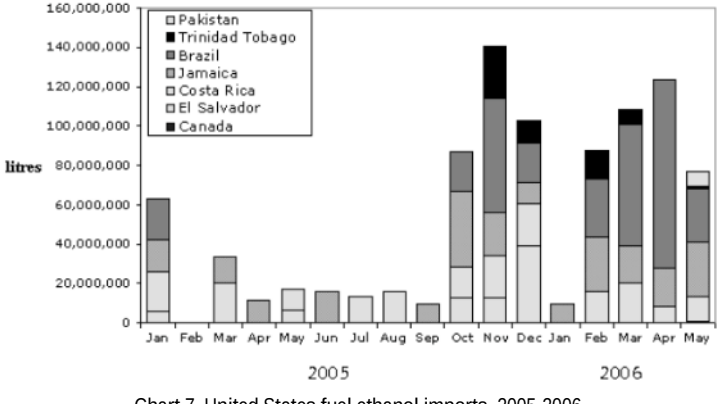

Chart 7. United States fuel ethanol imports, 2005-2006
Source: ITC

ernment programs and tax breaks offered to these producers. Despite this, US imports of ethanol have increased dramatically in the last two years, as revealed in Chart 7.

The more that South-South cooperation occurs in the biofuel sector, the more it will help to create a global market for biofuels, initially ethanol, which will come to be seen (sooner rather than later) as a complement to and alternative for the global market for oil. The South-South cooperation would be unobstructed by protective tariffs raised by the developed world against the countries of the South. Here the WTO has an enormously important role to play, in ensuring that the coming biofuels century is not wrecked at the outset by greedy and short-sighted protectionist measures enacted by the developed world to obstruct global trade in biofuels.

Why priority #1?

Building a development pathway around biofuels has the potential to unlock a chain reaction of favorable activities -- creating in the first place a successful national and export industry; promoting a space for local entrepreneurship and particularly rural entrepreneurship; creating an advanced science and technology-based industry that will create an incentive to stay abreast of technological developments in biofuels and bioreactors generally; demonstrating the significance of government policy in creating the right conditions for the industry to develop; and breaking down resistance to other renewable energy industries, like solar and wind -- thus getting a country onto a development trajectory independent of fossil fuels.

What enables the BICs to move on the biofuels frontier is the presence of superior skills - not just any - but scientific and engineering. Without investments in these, firms cannot even apply superior farm technologies, let alone cultivate crops for biofuels. Thus biofuels provide an excellent starting point for a program of industrialization for most countries looking to make a start in technological adaptation and learning-based development – which applies to almost all the tropical countries today. They can seize their advantage in being able to cultivate fast-growing biofuels crops – but only if they are able to apply advanced scientific agriculture and utilize the most efficient power conversion processes in ethanol and biofuel production – technologies available to them as latecomers, e.g. through South-South investment and cooperation.

The key that unlocks the potential of renewable energy sources for development is – as discovered by Brazil – flex-fuel vehicles. It works like this. Flexfuel vehicles give motorists a choice – fill up with ethanol or with petrol, depending on the price and personal preference. This choice engenders confidence, and overcomes any lingering doubts about ethanol. This builds consumer demand for ethanol, so bringing competition to the petrol forecourt. The oil companies can swim with the tide, and supply ethanol themselves, or they can go against it, and allow independents to supply the ethanol that motorists demand. Either way, an ethanol market is created. This then leads to realistic policies for supplying ethanol – either through imports (probably from Brazil) or through local production that gets a kickstart mandated by popular demand. In the tropical parts of the world, such as India or Thailand, there will be sugarcane and starch-rich plants such as cassava providing the feedstocks. In more temperate climates, it will be grains such as wheat, sorghum, corn and new varieties not yet seriously tested, such as sweet sorghum. The bioreactors built will be at the leading edge of technology, to capture latecomer advantages. They will be flexible, taking a variety of feedstocks and producing a variety of outputs, not just ethanol but also distillers' grains for animal feed, as well as plant wastes that can be fired to produce electric power for the bioreactors that will be collocated next to the grain or corn or cane fields. Entrepreneurial initiatives to produce ethanol and methanol from cellulose (woody and fibrous biomass) would be forthcoming, so that alcohol supplies could be produced on a scale that could provide a genuine alternative to oil and to fossil fuels more generally.

Governments can mandate these changes, by simply requiring that all new vehicles meet flex-fuel stan-

dards. And the governments of India and China would be pushing on an open door to make such requirements mandatory. The automotive industry is already producing huge numbers of flex-fuel vehicles, and would be enchanted to be given a chance to offer them against local competition in India and China.

The rest would follow. As India and China wean themselves off imported oil, and the results of producing ethanol and methanol and creating a national biofuels market become apparent, so the pressure to produce other 'green' sources of energy would mount. Confidence breeds confidence. There would be demands to clean the cities of smog and air pollution caused by vehicle emissions. Green electricity, produced from digestion of urban waste, from solar photovoltaics and from wind power, would be viewed as no longer a marginal supply issue, but central. The institutional reforms needed to mandate such a switch would be forthcoming, because the confidence to do so would be established by success with biofuels. Thus more and more electric power would be produced from renewable sources, as retail suppliers of power are mandated to do so, and consumers demand it. Reforms covering interconnection would be enacted, allowing small, independent power producers to use their own generated power locally and to sell off excess to the grid, at fair and reasonable terms. Thus the whole electric energy system would be decentralized, and made more robust as a result. Power blackouts and brownouts would become a thing of the past in developing countries.

As the savings from importing oil mount, so the countries that pursue this development pathway will be able to build export industries, first around biofuels, and then around the technology for producing biofuels and eventually the technologies for producing energy from renewable sources more generally. This would be an interesting 21st century variant of Akamatsu's 'flying geese model' which envisaged developing countries moving in lockstep with advanced countries as they import first their equipment, then develop industries, then exports, and finally end up exporting the latest versions of the equipment themselves. In this 21st century variant, it is the latecomers who take the lead in energy, and after importing advanced technology move quickly to build their own export industries in advance of the developed world. Led by Brazil, India and China, and with the full participation of Japan – and eventually of the US and Europe as they break free of oil-dependence – the renewable energy industry is set to become the largest industry of the 21st century – taking over that position from oil, which is currently the world's largest and has been for the past half-century and more. But the renewable energy industry promises much more than independence from fossil fuels. It promises to be a 'normal' industry, in the sense of one that promotes competition and innovation – two features conspicuously lacking in the international oil and automotive industries.

So the developing countries have everything to gain from promoting biofuels as the first of a series of renewable energy industries, and nothing to lose. They will not be sacrificing other options to do so, because they do not have other options in place – other than underdeveloped fossil fuel utilizing systems that are becoming prohibitively expensive and economically crippling as oil supplies peak. They will not be sacrificing resources such as land because they have land in excess supply, particularly the kind of degraded land that is best utilized for fuel crops such as sugar cane or *Jatropha*. They will be saving themselves from the trap of being dependent on oil imports at a time when the price of oil is rising inexorably, and security of supplies is anything but certain. They will be contributing to promoting cleaner air in their cities and reducing greenhouse gas emissions overall – for which carbon credits should become available soon under a Kyoto-like process. The issues that developing countries need to consider have been well documented and publicised, by the World Bank and other agencies.

Finally developing countries, in addition to all these advantages, can kick-start their own process of industrial development by focusing seriously and urgently on the building of a biofuels industry and on all its

concomitants, such as the promotion of entrepreneurship, exports and cluster development. But the opportunity, while the developed countries are still dithering over whether to get behind biofuels in a big way, could close soon. Now is the time for the World Bank to get behind the promotion of biofuels industries for developing countries as a major priority, and for the countries themselves to build the industries that will liberate them from the bondage of a fossil-fuelled future.