II. Energy Efficiency in Brazil

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» The Brazilian government has enacted a good set of institutional arrangements to help achieve end-use energy efficiency (EE) goals. These arrangements proved to be very effective, as shown during the serious power supply crisis in 2001. Despite EE improvements, there is large scope for cost-effective EE improvements in Brazil.

» Transforming the large losses of energy biomass into useful renewable energy, for instance, can prove rewarding, particularly as it can foster the emergence of solutions for application throughout the tropical world, thus creating considerable South-South trade and investment opportunities.

» According to the Brazilian Institute for Energy Efficiency (INEE), the best way to integrate EE considerations into energy policy is to assess all possible paths to energy transformation and transport on a "well-to-wheel" basis, and work to identify the more efficient options.

» Unfortunately, while EE is normally perceived as politically correct, it is considered to be a solution for implementation only in emergencies. To reverse that situation, strong cultural changes among all stakeholders and new institutional guidelines are required, highlighting the role of the government and regulators in triggering change.

Even though Brazil's energy mix is one of the least CO_2-intensive in the world, improvements in energy efficiency (EE) could further reduce the environmental impacts of energy use, especially by transforming losses from biomass energy generation into useful renewable energy. This comment discusses the main incentives and obstacles to designing and implementing an EE policy in Brazil. Based on the experience of the Brazilian Institute for Energy Efficiency (INEE) in promoting EE in Brazil, it highlights the role that EE could play in the further decarbonization of the Brazilian economy.

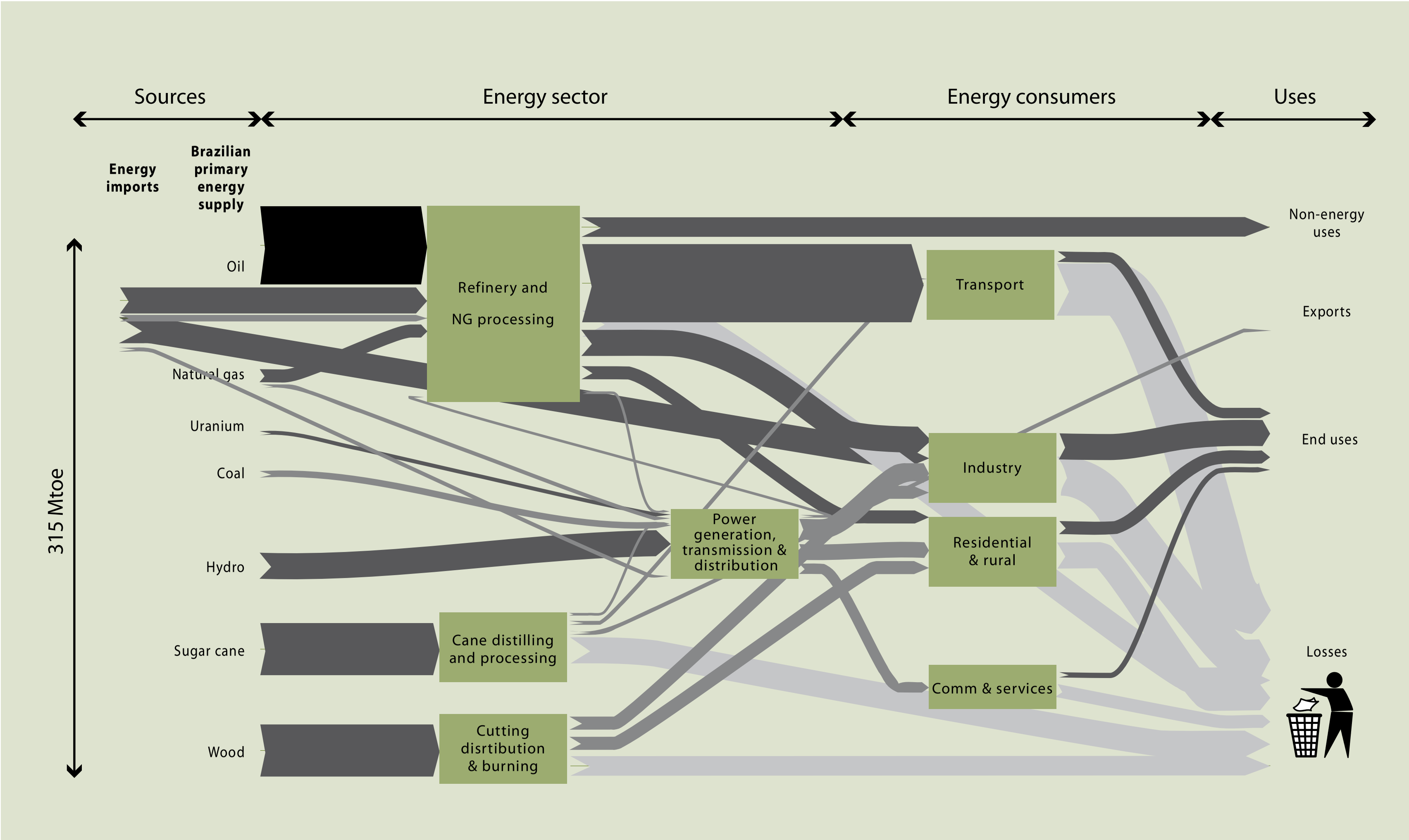
A. Energy efficiency in Brazil

Brazil's primary sources of energy are highly diversified (figure 1). A large proportion comprises renewable sources of energy, one third of which is hydropower and two thirds biomass. These renewable sources meet 45 per cent of the country's primary energy needs. The figure shows that useful energy in Brazil presently amounts to only about one third of the total primary energy inputs, while the remaining two thirds are lost. Energy losses (represented by a large garbage can in the figure) include transformation and distribution losses, as well as process energy consumption within the energy supply sector. In each transformation, the ratio of energy loss to input is a measure of inefficiency. There is considerable scope for avoiding or reducing such losses through EE improvements.

End-use energy needs can be met by increasing primary energy supplies and/or reducing energy losses, whichever is more cost-effective, taking into account environmental and social costs. A sound energy policy should strike a balance between the two, but, traditionally, emphasis has been placed on the generation of additional energy because externalities, among others, have been neglected. However, EE has gained greater visibility as energy sources have become scarcer and environmental concerns more pressing. The oil price increases of the 1970s, the high capital costs of increasing electricity supply and the need to cope with a serious power supply crisis in 2001 led the Brazilian Government to adopt several programmes and legislation which were designed to promote end-use efficiency. The following were the major milestones:

- CONSERVE, a Federal Government programme created in 1981 to reduce industrial energy needs and to develop local energy alternatives to oil imports. Managed by Brazil's Economic and Social Development Bank (BNDES), it was discontinued when international oil prices fell.
- National Labelling Programme, created under the Ministry of Industry and Commerce in 1981 to provide consumers with information regarding the

Figure 1. Energy flows in Brazil, 2007



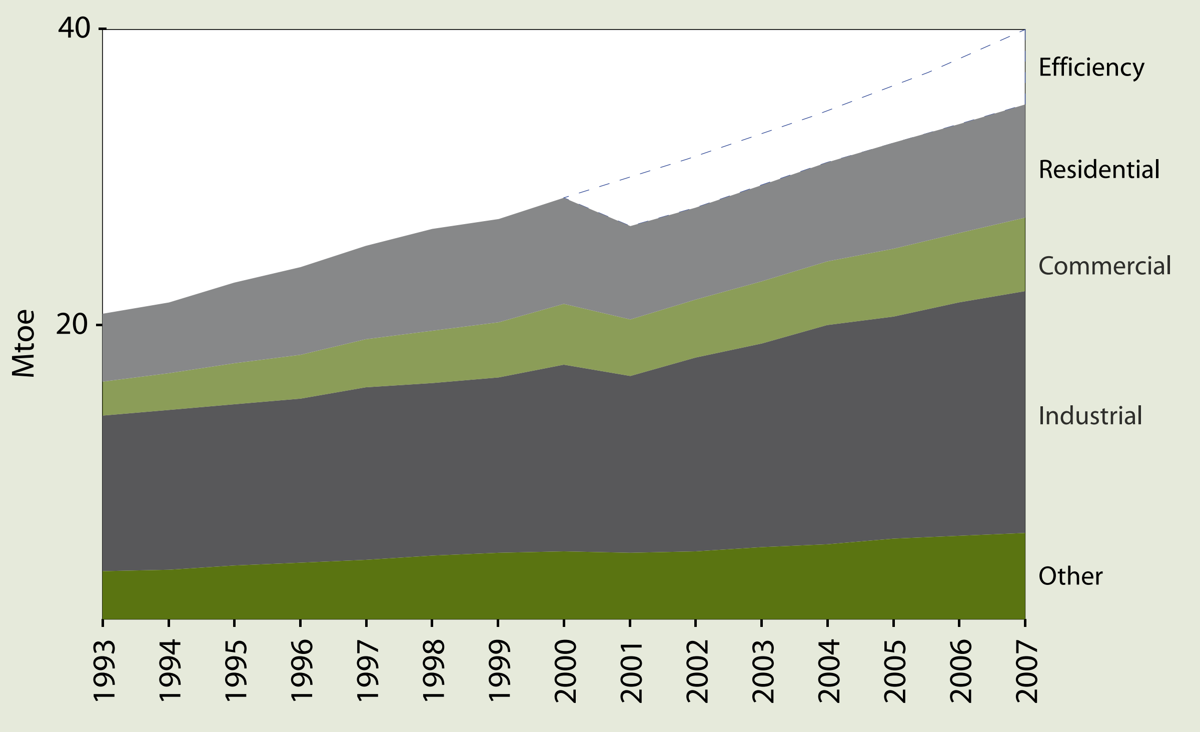
Sources: Ministério de Minas e Energia, 2007 and authors' calculations.

energy consumption of the most commonly used appliances. Under the programme 22 types of appliances are currently labelled.

- PROCEL, created in 1985 and managed by ELETROBRAS (a Federal Government holding company which has stakes in major power generation utilities), this programme aims at reducing the demand for electric power and investment needs of the capital-intensive hydroelectric programme at a time when funds were very scarce.
- CONPET (the national programme for rationalizing the utilization of oil derivates and natural gas), created in 1995, is managed by PETROBRAS, the Government-controlled oil and gas company. It addresses the end-use efficiency of oil derivates and natural gas, and focuses mainly on the conservation of diesel and natural gas.
- Law 9478 of 1997 defined the scope of Brazil's energy policy. Energy efficiency and environmental sustainability are explicitly mentioned as being among its priorities.
- Compulsory investments by utilities in energy efficiency: power utilities are legally obliged to invest 0.25 per cent of their net revenues in programmes aimed at increasing the end-use energy efficiency of their clients. The goal is to reduce energy requirements at a cost lower than that needed to supply it. These gains have to be evaluated by an independent agency, and utilities can be penalized by the power sector regulator (ANEEL) if they do not reach the goals set.
- PROESCO, a line of credit created in 2007 by the national development bank, BNDES, for energy service companies, accepts as a guarantee the expected cash-flow revenues from energy savings.
- Law 10295 of 2001 gives the Government the authority to establish minimum EE standards for manufacturing, trade and imports of energy-consuming equipment. The Government can also define minimum EE standards for buildings.

In 2001, a severe shortage of power supply, aggravated by a drought, led to power cuts throughout most of the country, including in the richer parts. As there was no short-term supply-side solution, and to prevent overall rate increases and supply interruptions, the Government decided to use EE as the main tool

Figure 2. Evolution of electricity consumption in Brazil



Source: Ministério de Minas e Energia, 2007 to adjust demand to availability. The President made a dramatic appeal to the nation to reduce energy use by 20 per cent. A carrot and stick programme was organized and speedily implemented in order to reduce consumption. The media was mobilized to disseminate ideas and information on how to save energy. A major contribution to reduced consumption was achieved by the substitution of fluorescent lamps for incandescent ones. People also modified their habits, turning off lights when not needed, discarding freezers that were barely used and reducing their use of air conditioning.

In one month demand dropped by 6,000 MW (figure 2). This market shrinkage had long-lasting effects, postponing the need for investment in new supply facilities. It was the largest experiment of its kind in the world and it showed conclusively that conservation measures can be very effective in meeting society's energy needs. The authors believe that the overall experience was positive and generally supported by the population, although it had a negative effect on many uninformed industries that refused to admit that they might reach their energy demand reduction goals by means of efficiency measures, instead choosing to shut down production lines and reducing their labour force in order to achieve their reduction targets. This experience helped the Government to push through Congress the bill that led to the energy efficiency law (Law 10295/01), a strong measure for breaking market barriers and anticipating improvements that might otherwise take a long time to be implemented.

As soon as the hydrological situation improved and the need to curb demand was over, the power authorities resumed their supply-side, business-as-usual attitude. Rates were increased to compensate for the market shrinkage and to pay the rent on 2000 MW of emergency diesel generator sets, based on the view that with the end of the power crisis consumers would resume their traditional habits of inefficient energy consumption. However, as shown in figure 2, this did not happen.

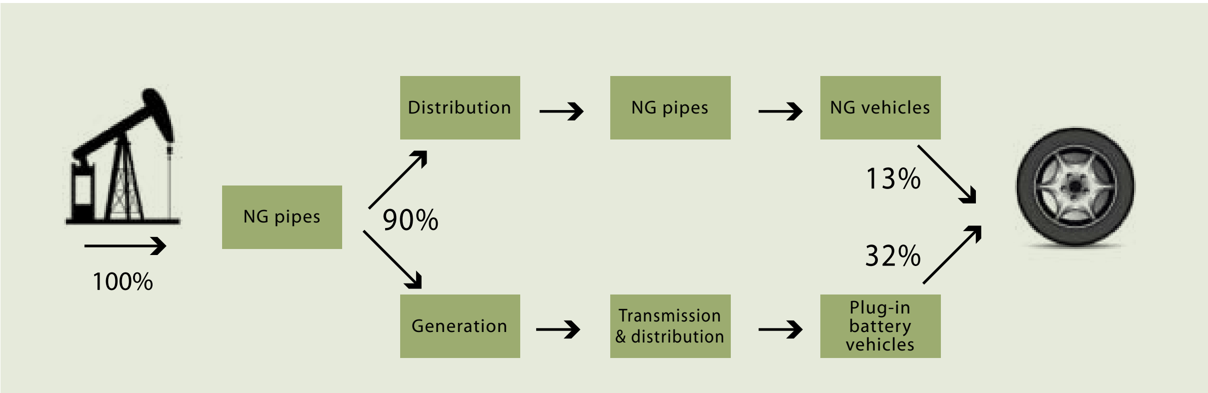
Once the risk of power shortage was over, investments in efficiency programmes dwindled to extremely low levels compared with supply-side investments. Although the quantum leap in efficiency was clearly a consequence of consumers' collaboration and their realization of the possibilities of rationalizing their electricity consumption, no major market study was conducted to analyse consumer behaviour and quantify the main contributions to the reduction in consumption that had been achieved. The most significant reductions were in the residential and commercial sectors (figure 3).

Summing up, Brazil has a good set of institutional arrangements to help achieve end-use EE goals, as shown in 2001. Unfortunately, while EE is normally perceived as politically correct, it is considered to be a solution for implementation only in an emergency. There is a need to inculcate a sense of urgency, whatever the supply conditions may be.

B. Barriers to energy efficiency

Some conditions that are at the root of energy inefficiencies tend to self-perpetuate and are hard to change, either because they benefit some agents (although not intentionally, but some agents may profit from market distortions they create) or because investment decisions may have been based on such conditions. For instance, power utilities used to give excessively high priority to becoming self-reliant: electricity prices were kept artificially low and capital costs

Figure 3. "Well-to-wheel" analysis of natural gas vehicles: percentage of energy reaching an intended end use



for eventual cogenerators were very high. Such factors, among others, led to the belief that only large power plants could deliver low-cost, reliable energy. This understanding has been considerably detrimental to the development of distributed power generation, including cogeneration.

Figure 3 is a "well-to-wheel" presentation that shows two paths of energy transformation. Both start with the same units of natural gas energy (100 per cent) and deliver the same amount of energy through transportation. However, in the upper path, which corresponds to the utilization of compressed natural gas (CNG) in passenger cars (highly promoted in Brazil until recently), only about 13 per cent of the energy reaches the wheels. The lower path, by contrast, in which gas is used to generate electricity to supply a plug-in electric vehicle, energy efficiency is almost three times greater. A similar analysis might be carried out to compare different procedures to obtain ethanol or to produce hydrogen for use in a fuel cell. Efficiencies of the different components of each energy chain are cumulative, so that the whole well-to-wheel effect is what determines the amount of primary energy that will be required to perform a given end-use service. A similar approach is used to compare overall emissions along different paths representative of different technologies.

In addition to enabling an overview of the energy chain, the well-to-wheel approach is also helpful for evaluating the ratio of fossil fuel energy that is required to obtain a certain amount of renewable energy. For instance, ethanol production in Brazil currently uses one unit of fossil energy to produce nine units of renewable energy. Ethanol therefore currently has a 10 per cent fossil fuel energy "content", most of which corresponds to the diesel used to transport the sugar cane from the fields to the mill. If ethanol was used as a transportation fuel, that fossil content would be virtually eliminated.

INEE has advocated many initiatives to promote end-use energy efficiency by focusing on issues that can increase overall energy efficiency through structural changes. To our knowledge, INEE is probably the only organization in Brazil using this approach. Possibilities for improving efficiency include:

i) Increasing energy prices;
ii) Increasing consumers' awareness of the desirability for EE, and of the social costs of energy consumption;
iii) Pushing for the substitution of inefficient equipment and systems by efficient ones, such as the use of LCD, instead of cathode ray, computer monitors and televisions. The latter need 10 times more energy as the former to perform the same service. This substitution was gradual over two decades until LCD prices dropped to a level where it was no longer profitable to sell the inefficient technology in Brazil. Energy consuming equipment has a natural tendency to increase in energy efficiency as technologies develop, and the traditionally inefficient systems are discarded in a Darwinian-like selection process; and
iv) Eliminating or reducing legal, regulatory and cultural barriers to energy efficiency and/or those that impede efficient energy uses. Examples of inefficient energy use in Brazil include the reduced role of cogeneration, the high proportion of incandescent bulbs (basically the same as designed by Edison 120 year ago) in use, and the widespread use of sport utility vehicles (SUVs). Inadequate rules which send wrong signals to the market also hinder EE improvements. For instance, the present rates structure leads to such a high average price of electricity during peak hours – quite above its supply cost – that many consumers are supplementing their energy consumption during peak hours with local diesel power generation.

In the late 1990s, when the unbundling of the power sector took place, INEE advocated the promotion of distributed generation and the creation of independent power producers (IPPs) -– new players that can produce power competitively due to proximity to users and to economies of scale. INEE also pushed for the development of highly efficient cogeneration facilities fuelled by natural gas and sugar cane residues – two fuels which have seen a considerable increase in consumption and which are still generally being used at low efficiency levels. In many, if not in most cases, cogeneration may compete favourably with conventional power plants partly because it tends to be located close to the consumers.

In 1995, Law 9074 set the main guidelines for the reorganization of the Brazilian power sector and its main agents, as well as criteria for authorizing their operation, including basic tariff rules. As a result of a fruitful collaboration between INEE and the Government, the text included the first explicit legal reference to cogeneration and district cooling/heating associated with cogeneration. INEE also contributed to the inclusion of distributed generation (DG) in the text of the 2004 Law 10048, which defines the new power sector model. This law and its ensuing decrees allow distribution utilities to buy up to 10 per cent of their energy needs directly from cogenerators and other DG sources, instead of by means of public auction.

INEE also foresaw the importance of disseminating the concept of energy service companies as a means to achieving higher energy and economic efficiency levels. It organized seminars and workshops that showed their importance for the Brazilian economy and environment. Such efforts contributed to the decision of the national development bank (BNDES) to create PROESCO, a credit line designed to provide an incentive to energy service companies. PROESCO provides loans and mechanisms that reduce bank loan risks.

Concern about the low efficiency of cogeneration based on sugar cane bagasse, mainly due to the use of low pressure boilers, led INEE to organize several seminars to raise awareness about the technical possibilities as well as possible commercial and investment advantages of increasing that efficiency. Sugar cane biomass, which was generally disposed of by incineration, constituted a large potential source of electricity and revenue. BNDES supported the replacement of inefficient boilers and adapted its lending criteria to this industry's needs. It started to offer attractive financial conditions which enabled the installation of high pressure boilers for the production of considerable amounts of surplus power, ranging from about 50kWh to 100kWh per ton of processed sugar cane, using conventional technologies. If all plants had been equipped in this way, about 50 terawatthours (TWh) could have been added to the public network in 2008.

Brazil's main efforts should now focus on reducing or removing the main inefficiencies in overall energy supply and use. As shown in figure 1, these are concentrated in four areas: (i) transportation, (ii) natural gas utilization, (iii) sugar cane transportation and residual biomass utilization, and (iv) wood production and utilization for energy purposes. These areas are discussed separately below.

1. Electric vehicle drivetrain

The use of electric vehicles (EVs) – battery powered and hybrids – is expected to grow rapidly worldwide, and thereby enhance "well-to-wheel" energy efficiency and emissions reductions, contributing to decarbonization. This shift is expected to take place not only with respect to cars, but also light vehicles, such as scooters, motorcycles and bicycles, as well as buses and trucks. This is a market-driven trend that is being accelerated by recent events in the world economy (see, for instance, the significant resources allocated to spur the development of electric cars in the the United States)[55]. INEE strongly supports this shift, and has published several papers to publicize the subject in order to help reduce market barriers and promote the wider use of such vehicles in Brazil. However, INEE is concerned about a possible, though not new, strategy of car manufacturers to import into Brazil the traditional internal combustion motor technologies that are becoming obsolete in their home countries, thereby delaying the utilization of EVs in the country. By supporting the Brazilian Electric Vehicle Association (ABVE), INEE improves awareness about business opportunities for EVs and EV components. At present, ABVE has 72 associates, including power utilities, electric equipment manufacturers, manufacturers of electric cars, bicycles and scooters and related businesses, battery manufacturers, as well as private persons. This initiative is encouraging the emergence of new players to supply the new market needs.

2. Sugar cane

Brazil's sugar-cane-derived ethanol is the most successful effort in modern times to replace a fossil fuel by a renewable alternative. The 2008/2009 sugar-cane harvest[56] had an energy content of 96 Mtoe, equivalent to 1.7 million barrels of oil per day.[57] About 40 per cent of the total juice from the sugar cane harvested in that period was used to produce ethanol and 60 per cent to make sugar. The energy content of the ethanol output was approximately 15 Mtoe, but significant amounts of energy were lost in both production processes.

Table 5. Energy content per unit of sugar cane

1 ton	10^3 kcal	%
Juice (sugars)	608	35
Bagasse	598	35
Leaves and tops	512	30
Total	1 718[a]	100

Source: Onório Kitayama, 2007.
[a]= 1.2 barrels of oil

Table 5 presents the average energy content of sugar cane and its distribution. It should be noted that the juice contains only one third of the energy offered by the plant, whereas the other two thirds are stored in the biomass that is burnt in the field to enable manual harvesting.

The bagasse is used as fuel to supply a mill's heat and power needs. The only energy input from an external source to the sugar cane agro-industry is the diesel used to fuel trucks and harvesting machines (totalling about 1 Mtoe).

Sugar cane mills' energy needs are much lower than the energy content of bagasse and leaves. When the ethanol programme started in the late 1970s, the mills used low pressure boilers (mostly 22 bar) to supply their steam and power needs. These mills could not obtain a long-term price for the surplus power generated and therefore had no incentive to invest in more energy-efficient systems.

The sole objective of the sugar cane programme was the substitution of gasoline, both for security reasons and to reduce the financial burden of high prices of imported oil on the national balance of payments. At the same time, due to investment subsidies and high oil prices that pushed up the price of ethanol, the new ethanol industry did not need the revenue that the surplus electricity would have generated. Furthermore, selling power surpluses would have meant entering a whole new business in a very regulated and, at that time, mostly Government-controlled environment.

Table 6. Boiler pressure and surplus power of a sugar-cane plant

	kWh/tC	TWh	Power (GW)[a]
Counter pressure turbine 65 bar/480ºC[b]	40-60	30	7,8
Counter pressure turbine 65 bar/480ºC[b]	100-150	70	16
Gasification	200-300	140	32

Source: Macedo and Horta, 2005.
[a] Considering a 50 per cent load factor.
[b] For a full-year operation and using 50 per cent of the leaves and tops.

As table 6 indicates, a quantum leap in the overall efficiency of power plants that use ethanol and sugar can be obtained by increasing the pressure of boilers. Ethanol- and sugar-derived energy producers could generate up to 20 per cent[58] of the country's electric power needs by relying on available technologies. In addition, power generation based on gasification of biomass, a technology still being tested, could double this output. As most mills are located near major industrial sites, they do not need to install extensive transmission lines. And as the harvest coincides with the dry season, it avoids and/or delays the drawdown of reservoirs, thereby increasing the overall availability of hydroelectricity. These reasons strengthen the case for a strategy of promoting sugar-cane-derived power.

The good news is that on the one hand there are fewer obstacles to selling power to the national grid, and on the other hand more efficient energy systems are increasingly being utilized in the sugar-cane-based industry. New plants are using high pressure boilers (up to 92 bar) and their electricity surplus has grown considerably, in a very competitive setting. However, about 90 per cent of the mills still use 22-bar boilers and other sugar plant equipment produces less surplus power.

Finally, regarding sugar cane transportation, it is possible to use hybrid electric trucks because their generator prime engines may be fuelled with ethanol that is used more efficiently. Actually, such internal combustion motors, which can work on an Otto-cycle, may be of a smaller size than those of conventional trucks using diesel oil. Since the truck wheels are driven by very high torque electric motors, the smaller internal combustion motors have lower torque requirements than the present diesel motors. Hybrids are particularly appropriate for short-haul and stop-and-go transportation and, as battery technologies improve, hybrid trucks will also be able to work as plug-ins, using off-peak power generated at the sugar mill. This would improve energy efficiency and reduce, if not remove, the dependence of the sugar cane industry on diesel.

3. Natural gas cogeneration

Natural gas (NG) supply is relatively recent in Brazil, and is mainly associated with oil production in the south-eastern part of the country, close to the main industrial centres. This supply is now supplemented with imports from Bolivia through GASBOL, a 1,200 km pipeline with a capacity to transport 30 million m³/day. Although the Government had set a market share target for NG of 12 per cent of the total primary energy supply, practically no preparations for the gas distribution and consumption were made prior to its commissioning in 1998. Even though that pipeline crosses the highly industrialized State of São Paulo, it remained largely idle for several years.

As in other countries, NG supply had difficulty penetrating the Brazilian market since it had to compete with well-established markets for other fuels (i.e. an increase in NG consumption would have required the reduction or relocation of competing energies). Market development has gone through a trial-and-error approach that included a government decision in 2000 to build 49 power plants with a total capacity of 14,000 MW. This belated and unrealistic decision was taken when the risk of a power shortage had become acute. That plan was dissociated from the existing hydro system, and was eventually dropped, but not before a number of plants had been built, including several open-cycle inefficient plants. Other experiments involved tax incentives to develop the market for compressed natural gas (CNG), including retrofitting light vehicles and gasoline-run Otto-cycle motors, which become very inefficient when fuelled with NG since their compression rate is too low for its use. This use of NG, with a well-to-wheel efficiency of less than 15 per cent, contributed to reducing the country's overall energy efficiency. Of course, at the time the decision was taken on a $/kcal basis, and the energy from NG was cheaper than that of gasoline or ethanol. But the setting of these prices proved inappropriate because NG prices have since increased and it ignored the major externalities involved, as often still happens when renewable and non-renewable energies costs are compared.

New appropriate uses of NG by industry are developing, but its most efficient use, in cogeneration, is developing too slowly. Cogeneration, which enables up to 85 per cent of the energy input to be converted into useful energy (much more than combined cycle power generation, the efficiency of which is close to 50 per cent), is still much below its potential, because the legal framework hindered self-generation (i.e. typically by the users themselves, such as solar panels in households) and the rates applied to large consumers of high voltage that were often subsidized.

As mentioned, however, the new power sector model lifted obstacles to accessing the national grid, and the new regulatory agency (ANEEL) is gradually reducing distortions in power rates. At the same time, newly found and very important NG reserves are under development in Brazil, which will increase the possibilities of using it more efficiently in the future.

4. Wood

According to the 2007 National Energy Balance, published by the Ministry of Mines and Energy, wood as an energy source contributed almost 29 Mtoe (i.e. 12 per cent of Brazil's total primary energy supply). One third was used for domestic and rural activities in a fairly sustainable way, while the remainder was used for industrial purposes. While the overall chain of transformations and uses of wood in Brazil is poorly understood, it is clear that the overall efficiency of biomass is very low. Wood is still treated as a non-commercial source of energy and is not covered by any regulation. This is certainly related to the fact that wood is widely available for use with primitive technologies, not to be compared with the "noble" sources (e.g. oil, coal and hydro) that require sophisticated equipment in their chains of transformation and use.

However, some industries and segments of the rural population in Brazil are heavily dependent on wood. Charcoal is used instead of coke and NG for 34 per cent of the country's pig iron production of 34 million tons.[59] It is also widely used in the steel and alloy industries. Nevertheless, the country has no specific energy policy for this source. About 5 per cent of wood (1.3 Mtoe) is used as an energy source in the pulp and paper, bricks and tiles, and lime industries. Whereas the pulp and paper industry and some iron producers use biomass residues from planted trees, most of the other industries rely on wood collected from the wild, and use primitive technologies and inefficient furnaces.

About half of the charcoal is derived from wood from planted forests, while other charcoal producers use wood collected from the wild. The latter use primitive and inefficient kilns built with local materials. Their prices, given the informal nature of production, are lower than those of charcoal from planted trees, although the latter is generally produced in industrial, more efficient, facilities. Worse still, there are no incentives for the industries to exploit the gases from combustion, which can be used both for energy and non-energy production purposes. The rudimentary kilns used in the forests to carbonize native wood are unable to preserve the fluid by-products of charcoal production, but neither is this done even in the majority of the relatively modern facilities. With the exception of the pulp and paper industry, that uses state-of-the-art cogeneration technologies, there is no incentive for efficient use of energy in the wood chain.

An energy policy for wood, with explicit rules for production, distribution and sale of all wood-derived energy products would be crucial to organizing the wood market. It would involve regulating physical and chemical characteristics of all wood energy products in a similar way as is done for all other commercial energy production in Brazil. Standardization will be paramount to optimize furnaces for pyrolysis and gasification. Market mechanisms, if properly organized, would increase productivity, reduce prices of charcoal and prevent the use of native forests much more effectively than today's efforts at enforcing environmental and labour laws in remote, barely controlled areas. At the same time it would certainly increase the utilization of wood by-products, such as bio-oils and tars.

Regulation would also help to develop the use of pellets and brickets – wood substitutes produced by compressing biomass residues – which are available in large quantities throughout the country. Some fieldwork by INEE shows promising results in using short-duration crops of high-yield grass (e.g. elephant grass and *Pennisetum purpureum Schum*) in the wood energy chain. These can produce cheap wood substitutes and bio-oils and charcoal by fast pyrolysis. The charcoal powder, obtained from grass carbonization, can be used as a soil enhancer and at the same time as a very cheap carbon sink.

C. Conclusion

Brazil's energy use is one of the least carbon-intensive in the world, in terms of both per capita and GDP. Energy efficiency could further improve this position, especially because, as argued above, there is plenty of scope for transforming the large losses of energy biomass into useful renewable energy. Accumulated experience in this field can be very helpful in providing solutions for application throughout the tropical world, thus creating considerable South-South trade and investment opportunities.

Diversity of energy sources in Brazil is certainly a blessing, but it also poses difficult challenges to policymakers and stakeholders in energy supply and use. There is a tendency to ignore this diversity and to focus on specific energy sources and their related technologies. Energy policies often concentrate on particular transformations and products instead of focusing on the entire chain. The Brazilian sugar-cane-derived ethanol industry is often compared with those based on cassava (in Brazil), corn (in the United States) and sugar beet (in Europe). The basic reason for the superior competitiveness of sugar-cane-derived ethanol is that all other alternatives are strongly dependent on fossil fuels, as the plants they use do not provide the process energy required, mainly for grinding and distillation.

In INEE's view, the best way to integrate EE considerations into energy policy is to assess all possible paths to energy transformation and transport on a "well-to-wheel" basis, and work to identify the more efficient options. That is not an easy task, as demonstrated by the case of power generation in Brazil's sugar-cane mills. While power-generating opportunities from bagasse were known when Proalcool was in its infancy,[60] they were neglected both by the power sector and the sugar-cane industry. In order to reverse that situation, strong cultural changes among all stakeholders and new institutional guidelines were required, thereby highlighting the role of the government and regulators in triggering change. Once efficiency gains are triggered, a self-sustained cycle starts because inefficient technologies tend to be superseded by more efficient alternatives.

The complete picture in a complex economy will reveal a number of possibilities and business opportunities. Governments must play a fundamental role in this process, as many market imperfections exist that are a consequence of a lack of political will to develop efficiency as well as a lack of appropriate fiscal and rate structures.

Notes

[1] EE provides significant opportunities to change development pathways towards lower emissions (Sathaye et al., 2009).

[2] For example, the IEA (2007a) estimates that in China, one dollar invested in more efficient electrical appliances could save $3.50 on the supply side.

[3] Commission on Climate Change and Development, 2009.

[4] However, in the longer term, and with more ambitious climate stabilization targets, the mitigation response may be shifting from EE towards reduced carbon intensity. The main reason identified in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) is that the costs of further EE are expected to grow in the longer term, while those of low-carbon energy sources are projected to decrease (Urge-Vorsatz and Merz, 2009).

[5] The reference scenario envisages the need for a cumulative investment in energy infrastructure of $26.3 trillion during the period 2007–2030.

[6] In 2007, Merrill Lynch introduced an Energy Efficiency Index including the stock values of 40 companies in these sectors that derive a significant share of their revenues from supplying the EE market.

[7] In France, the Government provides €1,000 to those who scrap a car over 10 years old and replace it with a car with emissions of less than 160g/km. In Italy, the incentive is €1,500 for a car over 10 years old that is replaced by a new car with emissions of less than 140g/km. Germany provides €2,500 if the purchaser deregisters a vehicle that is older than nine years, whereas Spain provides an interest-free loan. In the Netherlands, the Government introduced a scrap premium of between €750 and €1,750, with a total budget allocation of €85 million.

[8] The programme provided a rebate of either $3,500 or $4,500 per car. Rebate applications worth $2.877 billion were submitted, slightly below the $3 billion provided by Congress to run the programme. Under the programme, nearly 700,000 “clunkers” were taken off the roads and replaced by more fuel-efficient vehicles. Cars purchased under the programme are, on average, 19 per cent above the average fuel economy of all new cars currently available, and 58 per cent above the average fuel economy of cars that were traded in (United States Department of Transportation, 2009).

[9] See, for example, Edmonds et.al.,2007; and Blair and the Climate Group, 2008.

[10] For sector-specific barriers, see, for example, UNIDO (2007) on motor systems and the WBCSD (2008) on constraints in the buildings sector.

[11] In India, for example, much of the industrial output is derived from small-scale, often village-based, enterprises, fuelled by inefficient motors and equipment, and it has been difficult to implement efficiency improvements (IEA, 2007b).

[12] The Energy Efficiency Policies and Measures database of the IEA provides information on policies and measures taken or planned in IEA member countries, the Russian Federation and major developing economies. The database provides a comprehensive annual update of the policy-making process in place since 2000 (www.iea.org/textbase/effi/index.asp). Information can also be found on the website of the Collaborative Labeling and Appliance Standards Program (CLASP), at: www.clasponline.org/worldwide.php.

[13] They may also be needed where EE is not an important selection criterion of consumers (e.g. television sets).

[14] Comprehensive information can be found on the website of the Collaborative Labeling and Appliance Standards Program (CLASP) cited above.

[15] Although some states play a major role in establishing MEPS, a number of states’ standards have now become Federal law, and Federal MEPS have been given pre-emption over state standards.

[16] In 2009, the Commission also intends to submit implementing measures on televisions, domestic lighting, domestic refrigerators and freezers, washing machines, dishwashers, boilers and water heaters, computers, imaging equipment, commercial refrigerators, electric motors, pumps, fans, circulators and room air-conditioners (Commission of the European Communities, 2008a).

[17] The *WEO 2007*, table 11.8 (IEA, 2007a) summarizes policies that have already been enacted and others that are still under discussion in China.

[18] In some developing countries, second-hand appliances may account for a relatively large market share of the appliances sold, thus reducing the impact of labelling, which is normally restricted to new appliances.

[19] See website of the European Commission, Directorate-General for Energy and Transport at: http://ec.europa.eu/energy/demand/vol_agreements/index_en.htm.