

Balance of Power



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Energy Policy Priorities in Latin America

ENERGY POLICY IN TODAY'S WORLD IS DIRECTED ESSENTIALLY BY three main objectives: security of supply, efficiency of supply, and social and environmental sustainability. But given the varied characteristics of the many societies concerned, the emphasis in a particular region may be quite different. In effect, energy policy means very different things to Latin American countries than to the developed economies of Europe and the United States. The countries in Latin America do not yet satisfy the energy needs of much of their people, who must often rely on burning wood for heating and cooking. The additional objective of social justice and social equity becomes relevant. While some countries in the region are still facing low levels of electrification, others are crippled by insufficient investment in energy infrastructure. Finally, the region is resource rich, with a diversity of energy options (coal, gas,

hydro, biomass, wind) available but unevenly distributed among the countries. Hence, cross-border supply decisions to foster the development of given technologies are always being discussed. As energy demand increases with economic development, Latin American electricity growth rates have been greater than 5% per year during the last decade. Yearly needs for investment in energy infrastructure in the region are comparable with those of the United States and Canada put together. South America alone will require about US\$90 billion of investment in the power sector in the next ten years.

With such challenges, it is not a surprise that discussions about defining energy policy become very heated. The perception that energy plays a strategic role in economic development often tempts governments to intervene in energy markets, clashing with those who view markets themselves as the entities that should drive policy. In the early 1980s, Latin America pioneered in introducing market approaches to the energy sector, after a long period in which the state was the principal force behind major energy infrastructure development. Nevertheless, different supply crises have shaken the market's foundations, and many governments are now intervening again, trying to stimulate investment for energy supply. In other cases, political instability is weakening public energy policy development.

The European overinvestment condition, where a few major energy holdings keep investing to retain market share, has little to do with the Latin American condition, where the fear for underinvestment is chronic and societies have difficulty attracting investment. With such different conditions, it is awkward that public policy definitions in the region are being fueled by developments in the affluent societies of the Northern Hemisphere, which do not necessarily experience the challenges being faced locally. While the concern for energy dependence is common to the world at large, energy resources within Latin America are enormous, and the region's energy matrices can afford to pursue their own paths. While climate change is a global

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issue, with energy production and transportation the two main sources of greenhouse gases, the contribution of Latin America to global warming is almost nil.

Drivers of Supply: From Private Investors to the State

Electric power got off to a fast start in Latin America. Soon after Edison demonstrated the electric light in 1879 in New York City, it was being implemented in various other cities in the region. Thermoelectric and hydroelectric power stations were soon being built by mining and textile companies. It was always private investors who saw in this new energy form opportunities to improve their production or reduce their costs.

Public service soon started in many municipalities, and electricity companies were formed. Initially the power sector developed on the basis of private investment, with no special regulation other than the creation of concessions to extend networks through cities and request rights-of-way when needed. But during the Great Depression of the 1930s, private investment dried up throughout the region, to the detriment of electricity supply to cities, industry, and mining.

In most countries, governments seized the initiative and from the 1940s to the end of the 1970s put aggressive electrification programs into effect. National electricity companies were created. Power system development was their responsibility, and they built large hydroelectric plants and transmission lines tying previously isolated networks into interconnected systems. Similar conditions arose with the formation of national oil companies that initiated exploration and handled production and/or refining. Public energy policy and system infrastructure expansion was left in the hands of these state companies, some of them becoming so strong that they became political powers of their own, exercising more influence than the regulating agencies charged with their oversight and often confronting the central government themselves, irrespective of the public interest.

Private firms still existed, but mostly at the energy-distribution level in the main metropolitan areas. Energy was thought so essential to the functioning of society that it had to be in the hands of the state. The need to provide small-end consumers with low energy prices has always been a main priority in the region, and governments often acted accordingly. Underpricing energy while financing state-owned companies through central tax revenues was a common feature, often abused in years of political elections.

This period of a proactive state in Latin America ended in endemic problems, with the public authorities failing in the long run to adequately manage electricity companies. Electric power development in many countries was hamstrung by the inefficiency of state-owned, vertically integrated monopolies.

The Emblematic Reform of the 1980s

An upheaval reform process began in the region in 1982 when Chile formalized a major change of direction in public policy, centered mainly in the electricity sector but also extending to gas. Argentina followed suit in 1992, then Peru in 1993, Bolivia and Colombia in 1994, Central America in 1994 and 1995, and finally Brazil beginning in 1996. The initial drive was due to free-market ideas gaining currency and giving rise to the notion that government control over the economy should be reduced and the role of the private sector enhanced.

Chile in essence aimed at replacing the government in defining public energy policy with the market and the different economic agents that would participate naturally. This change came not so much out of a desire to reshape the electric sector as such but because of broader economic and political aims that were implemented at the time by the then-military government. It is interesting to note that similar ideas were flourishing in the United Kingdom at the same time, when Nigel Lawson, the British secretary of state for energy, in a famous speech given in June 1982, indicated that "U.K. energy policy is to have no policy; markets will deliver."

The governments in the region that initiated these reforms faced a condition where oil, coal, gas, and electricity prices, mostly set by large state companies, were completely distorted. In most cases, these prices were used as mechanisms to help control inflation. Cross subsidies produced an inefficient use of resources, unnecessary investments were made, and capital was being diverted from other social needs. The key new ideas were that decentralized decisions by energy consumers and producers were bound to yield economic efficiencies. Therefore, prices of the different energy products should reflect their true economic value so that individual decisions coincided with the least cost for the country. This was easy to implement for oil, gas, and coal, as they were traded internationally. But this was not the case for electricity. The revolutionary concept of creating a competitive wholesale electricity market at the generation level came from an understanding that an efficient and coherent electricity price policy could be based on the use of marginal supply costs.

The turn of the century brought different challenges to the energy supply in the region and to its market policy emphasis, coupled with a worldwide rocketing up of fuel prices.

The changes were bound up with a redefinition of the role of the state in Latin American societies whose economic development used to be led by their governments. In the energy sector, the main role of the government was to regulate activities that were monopolistic (for example, electric transmission and distribution), letting the private sector drive investment and operation in activities that could be developed within competitive market conditions. Decentralizing, decentralizing, and finally privatizing the activities and property of the electricity companies were part of the initially defined path. But the process implied conflict; reforms were only achieved in those countries where strong governments could drive them through parliament. Privatization was not an easy path, as it has historically encountered political opposition in the region. Foreign investment was unwelcome at times, particularly when the issue of the “strategic importance of energy” was raised. For example, this discussion arose in Chile when international entities sought to buy companies that were already private.

Besides aiming at market forces to shape efficiency in energy supply, countries looked at private investors to respond to the need for expansion to assure supply adequacy, as the government’s resources were not sufficient to fund the investments in new generation capacity required to match the significant load growth. Private participation in energy investment in Latin America has been a globally important theme, as shown in Figure 1.

The impact of the reforms and privatization was remarkable; the best example was Argentina, which had appalling conditions before. In power generation, Argentina developed one of the most competitive markets worldwide. Availability of the thermal generation infrastructure increased from a historic low of 47% in 1992 to 75% in four years, while average monthly electricity prices in the wholesale market dropped from US\$50/MWh to US\$25/MWh after deregulation and privatization, and domestic consumption grew at an average annual rate of

5.7% between 1992 and 2000. Distribution losses, energy theft included, were halved in just three years. Investment in the generation-transmission-distribution chain dropped from US\$6,000/kW to approximately US\$2,000/kW for installed capacity, indicating a tripling of the productivity of money put into the system. Two private dc interconnectors of 1,100 MW each were privately built to export electricity to Brazil. Increase of energy exports also included oil and gas. Argentina stopped importations of gas from Bolivia in 1994, while it started exportations to Chile and Brazil.

More efficient maintenance, the upgrading or replacement of existing equipment, and more sophisticated control systems for a tighter use of installations were all used to increase reliability and postpone further capital investment. The search for more efficient technologies in generation equipment, as well as cheaper energy resources, drove many private investors to build combined-cycle gas units, with related investments in transporting natural gas across international frontiers. South America soon became an international network of natural gas pipelines.

Reform paths differed among the countries of Latin America, stemming from independent assessments by each as to the advantages of one model over the other. It must be remembered that solid applied knowledge, worldwide, as to

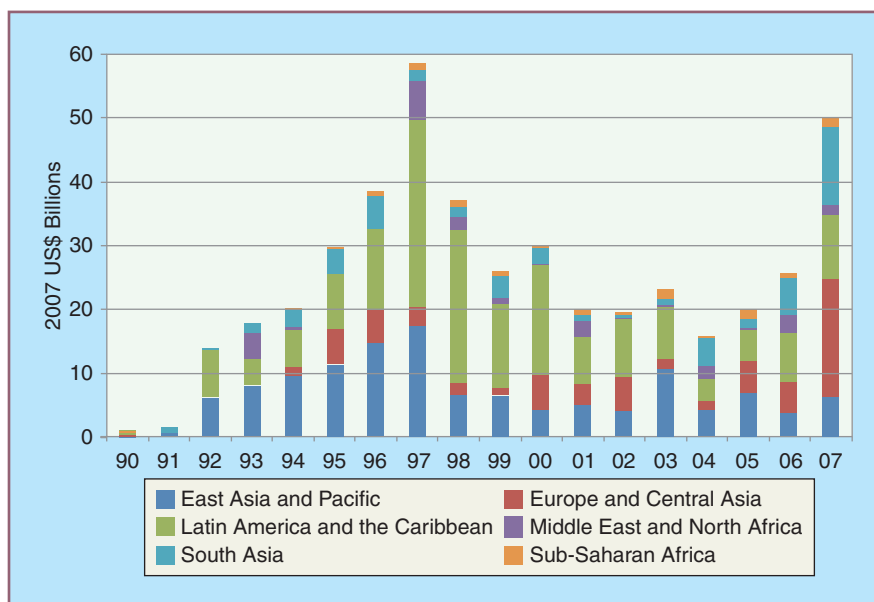


figure 1. Investment in energy projects with private participation in developing countries, by region, 1990–2007 (source: World Bank and PPIAF, PPI Project database).

the best industrial organization and regulation for this new energy market framework, particularly in electricity, had been absent. A distinctly experimental flavor pervaded the whole course of the reform process.

On the other hand, it is certainly not the case that reform and privatization, the market approach to energy policy definition, constituted a coherent path in the region. Chile, while completely privatizing its electricity sector, left oil exploration exclusively in the hands of the state, while Argentina privatized its public oil company, Yacimientos Petroliferos Fiscales, which had the monopoly on upstream activities. Brazil privatized most of its electricity distribution companies, but due to political opposition only 15% of the energy generated was privatized. Mexico considered reform several times to reduce inefficiency in the electricity sector, but its state-owned Comision Federal de Electricidad was always able to stay in control. To say that markets ruled in the region and defined public policy is only a partial truth.

New Challenges in the 21st Century

The turn of the century brought different challenges to the energy supply in the region and to its market policy

emphasis, coupled with a worldwide rocketing up of fuel prices. Trouble started in Chile in 1999 when the worst draught in a century put the market framework to a test and created problems in electricity supply. A similar development occurred in Brazil when a severe draught in 2001 left no alternative but to impose 20% energy rationing during nine consecutive months in 2001 and 2002. Finally, to make things worse, by the end of 2001 the energy supplier of those countries, Argentina, which sold gas to Chile and electricity to Brazil, faced a severe political and economic crisis, putting an end to the flagship reform. The Argentine economy reached an emergency status, which led to heavy government intervention, including the freezing of gas and electricity prices and the distortion of oil-derivatives prices. In what was a political decision of the government, the private energy sector had to contribute to support and finance the local industry during the crisis years, when the market was completely forgotten.

The Argentine crisis, coupled with a change of government in Bolivia that resulted in the nationalization of its gas fields, made the neighboring countries critically aware that energy supply security was a value in itself. It was not only a matter

Competitive Procurement and Energy Policy

Brazil and Chile pioneered the introduction of energy contract auctions in the region in 2004 and 2005, respectively. A procurement scheme for the regulated market was adopted in which auctions to contract energy for future delivery are carried out as needed. The core of these changes lies in three main rules: all consumers should be 100% contracted; all contracts that are financial instruments should be covered by "firm energy" or "firm capacity" certificates; and finally, contracts for regulated users must be awarded under competitive public auctions. These auctions were clearly a market-based policy decision. The advantage of the auction of contracts is to recognize that a power purchase agreement provides a degree of certainty in the generators' cash flow, thus allowing access to long-term financing, and can be cost-competitive if procured through international competitive bidding (competition for the market).

In the Chilean auction model, distributors separately auction their demand in a single, simultaneous process, during which every generator bids for a specific set of products. In the Brazilian case, distributors add their quantity needs (demand) in one process in which every generator bids for a quantity of average megawatt per product for future delivery. Although these auction mechanisms are both derived from a multiunit, pay-as-bid auction during which all distributors may auction their demands in a single process, they present large differences, basically due to the different configuration of market prices (energy and capacity payments) and the homologation of all demand from different distributors in the Brazilian case versus the nonidentical blocks of demand

in the Chilean case. Both processes have been successful in attracting new investment, ensuring long-term supply.

While Chile did not make any distinction among specific generation technologies and at the 2009 auction there were existing hydroplants competing with new coal and wind plants, Brazil made a different public policy choice. Separate auctions were carried out for existing energy (contract renewal) and new energy. In the auctions for new energy, all technologies compete together for a contract. The Brazilian regulation, however, lets the government carry out specific energy auctions driven by energy policy decisions. These auctions in general follow the same design of the standard ones but are carried out to foster the development of specific non-competitive technologies or to increase competition among investors in specific projects or technologies. From 2004 to 2009, this mechanism has been used three times:

- In December 2007 and May 2008, special auctions were carried out to contract new energy from the first hydro plants in the Amazon region that became commercially available. This involved a complex of two hydro plants, Santo Antonio (3,150 MW) and Jirau (3,300 MW), located in a single river (the Madeira). The scale of these plants resulted in a large capital expenditure by its potential investors (some \$US5 billion for each plant, excluding transmission costs), and it was felt that these would not be "standard" candidates for the regular new energy auctions (only a few investors could compete). Therefore, special auctions were carried out to

of efficiency and adequate prices but also of really having the energy when needed. Both Brazil and Chile finally faced the crisis by introducing more market-oriented decision making into their regulations through an auction-based mechanism to foster new generation capacity. Both countries also looked at ways to reduce the risk of energy dependence.

But the changes in Brazil and Chile were not all pro-market, as governments, looking to timely investments and diverse suppliers, started intervening directly. A good example is Chile, where the market approach was born and where the government decided in 2004 to build a liquefied natural gas terminal, aiming to make the country independent of Argentine natural gas. It was a geopolitical decision by the state that had support from some private companies but was not born out of market interactions. The government decided to build a second terminal in 2008. Still, neither Chile nor Brazil aimed at recreating the old government companies, as Argentina did in 2004 when it formed a new state-owned company. The Argentine politicians argued that the withdrawal of the government from the energy sector during the 1990s was excessive, and consequently a more significant presence was required.

Chile, more cautious, decided to have a stronger regulatory government presence in the energy sector and is in the process of creating a ministry of energy, which did not exist previously.

Power System Expansion

The challenge of fostering investment in new generation is very critical in fast-growing markets such as Latin American countries, which have quick (and volatile) load growth and where the introduction of new generation is critical to support their growing economies and determine their competitiveness in the global market. Investors in these countries need to avoid the energy spot price volatility of their hydro-dominated spot markets and support their projects with stable cash flows, which enable them to obtain low spreads in their project finance structure. Mechanisms for stimulating generation expansion have been experimented with in the region; these include the capacity payments introduced in several countries, which complement the energy spot pricing scheme.

A new mechanism, energy contracts auctions, emerged in the region as a good solution for reconciling risk

contract these plants (one specific auction for each plant) so as to increase the number of interested investors and foster competition among them. Contracts for 30 years were offered for delivery five years ahead.

- In August 2008, a special auction to contract new energy from the cogeneration of sugarcane bagasse (bioelectricity) was carried out. The motivation of this decision was the ethanol boom observed from 2006 in Brazil, which fostered an expansion of sugarcane production areas and the installation of 90 new ethanol mills from 2007 to 2012. Sugar and ethanol production require both steam and electric power, which are produced through the combustion of bagasse, the residue of sugarcane left after crushing for syrup extraction. This use of bagasse as a fuel immediately opens the possibility of producing and selling electric energy surpluses, e.g., by the use of more efficient (higher-pressure and higher-temperature) boilers. Hence, to free-ride on the ethanol expansion with benefits for the power sector, a special contract auction was carried out in 2008 to contract new energy from this *technology*. It had as an objective motivating the installation of more efficient boilers in the new ethanol mills (meaning more available electricity) and creating competition among the sellers of this technology.
- In November 2009, a special wind-power energy auction will be carried out. Wind power is still not competitive economically in Brazil, and the motivation behind this auction is to take

advantage of the financial crisis, which has lowered equipment costs, and to foster competition among the interested investors of this technology, thus sparking its development in the country on a larger scale. Energy contracts for 15 years for delivery in 2012 will be auctioned. Remuneration will be according to production, with some revenue stabilization.

One advantage of the Brazilian joint-contracting scheme, not present in Chile, is that it is able to take into account economies of scale in the contracting process, which are especially beneficial for small distribution companies (“discos”). Each separate winner of an auction will sign individual bilateral contracts with each distributor participating in the auction, with the energy amount of each contract being proportional to the disco’s declared demand and the total contracted quantity for each generation company matching its offered quantity. Although a “central procurement” is made, discos are responsible for deciding how much energy they want to contract (i.e., they are responsible for load projections). This fact avoids the “optimistic” government bias that in many countries has led to overcapacity and expensive energy contracts and moves energy procurement away from the single-buyer model, as the government does not interfere in the contracts or provide payment guarantees. The product auctioned is a standardized forward energy contract. As mentioned earlier, in the Brazilian and Chilean auctions, all candidate projects compete together for contracts in an auction mechanism that follows a hybrid design, mixing a simultaneous descending clock scheme with a final pay-as-bid round.

Public energy policy has acquired a new dimension in the last decade with the phenomenon of global warming.

reduction for new investors with efficiency in energy procurement for regulated users, thus ensuring new investments in generation. Both Brazil and Chile aimed at attracting competitive investors that would offer investment in power generation to supply distribution companies with prices that, for a change, would not be defined by the regulator but would be the result of the auctions themselves (see “Competitive Procurement and Energy Policy”). The challenges consisted in achieving both energy supply security and adequate prices.

A central question in these processes arises with respect to the state’s role in directing power expansion into specific generation technologies. During the period when state electricity companies ruled the region, their centralized planning decided which path to follow and (for example) initially forced large hydro development. The market approach of the 1990s declared itself neutral to technology; the aim was to have the most economical technologies dominate the market, with costs and prices driving decisions by private investors. At most, governments would determine *indicative* expansion plans, similar to the centralized plans of yesterday but not compulsory. As markets became mature, those indicative plans were often largely surpassed by reality.

However, such technical neutrality has recently given way to government intervention and direct support of specific technologies. While Chile passed a law that forced a 10% renewable energy quota, not including large hydro, to be incorporated in all long-term contracts, Brazil used a backstop mechanism of its auction model that lets the government carry out specific energy auctions driven by energy policy decisions whenever necessary (see “Competitive Procurement and Energy Policy”). Although in the Brazilian approach the objective is to foster competition among the different candidates for the same technology, government promotion of specific technologies has the zest of the old days of central planning. The beauty of a fully competitive mechanism where all technologies compete is the discovery of the most competitive ones and the possibility of having participants that would hardly be in the planning studies of a central agency as mainstream generation players.

Public Energy Policy and the Environment

Public energy policy has acquired a new dimension in the last decade with the phenomenon of global warming. There

is a scientific consensus that the increase in the earth’s temperature is driven by greenhouse gases in the atmosphere as a consequence of human activity, mainly energy consumption and electricity production. The increase of temperature is forcing a global climate change that will have long-lasting effects. Thus, climate change has become an important driver of energy policies in the developed economies, particularly in Europe. The transition to a low-carbon global economy is defined as a goal and developed countries, responsible for 46% of greenhouse gases, are increasingly committing to achieving it. This has meant, for example, that the European Union has committed to increase the use of renewable energies to 20% of total production by 2020.

But what level of intensity and swiftness should emerging countries, especially in Latin America, adopt in responding to climate change? Emissions of greenhouse gases in the region were only 4.9% in 2004. Regional carbon dioxide emissions caused by electricity production are substantially less than worldwide averages, due to the large component of hydropower generation. As an example, Brazil and Chile contribute only 1.1% and 0.2%, respectively, of world carbon dioxide emissions. Mexico, the largest emitter in the region, produces 1.5%. In terms of emissions per capita, in 2004 Chile released 3.9 tons of carbon dioxide, which puts Chile in 90th place worldwide. Figure 2 shows a comparison of CO₂ emissions worldwide as a percentage of global total emissions, indicating the small contribution by the region. Should these conditions, similar in all countries in the region, really drive energy policy in Latin America? Should governments initiate subsidy programs for renewable energies similar to those in Europe and the United States? For example, the Chilean quota of 10% renewable energy is not an explicit subsidy, but specialists assess that it will imply a higher energy cost for the country of around US\$4 billion, present value. Brazil has also been discussing green energy compensations for new fossil fuel plants. It is easier for governments in the region to assign the burden of emissions cuts and control to the power sector, as this industry is much more regulated and institutionalized than others that may contribute even more to emissions (such as transportation and, in the case of Brazil, deforestation).

The negotiation of the post-Kyoto protocol, to be held in Copenhagen in December 2009, will have to address important issues, since it is clear that the Kyoto objectives will not be sufficient to contain climate change. Certainly the energy sector, which makes a major contribution to the greenhouse

gas emissions, will be in the spotlight. And the question is how will different countries of the developing world be asked to contribute to emission reduction as their emissions grow in tandem with their economic development? China and India are the most outstanding examples. Although Chile does not contribute significantly on a global scale, emissions per capita have shown an increased growth rate far higher than those of other countries in the region. Between 1990 and 2004, per capita emissions had an average annual growth rate of 5%, adding up to total growth of 97%.

Even before Copenhagen, there have arisen environmental movements in the region on a local scale. The development of power plants is facing increased opposition, not based on their contribution to global warming but on how they affect local populations and habitats. Large- and medium-size hydroelectric plants of both the run-of-river and reservoir type have faced heavy opposition organized by nationally or internationally supported environmentalist groups, developments along the Amazon and in Patagonia generating the most intense reactions. Environmental licensing has also been troublesome, often becoming a highly disputed process. But since energy growth must be served, coal-fired plants have been flourishing; though they also face opposition, it is often local and not well organized.

Energy efficiency has played an important role in developed countries and is starting to be adopted in Latin America. There is no doubt about the need to move forward in implementing energy efficiency plans, working towards decoupling energy growth from economic growth. But considering the social and economic growth needed in the

region and the impact on energy demand, the effect of energy efficiency programs will be limited and will not replace the need for the development of new power plants, at least in the medium term.

On the clean-energy path, there was one outstanding public policy decision that was made in the region in the early 1970s that attracted worldwide attention: the ethanol development of Brazil (see “Brazilian Oil Policy and the Emergence of a Multimarket Ethanol Industry”). It was aimed at reducing the country’s vulnerability to international oil prices and gave rise to a multimarket ethanol industry that is considered a success worldwide.

Public Policy and Its Social and Economic Impacts

Energy is recognized as one of the single most important issues in modern society, having a great impact on social and economic development. The quality of human development is dependent, among other factors, on energy supply being available, efficient, reliable, and sustainable. Particularly in Latin America, energy plays an essential role in social development, and it is perceived as of strategic importance for economic development.

The primary challenge faced by the countries in Latin America is to ensure sufficient capacity and investment to reliably serve their growing economies. Social and environmental concerns are an inherent challenge and must be addressed accordingly. Energy supply can determine competitiveness in a global marketplace where economic activities must compete not only on the local and regional levels

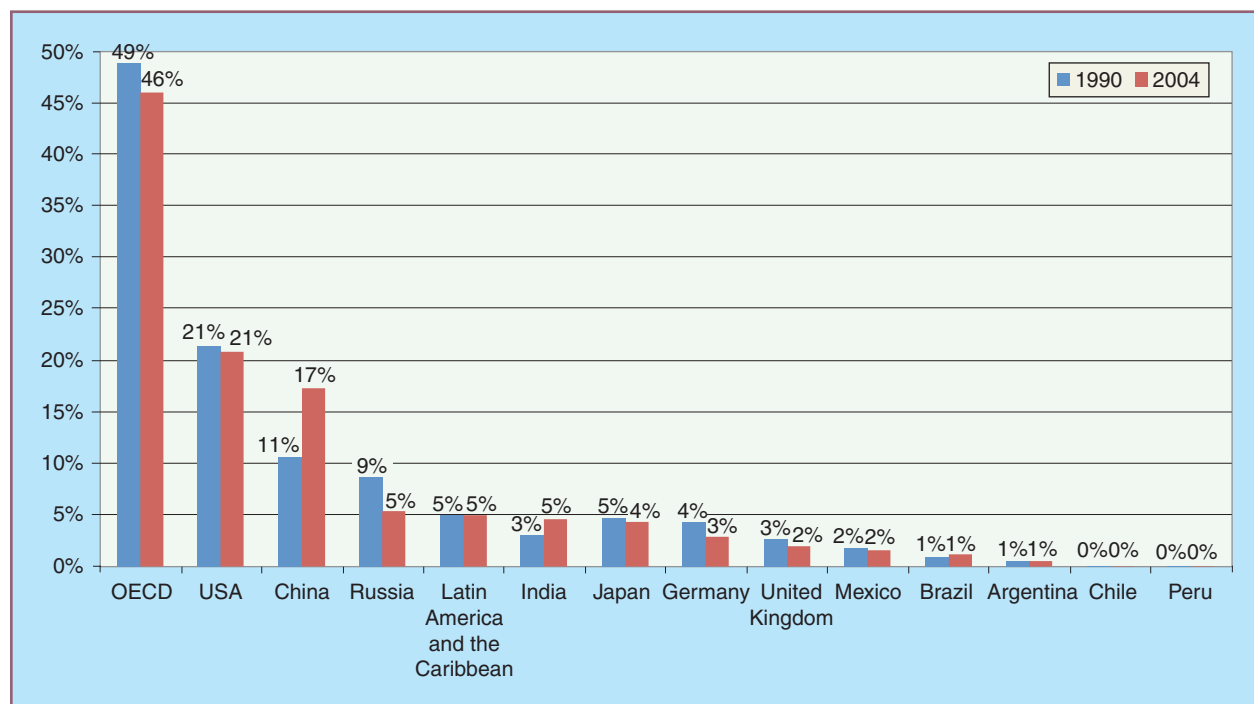


figure 2. Comparison of CO₂ emissions as a percentage of global total emissions (source: Human Development Report 2007/2008).

Brazilian Oil Policy and the Emergence of a Multimarket Ethanol Industry

In 1973, the world faced its first oil shock, with a sharp increase of oil prices by OPEC. Brazil, which at the time was growing by 11% per year, was severely hit economically because its oil imports accounted for 80% of domestic consumption. In order to lessen the country's oil dependence, the Brazilian government launched a subsidy-oriented program to develop ethanol from sugarcane, a natural resource abundant in the country.

The "Pro-Alcohol" program started with a tax incentive to foster a production increase from existing sugarcane producers. The Brazilian government also made the use of ethanol blends with gasoline mandatory to boost ethanol consumption (see Figure S1). At the time, vehicles had no capacity to run on ethanol by itself.

In 1979, the second oil shock came, but this time it was accompanied by a sharp increase in the U.S. interest rates that "anchored" Brazil's external loans. It was also during this period that the first all-ethanol (E100) cars were launched in the market. Brazilian automakers modified gasoline engines to support ethanol characteristics; changes included compression ratios, the amount of fuel injected, replacing materials that would be corroded by contact with ethanol, the use of colder spark plugs suitable for dissipating the heat due to higher flame temperatures, and an auxiliary cold-start system that injects gasoline from a small tank in the engine compartment to help with starting in cold temperatures. In addition, 30,000 fuel stations were adapted to supply ethanol in addition to gasoline. The availability of ethanol-run vehicles

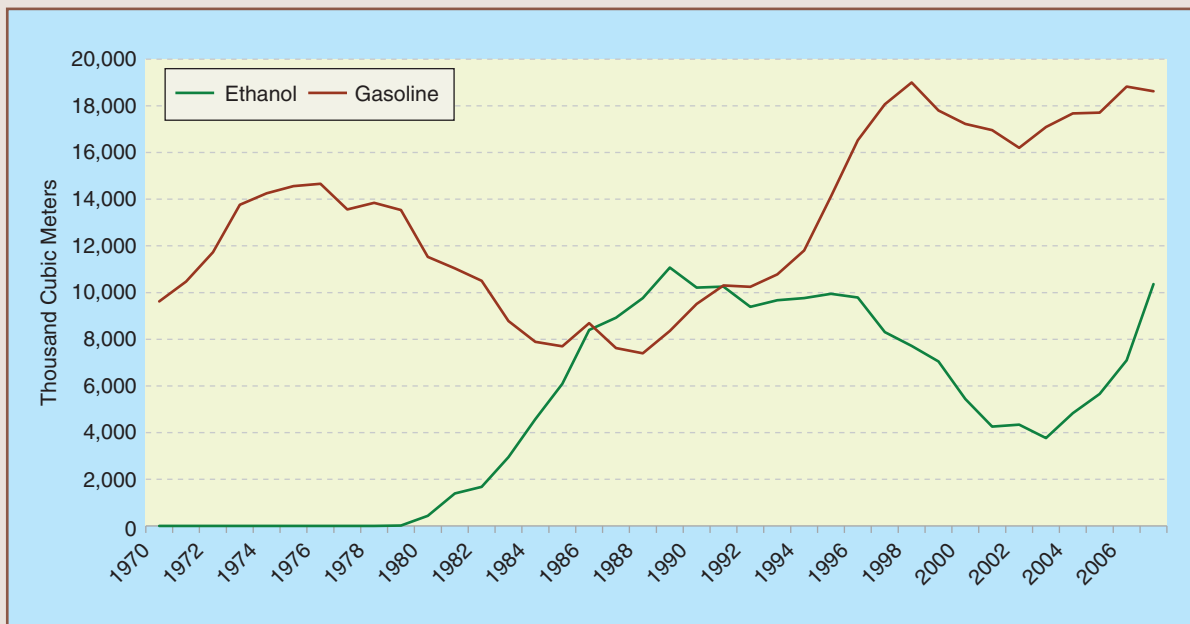


figure S1. Ethanol consumption evolution in Brazil (source: BEN 2008).

but in a global context. Energy policy is certainly conditioned by the energy sources available, energy consumption growth, and the general social and political context, among other factors, but also by history. Due to recent events, energy policy decisions in Latin America have been based on various crises during which a lack of investment resulted in a lack of supply security and supply inefficiencies. These remain key issues in the region. Nonetheless, climate change has drawn attention away from these important problems, often preventing policy making from focusing on the fundamental issues. So one question remains to be answered in Latin America: What are the economics that provide balance with respect to *all* the key aspects of an energy policy?

Finally, the developed world must be cautious in pushing for environmental standards in the electricity industry in undeveloped countries. Such standards may be beyond their economic reach, especially when one takes into account the needs of these countries for social investment, particularly in order to reduce poverty.

For Further Reading

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created a powerful ethanol demand, and the percentage of this type of car in total production increased from 0.5% in 1976 to 76% in 1980.

The following years, however, were marked by lower oil prices, which led the Brazilian government to reduce the ethanol incentives. As a consequence, there was a decrease in ethanol production, which created a fuel scarcity for ethanol-only cars. This led to a generalized mistrust by consumers of ethanol cars and seemed to be the end of the ethanol industry in Brazil.

In the 1990s, however, the government liberalized sugar production, which up to that time had been heavily regulated. At the same time it eliminated all subsidies. The effect was a boom in the industry, which realized it could be quite competitive. In 2003, flex-fuel cars, which can use any blend of ethanol and gasoline, were introduced. Flexible-fuel technology was only developed at the end of the 1990s by Brazilian engineers. The Brazilian flexible-fuel car is built with an ethanol-ready engine and one fuel tank for both fuels. The small gasoline reservoir for starting the engine with pure ethanol in cold weather, used in earlier ethanol-only vehicles, was abolished. A key innovation in Brazilian flex technology was avoiding the need for an additional dedicated sensor to monitor the ethanol-gasoline mix. The flex-fuel cars restored consumer confidence in ethanol, because in case there was a scarcity of one fuel, the other could be used. Also, the driver could always choose to use the cheapest fuel available at any time. These facts, together with the mandatory use of gasoline-ethanol blends throughout the country, allowed Brazil in 2008 to achieve more than 50% of fuel consumption in transportation from sugarcane-based ethanol. Flex-fuel vehicles enabled the ethanol industry to recover its growth independently of government subsidies. Flex-fuel cars made up 80% of auto sales in 2007 and 90% in 2008, anchoring the ethanol consumption. Additionally, the world's need for clean fuel in a

carbon-constrained world created another reason for this industry to grow.

Since 2004, the sugar-ethanol business has included a third factor, which is electricity production. As a by-product of the ethanol production process, the sugarcane biomass (waste) is used for electricity cogeneration (cogen), mainly for auto-consumption. Any surplus power is sold to distribution companies. With the increasing development of ethanol production, more efficient boilers are being ordered for the new ethanol plants, and more surplus power is becoming available to be sold to the electricity market. Recent changes in the electricity market design have allowed biomass plants to compete for long-term firm energy contracts in the supply auctions carried out yearly by distribution companies. In this framework, the cogen from sugarcane biomass (known as bioelectricity), has become very competitive. This cogen has a low investment cost—just the incremental cost of installing a more efficient boiler for the ethanol plants. It is able to benefit from additional factors, such as: 1) the location of harvests being near load centers, implying a reduction in transmission losses and tariffs; 2) full complementarity with hydro resources; and 3) the possibility of receiving carbon credits as clean-developed projects. Therefore, bioelectricity plants have been displacing “mainstream” technologies such as hydroelectric power and combined-cycle natural gas-fired and coal-fired plants in the contracts auctions. Currently, Brazil has an installed capacity of 2.5 GW of biomass cogen. The potential for 2015 is about 12 GW (for an annual energy average of 7 GW) of bioelectricity capacity from sugarcane, which is enough to meet 2.5 years of load growth.

In summary, ethanol development in Brazil is an interesting mix of public policy for technological development in the early 1970s and market opportunity in the late 1980s, with an overall positive result for the country.

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