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Mikael Roman
Mikael.roman@tillvaxtanalys.se

Energisystem med variabel elproduktion – Brasilien

1 Introduction

Following drastically increasing global energy demands, along with alarming signs that climate change is in fact a reality, there is in the international policy debate a growing emphasis on the need to move towards more weather-dependent, and supposedly more sustainable, energy systems. The major challenge, however, is to find ways in which this could be done without compromising economic growth and social development. What types of interventions will be needed? What kinds of policy instruments are the most effective? The complexity of the issue, along with the specific conditions of each particular context, implies that there is an ample need for institutional and administrative innovation, where the need for continuous learning will be critical.

In this perspective, Brazil constitutes a particularly interesting case. The country is not only blessed with abundant energy resources, ranging from large quantities of offshore oil and gas to – even more critical – almost inexhaustible assets of renewable energy, such as: solar power, biomass, hydro energy, and wind power. Perhaps more importantly, Brazil is also peculiar for its adopted policies. Over the years, the country has, through various critical state interventions, achieved a pioneering green energy matrix, particularly with respect to electricity. Hence, while many countries are currently adopting policies to increase energy supply based on renewables, this is largely a reality in Brazil.

With this background, it would seem ironic that Brazil is currently confronting a severe energy crisis that raises serious doubts about many of the policies once applauded. In this case, the situation goes beyond simply admitting previous mistakes. Instead, it is increasingly clear that past policy decisions are putting cruel constraints on what seemed to be an endless list of possibilities. In this sense, the Brazilian experience as a pioneer with respect to renewable energy becomes particularly important, as it could provide critical insights to the continuous learning process and, ultimately, the formulation of policies elsewhere. As a pointer to the future, one of the questions coming out of the Brazilian experience is: "What do we do when the low-hanging fruits have been picked?"

In order to identify some of the pitfalls inherent to the ambition of introducing renewable and more weather-dependent energy systems, the present report analyzes Brazilian energy policies since the mid-1970's from two broader questions: 1) What has driven the Brazil to become vanguard with respect to renewable energy?; and 2) How and why did this process end up being in itself the principal challenge?

To pursue this effort, three concepts will be introduced that seem to be particularly relevant to understand the overall development. The first is *sustainability* that arguably has operated as constant, but for its content continuously moving, policy objective. A second is the notion of *path dependency*, according to which investment in certain technological solutions create larger socio-technological systems, involving both financial and legal institutions as well as financial and cognitive patterns, that ultimately are exceedingly different to alter. Finally, it is critical to understand that the energy sector is not one – but several – markets organized along a *value-chain*.

The Brazilian experience provides four broader observations.

One is that *the ambition to create energy systems entirely based on renewables is not sustainable*. There are two reasons for this. First, presuming that climate change is a fact, there is something inherently contradictory about making large-scale, focused investments in weather-based energy systems. Instead, as the latter presumably are the ones' most affected by alterations in climate patterns, and therefore technology investments with increasingly high uncertainty, a great degree of caution will be needed at the policy level. Second, the latter is further emphasized by the fact that any investments in large-scale technology will create larger socio-technological systems, and thereby put societies on policy path dependencies, that affect all aspects of sustainable development. This implies simply that they have implications well outside the principal area of energy, something that will generate multiple interests and occasionally contradictory policy objectives, with the potential for political infighting and maneuvering.

Instead, there seems to be *a strong case for a diversified energy portfolio*. Again, there are various reasons for this. First, as the Brazilian experience illustrates, there are inherent risks in being dependent on one energy source, be it fossil-based or renewable. Second, less emphasized in the current debate, though, is the importance of diversified energy systems as a means to mitigate for 'political risk' in the policy process. The latter is, as the report shows, largely related to 'anticipation' and 'trial and error', wherefore the notion of portfolio strategy becomes particularly relevant.

A third observation coming out of the report is *the continuous but changing role of government*. The point here is that climate change, along with transformations in the global economy more generally, has altered the societal context in which we all act. This has implications also for the State that now will have to pursue other functions than earlier. The phenomenon becomes particularly apparent in the Brazilian electricity sector that, through an extensive privatization process, in less than a decade went from being a state monopoly to an open horizontal energy market. As the report shows, there are still various functions that the State will have to pursue, principally when it comes to regulatory oversight. The critical point, though, is that many of them will yet have to be identified and discussed, so that government does not interfere based in an outdated traditional way, thereby having counter-productive effects.

To round off, this discussion regarding the Brazilian experience in terms of picking 'low-hanging fruits' and creating 'path dependency' only *emphasizes a new type of policy-making*. Currently, the only thing we know is that the climate is changing. This means that, instead of making decisions based on incomplete information regarding both the extent of the problem as well as ideal solutions, we have to think carefully about applying a process for continuous, goal-free and contingent policy making. Put differently, instead of banking on uncertainties, we should learn to play with uncertainties.

2 The Brazilian energy system

Brazil is with its large share of renewable resources an anomaly in the global energy context and thereby in a position that most countries are currently aiming for. This follows not only from a unique access to a diverse set of energy resources but also from active policies promoting the use of weather-dependent energy sources. One question is, obviously, to learn from these experiences in order to promote similar developments elsewhere.

At the same time, Brazil is currently facing severe constraints on its energy system that now at least partly questions previous policies. This is, perhaps, even more interesting since it allows us to further analyze the potential pitfalls in promoting renewable and weather-dependent energy sources. What went wrong in the earlier steps? What does that imply for future policies?

Yet, any discussion on energy policies will necessarily have to depart from an understanding of the energy system itself. Hence, in order to understand Brazil's current challenges and how the country got there, we shall in the upcoming section describe the particularities of Brazil's energy system by: 1) putting it in a global comparative perspective; and 2) thereafter discuss the particular configuration of the domestic electricity system.

2.1 Brazil in an international comparison

The Brazilian energy system is unique in the international context, with respect to three different dimensions: 1) its configuration of primary energy sources; 2) its corresponding electricity matrix; and 3) its carbon emission when producing electricity. The fact that there has been a certain evolution with respect to the first two, particularly between the years of 1980 and 2010, also indicates that Brazil's present characteristics result from a long period of investments and active policies.

Considering the world´s primary energy matrix, significant differences can be noticed between the referred years (VENTURA FILHO, 2012). Basically, there was a decrease in the use of fossil fuels from 85 to 82 percent. This indicates an increasing ambition to change the energy source pattern, following concerns regarding climate change. Brazil, on the contrary, presented an increase in the use of fossil fuels, where the participation of the latter rose from 45 to 52 percent. This is a considerably increase that should not be ignored by the fact that Brazil still maintains a largely green energy matrix. The trend is clear.

With respect to electricity generation, the contrast is even starker. While the world reduced the use of fossil fuels from 70 to 69 percent, Brazil saw a corresponding increase from 6 to 11 percent. The relatively minor contribution from fossil fuels is due to the massive use of hydropower, which corresponds to more than 70 percent of the Brazilian electricity matrix.

This comparatively green energy matrix has in turn resulted in extremely low carbon emissions, especially with respect to electricity production. Brazil emits an average of 94 t of CO2 per GWh, while the world´s average is 580 t of CO_2 GWh. While power generation constitutes the principal source of CO_2 emissions for most countries, in Brazil more than 70 per cent of the emissions is attributed to different forms of land-use (deforestation, agriculture and cattle) (MCKINSEY, 2009). This, some would argue, puts Brazil in a particularly favorable position in the ongoing climate negotiations, since it up to now have been able to promote industrial growth, without necessarily increasing its carbon emissions. The latter would then, in a carbon-constrained global economic context, constitute a considerable comparative advantage.

2.2 Domestic configuration

Another critical aspect of the Brazilian electricity system concerns its horizontal configuration. The latter is principally illustrated by the way the electricity system has been divided into three different markets: 1) generation; 2) transportation; and 3) commercialization.

Differently from the other two, *transportation* – which covers both transmission and distribution – has been targeted as a natural monopoly, mainly due to the combination of the country´s continental size and the physical distance between generation and consuming centers. Consequently, the use of different public incentives is significantly stronger in the transportation market than in the other two. This, in turn, has generated nearly 63 companies in the distribution area and 77 involved in energy transmission (ABRADEE, 2015a). As for the latter, the Brazilian government made at an early stage considerable investments to create a gigantic transmission system, which would interconnect production and consumption centers throughout the "Brazilian continent". This so-called "National Integrated System" (SIN) transmits 98.7 percent of all produced electricity in the country, thereby delivering it to almost all Brazilian consumers. Despite the existence of an area not covered by such system, which corresponds to 40 percent of the national territory, only 3 percent of the population is not integrated into it (ABRADEE, 2015b). This ultimately illustrates the unequal demographic distribution of Brazil.

In direct juxtaposition to the above, the competitive feature of energy *generation* has allowed for a minimal state intervention in the sector. Instead, it relies almost entirely on a self-regulating market that also sets the price – the only impediment being a maximum price defined by the State in order to protect consumers from speculations.

One of the few government responsibilities in the area is to organize centralized energy auctions, which are intended to facilitate market operations as well as the introduction of new energy sources. On such events, generators present an estimated price based on production prospections. Distributors, on the other hand, hire a specific amount of energy, according to their previsions of how much quantity will be necessary for the supply of their captive consumers during a specific period of time.

Considering the dynamics from the energy generation until its distribution, a final tariff based on the aggregation of three values is settled to the final consumer: 1) the generation price; 2) the transport price, established by the government and 3) taxes. It is important to highlight that despite the existence of a national integration, especially in what regards energy transport, the government determines variable prices depending on the geographic region. The latter is attributed to the large socio-economic differences within the country (ABRADEE, 2015c).

Some regions have more consumers than others, which impacts in the tariff value. So does the social complexity. Usually, regions where the amount of poor families is larger have a great significance of energy stolen by illegal connections in distribution cables. This demands from such distributors a more advanced system in order to avoid the net overloading. Consequently, tariff in such areas tend to be higher as maintenance costs are also higher.

Finally, the third market is *commercialization* itself, which in this case corresponds to the possibility of each consumer to buy energy directly from generators. Commonly, such market is dominated by the industry since its need of energy is more intense. However, distributors may also buy energy in the spot market, especially if their auction contracts prove to be insufficient for covering variations in consumer demand. Since auctions are not necessarily organized on a regular basis, it may be too risky to wait for the next one. Under those circumstances, distributors may instead opt for the spot market to guarantee consumer needs.

3 Outlining the policy paths

Now, the larger question is what actually brought Brazil to this particular configuration of its energy system. What were the conditions and considerations that guided critical decisions at critical points in time?

To answer this question, we will in the upcoming discussion focus on three particular events that, arguably, constituted formative moments in the evolution of the current Brazilian energy system. One such event is the oil crises of 1973 and 1979 that largely defined the military government's investment in the energy sector during the 1970s. A second event concerns the energy crisis in 2001 that took the

Brazilian government by complete surprise and caused yet another restructuring of the electricity sector. Finally, we shall also discuss the current situation, which in different ways challenges some of the previous policies.

The discussion itself will be built around three concepts that seem particularly relevant to our understanding of the overall development.

One is the notion of policy paths, or *path dependency*, according to which new technological solutions occasionally generate broader socio-technical systems that may be very difficult to change or undo. More concretely, these socio-technical systems are in turn made up by interlinked combinations of institutions, actors, technologies, and socio-ecological premises that surround a certain energy technology, either in production, distribution or use. Now, the critical point here is that socio-technical systems, once in place, create pathways that are exceedingly hard to alter.[1] This is particularly true for the type of 'carbon lock-in' that comes out energy systems but the conceptual approach applies also to other production systems.[2]

A second concept of particular relevance to this study is *value-chains*. The latter, which is widely used in the strategy and economics literature, provides a means to define the wide range of activities that are required to bring a product or service from conception, through the different phases of production, delivery to final consumers, and final disposal after use.[3] In this specific study, it become particularly useful since it allows us to identify where, how, and for what purpose particular policy interventions were made.

Finally, the notion of *sustainability* will also be central to the upcoming discussion. Yet, in this case it is important to emphasize that we do not in any way intend to define the concept, which over the years has been heavily contested and given multiple interpretations. Quite the contrary, the point is instead to illustrate how that very debate has influenced Brazilian policies over time. This specific dimension of the policy debate is particularly interesting, given that a large part of Brazil's investments in a green electricity matrix, date from a moment when the consciousness regarding global warming was not consolidated.

3.1 The military government's energy policies in the 1970's

The 1970s constitute in many ways the starting point for Brazilian investments in renewable energy. At the time, Brazil was extremely dependent on energy international supply, as oil constituted one of the principal building blocks in the military government's policies for a rapid industrialization. With oil imports reaching 80 percent of national demand, the country was therefore severely hit hard by the international oil crises of 1973 and 1979, that both put the entire national development project under threat (COLACIOS, 2009).

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[1] Berkhout, F. Technological regimes, path dependency and the environment. Global Environmental Change. Vol. 1, No. 1, pp. 1-4.
[2] Unruh, G. (2000). Understanding carbon lock-in. In: Energy Policy, Vol. 28, pp. 817-830.
[3] Kaplinsky, R. and Morris, M (2001). A handbook for value-chain research. Institute for Development Studies: Brighton, UK.

In the electricity field, the situation was comparatively more under control. This could be attributed to an early understanding of the strategic use of hydropower. Obviously, the abundance of water contributed to the establishment of such policy. Yet, even more appealing to the military government were the prospects of achieving energy independence and thus guarantee national security. Similarly, the economic dynamism that followed from the construction of large dams, particularly in remote areas such as the Amazon, also served internal geostrategic and military interest. More concretely, in addition to producing electricity, these large infrastructure projects constituted de facto instruments for regional development and thus the protection of national sovereignty by economic integration. The latter explains also why investments in new dams continued when the oil crises had faded. Finally, the immense task of constructing big hydrological dams fit also perfectly with the military's ambition to develop large national industry complex and promote economic development (TOLMASQUIM, 2012).

Yet, the situation was not as favorable in other fields. The transport sector, for instance, needed rapidly a national and abundant resource to substitute for oil and gasoline. In this context, sugar cane soon emerged as a new and critical source – and, again, the link between energy, security and economic provided the rationale for political support and large-scale investments. The key in this case was that the crop itself, i.e. sugar cane, could be used interchangeably in both agriculture and transport *value-chains*, all depending on market fluctuations. Hence, by providing Brazilian sugar producers with an alternative market, which at the time helped them to mitigate for low international sugar prices, the military government not only boosted the domestic agriculture industry, but it also guaranteed support from one of the country's strongest political constituencies.

In 1975, the National Program for Alcohol, *Pró-Alcool*, was officially launched with the outspoken objective to save foreign exchange by using ethanol as a supplement to the nation's gasoline supply. This broader aim was to be achieved through a series of government incentives, ranging from subsides for ethanol production to a reduction of taxes for the development of flex-fuel cars. Hence, there was a series of parallel and combined interventions in various stages of the value-chains of both agricultural and automotive industries, which in effect created a new socio-technical system (MAROUN; SCHAEFFER, 2012). Between 1975 and 1979, ethanol production increased by 500 percent, indicating that the market was largely responding the incentives. Similarly, in the mid-1980s pure ethanol-fueled cars accounted for more than 90 percent of all new cars sold in Brazil, with the remaining of the fleet running on a blend of 25 percent ethanol and 75 percent gasoline. Perhaps more importantly, the resulting socio-technical system proved later to be exceedingly resistant and, despite a considerable drop during the 1990s, the ethanol industry was once again resurrected with the introduction of the flex-fuel car in 2003. In 2008, the ethanol sector generated more than 1 million direct and indirect jobs in the country, apart from an investment rate of US$ 30 billion (PASSANEZI; NOHARA; ACEVEDO, 2010). Clearly, a strong *path dependency* had been established in the process.

There are several learning points from these two examples. One of the more critical, though, concerns the political justifications for moving ahead on renewable energy investments. Here the Brazilian military government made, somewhat ironically, an important contribution to the incipient global environmental debate, by emphasizing the national control over one's domestic natural resources as an essential and explicit component of *sustainable development* (ROMAN, 1998). Also, it provided concrete examples on how to scale up the use of renewable energy.

3.2 The energy crisis of 2001

A second event that would be critical for the Brazilian energy policies was the energy crisis of 2001. The political and economic context had by then changed dramatically since 1970s. Starting in 1985, there was a gradual transition to a democratic government, which soon embarked on extensive privatization programs affecting all sectors of society.

One of the first targets for these new economic policies was the energy sector. During the 1990s, there was a radical unbundling of the electricity sector that went from being a state monopoly to become horizontally organized. Yet, although this entrance of private actors was fundamental for the continuity of the entire system, it did not avoid a new crisis. In 2001, a massive drought and consecutive electricity rationing took Brazilians by surprise.

The events made it painfully clear that neither the government nor the private sector was able to administer the electricity system on its own. Instead, the market had to be regulated somehow in order to guarantee constant investments. This led in turn to the introduction of the previously described mechanism in which the State interferes in specific moments, mainly through different auctions, to control both the permanence and quality of the electricity structure.

Parallel with these developments, in which past policies were being evaluated and reconsidered in the Brazilian domestic context, the debate regarding global warming and *sustainable development* was intensified on the international arena. In these discussions, Brazil was initially considered a model for its use of renewable energy and particular attention was given to the use of water resources in the electricity sector. At the time, the government's ambition to use large dam projects as a vehicle for regional development fit perfectly in the global debate. This allowed the Brazilian government to taking a leading role in many international conferences, while at the same time it pursued active policies at home. In these years, Brazil adopted new regulations, such as: 1) the obligation of authorized water explorers to contract local employees and to offer them capacity courses; and 2) compensation payments for the municipalities where hydro exploration occurs.

Ironically, as the global *sustainability* debate matured it would soon end up questioning the same dam constructions it had once defended (WERNER, 2012). Similarly, although the importance for a deepened integration of the Amazon was recognized, the impacts were increasingly questioned. Several studies emerged, for example, that illustrated how the region, despite this type of integration projects, continued to hold a peripheral position in the national economy. Despite a few minor alterations, economic activities were still concentrated to the South, while the Northern region was in effect designated to provide the former with electricity. This caused in turn civil movements to claim that while the generation of hydro electricity had benefits for the entire country, its costs were in effect restricted to the North. Worse, existent regulations were not going to change this reality.

Yet, this was not the only critique that surfaced regarding large dam project. Another major challenge to hydro electricity projects in the North that soon became a hot topic was their impact on native populations. Similarly, dam projects were soon criticized for their impacts on deforestation, biodiversity, and the disorganized use of soil.

This consolidation of the *sustainability* concept had far-reaching for the global society's view on large dam projects. Clearly, large hydro projects entailed more than just generating energy and, as the understanding of sustainability broadened, they were increasingly questioned. Instead, many claimed that electricity policy in general had to be revised to include a new generation pattern.

However, despite this overall change in the global debate, the Brazilian government did not back off from its use of hydropower. Quite the contrary, the latter's strategic advantages, most importantly in the form of its long aggregated *value-chains* creating spin-offs in large parts of Brazilian industry, increased the opportunity cost for any other energy resource. More importantly, the socio-technical system created around the technology was also tremendously difficult to break. Only the sunken costs in extensive infrastructure made it in this case practically impossible to back off from previous commitments. Instead, as an illustration of this *path dependency*, the Brazilian government increased its investments in the sector by, among other measures, in 2010 providing the largest loan ever – a total of US$ 2.3 billion – to one single project, the "Jirau" hydro plant.

Yet, as the development of new of dam continued, the more the criticism intensified, thereby finally making it impossible for the government to reject the activists. Instead, the government adopted a series of middle ground solutions that sought to balances the competitiveness and disadvantages of large-scale dam projects.

First, it imposed a mandatory requirement on environmental and social feasibility studies before granting the concession of any new dam project. The results of these policies have been mixed, mainly because the inherent uncertainty of similar analyses. One direct consequence is that many dam constructions are currently stalled, as activists confront investors through appeals in court. This situation is in turn further complicated by the fact that judicial institutions often are slow and so far have been unable to find a common reasoning on these issues. Instead, similar projects are now considered increasingly unpredictable among investors that, consequently, are less interested in financing similar endeavors.

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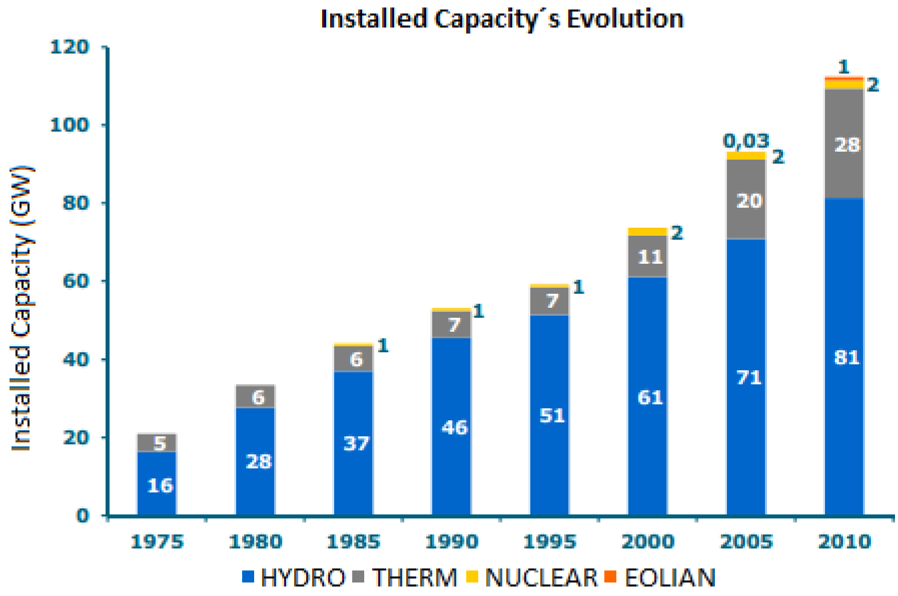
Second, new hydro energy projects were also considerably restructured. Instead of seeking alternative energy sources, the government decided to maintain hydropower as the base of the electricity system, but opted instead to seek new technological solutions. This meant in effect that the previous emphasis on large reservoirs was gradually substituted for the less intrusive 'run-of-the-river technology'. The impact would be immense. Most importantly, the resulting lack of storage capacity made it imperative to install new *compensating* resources for drought seasons (PIRES; HOLTZ, 2011). In effect, this meant that both thermals and wind power received more investments.

This is also where economic-strategic considerations and the emerging effects of climate change clashed, thereby paving the way for the current energy crisis. The choice of complementing energy sources was a rational consequence of their respective characteristics and can, in retrospect, be justified as highly rational. While wind power has the natural advantage of having its production peak during the dry months, when the production of hydro energy is low, the best physical locations for this type of installations is normally far from the large dams. This means that extensive transmission lines will have to be put in place before wind energy will reach major consumption centers. Thermals, on the other side, can be constructed close to consumers and was therefore soon prioritized, as indicated in the following graph. The critical point here is that, in this initial phase, their non-renewable feature was not considered an obstacle, since the back up attribution of thermals would make little to change the green quality of the overall electricity system.



Source: Pires, A. , Holtz, A. (2011)

To conclude, it needs to be emphasized that, despite the initial differences in investments between thermal and wind power, the latter would subsequently see an elevated presence in the system. In fact, there was an increase in wind power of 829 percent between 2006 and 2013. Currently, Brazil has 167 wind power centers (JORNAL NACIONAL, 2014).

3.3 The current energy crisis

At the time of writing, Brazil has once again been hit by a drought period, this time even more severe than in 2001. As a result, thermals are currently being used at its maximum potential (BORGES, 2014). Three components have contributed for the current scenario: 1) the insufficient amount of investments in the electricity sector; 2) the continuous relegation of transmission and distribution in the energy value-chain; and 3) the emerging impacts of climate change.

Judging from the previous section, it would seem as if there have been major *investments* in the electricity sector over the past few years. This is partly true, at least in absolute terms. However, if compared overall energy investments, the picture changes somewhat. Instead, of the US$ 314 billion that the 2010 Investment Plan allocated for the energy sector as a whole during the subsequent decade, 70.6 percent were designated to the oil and gas industry, while the electricity sector would receive only 22.5 per cent (EMPRESA DE PESQUISA ENERGÉTICA, 2010) .

This drastic change in policy priorities is a direct result from the recent discovery of gigantic oil and gas field in the deep-sea layers outside the Brazilian coast and has, in combination with the recovery of international oil prices, brought massive and focused investments to the petrochemical industries. The effects, however, are now being felt also in other energy sectors, not the least the ethanol industries, which investors claim have been completely left aside by the government since 2007. This situation is further aggravated by the fact that the government for a long time put a cap on gasoline prices in order to balance inflation. These policies did not only distort market competition between ethanol and gasoline but, as a consequence, it also reduced the demand for flex fuel cars. As a result, 83 out of the 384 sugar cane mills installed in the country until 2015 have now been deactivated over the past 7 years. Similarly, the total industry debt has been estimated to US$ 27,3 billion and more than 60 thousand jobs in the sector have been lost (BORDA; GOMES; REZENDE, 2014).

Interestingly, as the current energy crisis is taking off, some of the remaining mills are now taking advantage of the situation, by selling their surplus energy on the spot market. However, these economic profits are not sufficient to cover the long period of deficits. Similarly, over the long term these ethanol mills do not have the capacity to produce the necessary electricity. Instead, following the extended period of competitive disadvantage against oil and gas, the mills have not been able to invest in new technology and improved productivity. This is now creating additional constraints compared to other sectors of agro business that in the same period have taken advantage of innovation and investments. Consequently, when tillväxtanalys

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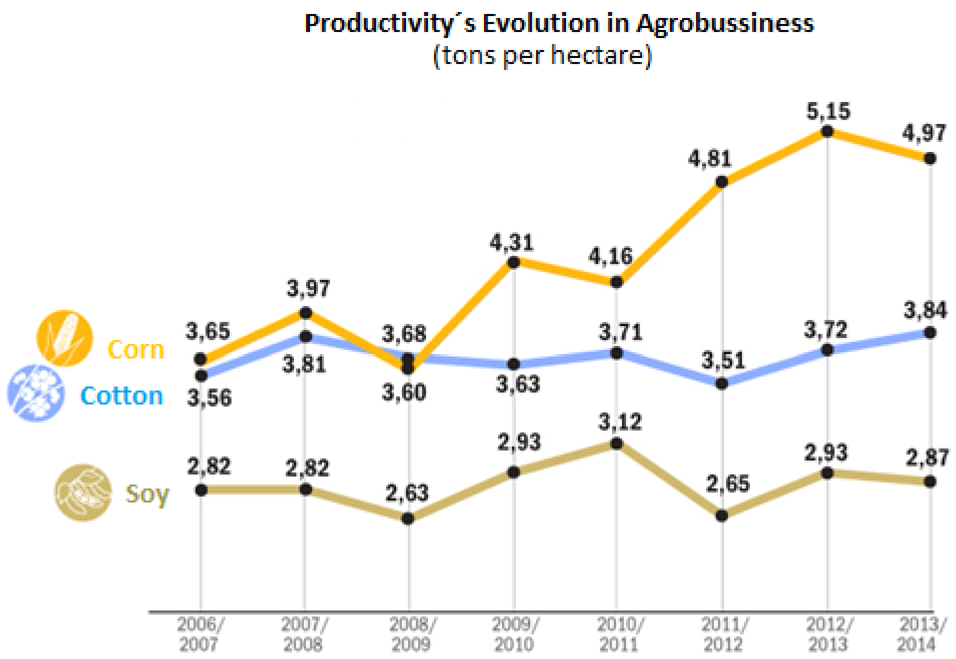
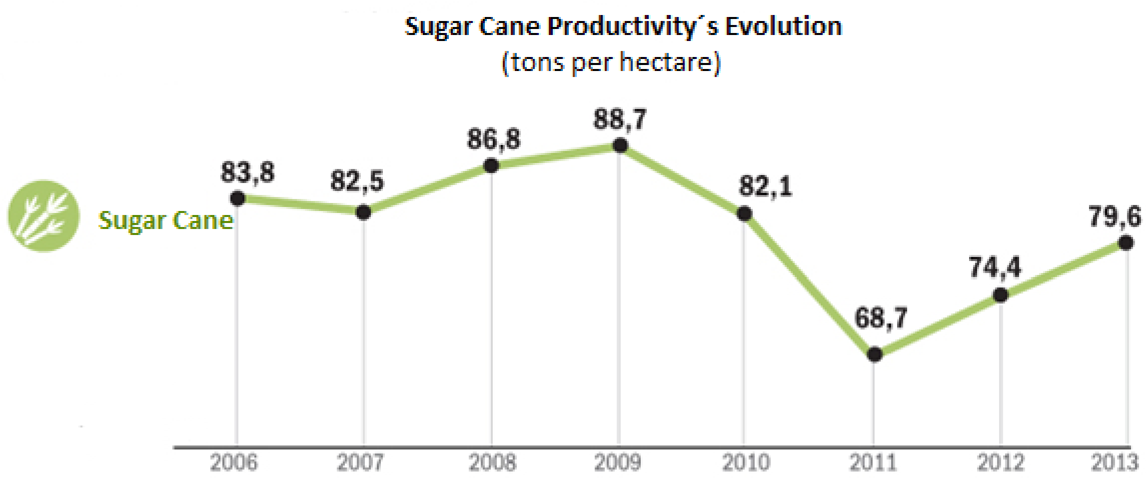
the demands for bioenergy now increase, the opportunity costs for potential producers to switch from traditional crops to energy is simply not there (BERTÃO, COSTA, 2014).



Source: CONAB apud Bertão, N. I. ; Costa, A. C. (2014)



Source: Centro de Tecnologia Canavieira *apud* Bertão, N. I; Costa, A. C. (2014)

A second reason behind the current energy crisis is the *strong investment bias towards electricity generation*. Of the 22.6 percent of the total energy investments intended for electricity, only 4.1 percent have been allocated for transmission. This is even more alarming since it is a natural monopoly. Perhaps even more worrisome, though, is the increasing constraints for private investments in energy transportation. Pressed by the emerging crisis, President Roussef introduced in September 2012, a presidential decree that established the possibility to renew expiring transportation and generation concessions instead of proceeding with new auctions. In return, concessionaries would have to reduce their tariffs and make an established amount of investments in infrastructure. Similarly, the government promised to cut incident taxes on energy prices, thereby reducing consumer tariffs by 12 percent. Behind the lines, the measure was also a political move to assert that policies towards the inclusion of thermals were granted.

However, if the decree was initially well received by consumers, investors soon expressed their discontent. The impacts of the presidential decree were enormous in many areas of the electricity industry. First, it caused a peculiar situation on the generation market, which had been self-regulated since early 2000. This pattern was now broken since the decree effectively put two markets into one: generators that did not renew their concessions and therefore were largely independent from government; and generators that accepted the renewal in exchange of more price interference. Experts soon pointed out that this would have fatal consequences over the years to come (ABRADEE, 2015a).

Moreover, the decree also created a general uncertainty among energy investors, regardless of their specific markets (PRADO JR.; SIVA, 2011). As distinct from a law project, a presidential decree takes effect immediately and is, therefore, supposed to be used only in urgent and extreme situations. Consequently, the government's choice to introduce a decree, instead of a law project, was thus interpreted by investors as a clear change in policy, in which the government signaled that it from now on would pursue top-down intervention and less negotiation. Given the uncertainty about the next move, private investments were soon substantially reduced. These decisions were also nurtured by the imposed tariff reductions that further limited the prospects for a decent return on investments.

With these events in hindsight, one critical lessons coming out current crisis seems particularly important: if investments are not evenly distributed over the value-chain, they will all be inefficient. This becomes painfully evident when we consider the negligence of transmission in the Brazilian electricity sector. Two examples illustrate the point. First, there are 36 wind power plants producing energy in vain, because of a lack of transmission lines (JORNAL NACIONAL, 2014). Following the government's excessive focus on generation, there have simply been too little investments in transmission lines connecting wind parks with consumers. A second example is the general blackout on January 19 this year that left 12 out of 27 Brazilian States without power for several hours, mainly due to problems in the transmission system.

The latter is also important as relates directly to the third explanation to the current crisis, i.e. the emerging effects of *climate change*. According to experts, the blackout resulted from the lack of investment in the expansion and maintenance of existent infrastructure and a drastic increase in consumption levels. The latter in turn was mainly caused by the previously mentioned reduction of consumer tariffs as well as unprecedented heat waves. As temperatures grow, Brazilians are increasingly buying air-conditioners and fans to cope with the heat. This is now putting additional pressure on the energy system, which is already operating on its limit due to: 1) the disequilibrium between offering and demand; and 2) the already mentioned transmission losses. On January 19, the system simply collapsed as the registered demand forced government to shut down outdated transmission lines that could no longer bear the load (ALVARENGA, 2015).

Apart from these impacts on consumption patterns, climate change is also starting to have serious impacts on electricity generation. Recent studies show that not only the frequency and the length of droughts but also rain patterns are changing all over Brazil (CALIXTO; DURÃES, 2013). Consequently, large dams are increasingly suffering from the lack of rainfall, which instead are moving to areas where there are no dams. The situation has now reached the point where energy reserve levels for the entire electricity system, which is established at 5 percent, has not been maintained since February 2014. Currently, the system is operating at a 2 percent reserve level (SALOMÃO, 2014). In effect, some regions are also using their proper back-up reserve to provide electricity to other parts of the country where the generation of hydro electricity has been practically stalled.

Again, it is in this context that the thermals, which were initially planned to be a back-up resource, are running on a permanent basis to uphold the system. Even worse, the high demand of energy is creating additional demand for natural gas, wherefore Brazil has been forced to increase its import of natural gas (VEJA, 2015).

The present situation is, clearly, the combined result of several misguided policies that themselves created perverse effects with the inherent path dependency that exists for hydro energy. The point here is that changing the policy context to achieve long-term energy solutions will require structural modifications that cannot solve the imminent energy crisis. Consequently, the Brazilian government is currently faced with the challenge to, apart from thinking about the distant future, also identify *short-term solutions* based on conditions produced by past policies.

4 Long and short-term solutions and constraints

While summarizing the Brazilian experiences from an energy value-chain perspective, one observation is exceedingly clear; with respect to electricity generation, there is a critical need to diversify the energy sources. The 2001 crisis is commonly interpreted as the result of having water as the predominant base of the system. Yet, the solution presented at the time meant in effect that the same mistake was de facto committed again. By concentrating the back-up system into one energy source, i.e. natural gas, the country is now once again dependent on other countries. Hence, if anything, there is an imminent need to create a more diversified energy system, in which distinct energy sources may compensate for one another, thereby increasing predictability.

Consequently, the government is currently trying to *stimulate a larger portfolio of investments* in electricity generation. New auctions are, for example, in process that involve not only fossil and hydro energy but also wind and solar – and even nuclear – power. In this context, there are also complex discussions regarding the price levels suggested by the government, particularly with respect to wind and solar energy. Investors claim, for their part, that prices are not high enough and thus provide little return for sectors that need to be further developed in terms of competitiveness (BITTENCOURT, 2014). Another challenge is to bring down the high local content requirements for public financing that currently prevent some of the more critical technologies from entering Brazil (VIRI, 2014).

The problem, though, is that creating a similar diverse energy system constitutes a long process, when in fact Brazil needs electricity as of yesterday. Hence, other measures will also have to be added to the mix. Under the present conditions, two solutions seem more promising and viable in the short- and medium terms. One is the reduction of electricity demand. Another concerns the attempt to prevent losses in the system. Both will require interventions in parts of the energy value-chain that so far have been left largely unattended.

With respect to the *reduction of demand*, there are important lessons from the 2001 energy crisis. At the time, there was no other option than rationing. This had a profound impact on industry that witnessed a drastic drop in productivity rates, with far-reaching implications on the entire economy. Following this experience, the Brazilian industry has since then made substantial efforts to reduce its energy use – and thus preempt future electricity crises. This trend was further reinforced during the global economic crisis in 2008. Data indicate, for example, that industry reduced its energy consume from 45.8 to 37.6 percent between 2007 and 2014 (POLITO, 2015).Moreover, to improve energy efficiency in general, the sector has also reduced its dependency on the integrated transmission system, by producing its own energy or simply buying it directly on the spot market. Interestingly, this all came out as independent responses by the private sector itself.

This overall development stands in stark contrast to the service and residential sectors that, during the same period (2007-2014), increased their energy consumption by 52.5 and 45.2 percent respectively. These trends are, as already indicated, explained by changes in weather patterns and reductions in energy tariffs. Still, altered income distribution policies have also contributed to this change. As a result, the government is now directing its efforts primarily on these two sectors. The strategy makes sense, particularly with respect to the residential area, which presents the worse level of energy efficiency of all sectors (CUNHA, 2015).

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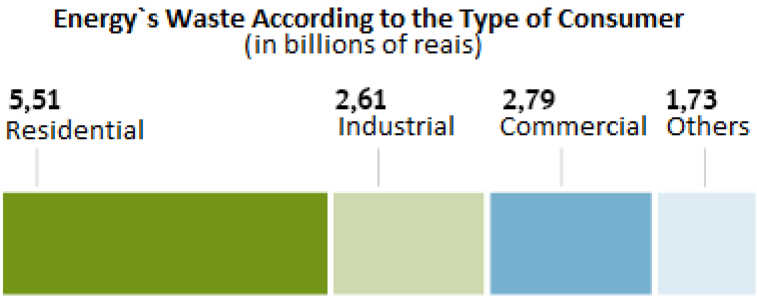

Source: Abesco *apud* Cunha, J. (2015)

One of the immediate measures to decrease energy consumption has been to revert from precious decisions and increase the electricity tariff. Only in 2015, there has been an average price increase of 23.4 percent at the national level (AMATO, 2015a), with some localities reaching more than 45 percent (AMATO, 2015b). Clearly, there is more behind the policies than just to discourage energy consumption. In effect, the government is thereby also responding to the pressures exert by distributors after the Presidential Decree in 2012.

The effects for distributors have been cautiously positive so far. Due the lack of rainfall, they have in recent months been forced to buy energy on the spot market, mainly from fossil plants, in order to guarantee consumer supply. At the same time, the price alterations on these markets have been monumental, ranging from US$ 67 per MWh in February 2013 to US$ 258 per MWh in February 2014 (LONGO, 2014). This situation, distributors claim, has been even harder to cope with because of the cash constraints caused by the mentioned Presidential Decree. Hence, the fact that the government now backs off from its earlier, is in itself a relief to distributors. Moreover, government has also provided additional loans to the sector, corresponding to nearly US$ 6.6 billion at the time of writing. The question, though, is whether this is enough and how long there will be more public money available. Adding to the complexity, Brazil is currently facing economic recessions and consequential fiscal adjustments. Hence, despite pressures for more loans, it may well be that governmental help now have reached exhaustion.

At the other end of the spectrum, it is still unclear what exact impact of the tariff elevation has had on actual demand. Data comparing the first trimester to the same period last year indicate a reduction of 1.8 percent in consumption rates – although variations make the tendency unpredictable (BORBA, 2015). In April, for instance, the demand was 0.3 percent higher (RAMALHO, 2015). Instead, it seems as if the most powerful factor behind the decrease energy consumption is the economic recession itself. According to experts, the poor productivity is in this case actually preventing the crisis from being worse (LAPORTA, 2015).

If we turn to policies that could *prevent losses in the system*, we find that total losses in 2012 represent 17.5 percent of the generated electricity in the system as a whole. Of this total, distribution and transmission contributions correspond to 13.3 and 4.2 percent respectively (ROCKMAN, 2012).

With respect to transmission, there are some divergences among specialists what exactly these numbers entail. Some argue that the losses are not problematic considering the great distances between generators and consumers, resulting in more than 110.000 kilometers of transmission lines. However, others point out that, while the ambition is to increase generation capacity in remote areas of the Amazon, these numbers are destined to grow. At the end of the day, similar losses impose a nearly 5 percent increase on the final consumers tariff (REY, 2012).

At the same time, most experts agree that in fact the numbers regarding distribution deserve special attention. This is, clearly, the area that so far has received less attention so far and, consequently, there are potentially many opportunities to be explored. Data shows, in this case, that out of the 13.3 percent losses attributed to distribution, approximately 60 percent are related to frauds and thefts throughout its cables, a number that is likely to grow with the current increase in consumer tariffs. In Rio de Janeiro State, for instance, this type of commercial losses represent 19. 91 percent of the energy distributed by one of its companies. This results in a collection reduced in US$ 12.7 million per each percentage number and in a tariff 8 percent more expensive to the final consumer (RESENDE, 2013) .[4] Hence, rather than elevating electricity supply, improved monitoring of frauds could, in effect, generate more investments and better service.

Yet, although the reduction of commercial losses may constitute solution in the short-term, there are also considerable challenges involved. More than anything else, there is the question of financing. Neither the control of losses, nor the introduction of a smart grid with distributed generation, will be achieved without substantial investments. Yet, under the current macroeconomic scenario this is not likely to take place.

Another challenge with respect to commercial losses is the way it correlates with the social complexity of Brazil. Even with a more favorable investment scenario, a stiffer supervision of frauds and thefts would in the short term leave millions of poor families without access to energy and all side benefits that come with it. The socio-political consequences from a similar development would be potentially devastating. A research study from 2013 indicates, for example, that more than 70 percent of all energy distributed in one specific *favela* of Rio de Janeiro resulted from frauds and thefts. Needless to say, cutting energy use in a reality that is already highly correlated to militias and drug dealings would potentially lead to riots (AMADO, 2013). Clearly, there are still important considerations to be made regarding economic and political sustainability.

[4] Resende, Tatiana. (2013). Perdas na distribuição: baixa tensão, altos prejuízos. *Canal Energia*, October 11th. Available at <http://www.abradee.com.br/imprensa/artigos-e-releases/1018-perdas-na-distribuicao-baixa-tensao-altos-prejuizos-reportagem-especial-canal-energia >.

5 Final words

The Brazilian energy challenge is by all means enormous, and the very fact that the country for a long time was considered an example for its wide use of renewable energy, implies that any decision on future policies extrapolates the proper frontier of energy policies. Consequently, there are various reasons why we should pay attention for what Brazil does in this situation.

A first critical observation is that Brazil, as a pioneer, was always short of a model to follow and, consequently, its policies were largely a process of trial and error. The 2001 crisis, for example, provided a brutal illustration on how past measures had failed to consider the link between industrial development policies and increasing electricity demand. As noted, the immediate response was to avoid a future disequilibrium between generation and consumption. In the Brazilian context, this generated large investments in generation capacity, since increased consumption was regarded as inherent to the desired economic development. However, in their analysis the government failed to consider a new dimension in energy policies, i.e. climate change. In fact, the crisis was not only attributed to a simple lack generation capacity but, perhaps even more, due to profound changes in weather patterns.

These blind spots are now having severe consequences, as the decision to maintain hydropower as the principal energy source in the Brazilian electricity system is, once again, challenged by an unpredictable lack of rain. As we have seen, the government is trying to meet the increasing demands by promoting electricity production from various sources. Still, this is not enough to meet the demand, since the entire system was designed to operate almost exclusively on water. Only now, and very brutally, has Brazil come to realize that the main policy failure resides in the electricity system's lack of structural diversity.

The government's long-term current ambition is to introduce new energy sources at a larger scale. In that sense, climate change seems to have opened up a new perspective of diversity. Brazil decided early that it wanted to be independent and self-sufficient on energy. In doing so, it chose to explore and exploit the country's renewable natural resources, something that was initially applauded in the global sustainability debate. However, what we see now is Brazil being hit again, not by its dependency on other nations, but rather by its increasing reliance on nature itself. Worse, the latter has proved to be an unreliable ally because of climate change.

There is obviously something ironic and tragic over the whole situation, in which, as for Brazil, investing and relying on renewable natural resources becomes unsustainable. Obviously, this raises several important questions, particularly with respect to policy design, as the world seem to be increasingly aiming towards a carbon-free society. The principal learning points must be caution and humility. Clearly, there is something contradictory about making large investments in large-scale, weather-dependent energy systems, thereby creating new socio-technical path-dependencies, when in fact changing and unpredictable weather patterns constitutes the very essence of climate change. Instead, ‘diversity’ seems to be a key word in the Brazilian story. The implications go far beyond the engineering pursuit of configuring a technically ideal energy matrix. Instead, the access to multiple energy sources has also wider policy implications, principally by providing a portfolio strategy to guarantee energy security – and thereby anticipate and mitigate political risk. Also, it constitutes the basis for spurring innovation at all levels of society.

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