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The evolving Brazilian automotive-energy infrastructure: Entanglements of national developmentalism, sugar and ethanol production, automobility and gasoline

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ABSTRACT

This paper addresses the dynamic sociotechnical construction of automotive-energy infrastructures, based on the case of ethanol fuel in Brazil in the 20th and early 21st centuries. Energy infrastructure projects are afforded but also constrained by technical and institutional "residues" of previous initiatives and achievements. The notion of "knots" is introduced to explore how sociotechnical entanglements interlinking elements from distinct levels of the societal fabric become stabilized and shape subsequent developments. This extension of the sociotechnical approach is shown to be fruitful to better understand the embedding of ethanol fuel in the process of evolution of the automotive-energy infrastructure in Brazil during the 20th century. This then offers building blocks for analysis and design of energy infrastructures in general.

1. Energy infrastructures emerging from sociotechnical knots: the case of ethanol as an integral part of the Brazilian automotive-energy infrastructure

The emergence of the Brazilian automotive-energy infrastructure is embedded in the country's efforts towards modernization since the beginning of the 20th century and it reflects broader economic, political and technological dynamics within the country.[1] For instance, it was shaped by the developmental role the State played to push Brazilian industrialization, but also by the power of traditional agricultural oligarchies, and newly influential groups, as the industrialists from the State of Sao Paulo. Here we show how the story of the automotive-energy infrastructure in Brazil is the story of the entanglement of the interests of a modernizing developmental state with the resources of the sugar sector and the artefacts of the automotive sector. Apart from its own historical interest, the case study we present in this paper illustrates a general perspective on emergence and stabilization of infrastructures.

Our theoretical departure points are, first, that infrastructures are much more than the association and alignment of its material components, they are sociotechnical. Second, that while energy infrastructures can be designed and implemented as such, often they are the result of various projects and interactions which cumulate over time (cf. also [1]). Their political economy is more than the traditional conflicts and negotiation of interests of various parties. The struggles are also about actual performance of the artefacts and the directions of development (including path dependencies). Residues of earlier projects can thus be just as important as new ventures; they all afford and constrain what can happen next. The notion of 'residues' is even more important when energy infrastructures are linked to projects and policies in specific sectors, in our case automobility, leading to strong mutual shaping. From a sociotechnical perspective, the dynamics of mutual shaping reside in the linkages that occur and can get more or less solid, forming "knots" in the network of entanglements [2].

To analyze the force exerted by those infrastructural knots over specific projects and initiatives we will refer to the so-called multi-level perspective (MLP) as developed in Twente [3–5]. Important here is its distinction between overall processes and interactions (and circumstances) that are located at the macro- or "landscape" level while micro and meso-level projects and interactions have to some extent own dynamics. At a deeper level, we see what Edwards [6], in a nice turn of phrase, has called the "circulatory systems of modernity".

The eventual development of macro-level infrastructures is shaped by "knots", i.e. stabilized entanglements of the interactions originally started at the micro- or meso-level. For example, institutes involved in the coordination of sugar production or in the development of the

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[1] In this way, it is similar to other papers in this special issue [61–65], even if we take a longer time horizon.

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ethanol fuel during the first half of the century should be seen as such knots because of their importance in the latter stages of the story as told here. Meso-level enactors, as we will call institutional entrepreneurs in general, but specifically those enacting new technology, are also important in the multi-level dynamics of the evolution of the automotive-energy infrastructure in Brazil.[2]

We are particularly interested in understanding how ethanol has been used as a fuel, blended with gasoline, at least since the 1920s, and eventually also as such when the so-called Brazilian Ethanol Car was developed in the 1970s and widely used in the 1980s. As mentioned, we will analyze how the development of an alternative fuel was shaped by long term dynamics between sociotechnical knots, meso-level enactors and contextual changes and pressures. There were two major linkages: with the sugar sector where ethanol was produced as a by-product, or sometimes as a main product; and with the Brazilian state, which had features of a developmental state [7], at an early stage already but particularly during the dictatorial regime (1964–1985) with its economic modernism, and the build-up of own industries, infrastructures and independent energy sources. There were further linkages, of course, as with automobile assemblers and with maintenance and repair actors (cf. [8] on maintenance constituencies). The Proálcool Programme of the Brazilian Government, starting in 1975, played an important role as a 'knot' tying the network linkages together, and creating path dependencies, at least for a time.

The country's modernization was pushed by the ideology of a Developmental State emerging during the Vargas Regime (1930–1945) in opposition to the earlier tradition of an export-based economy and the related elites of landowners. In a Developmental State, nationalistic initiatives were enacted to base its economy on an import substitution approach, which aimed at reducing the country's dependency on foreign technology, including its dependency on imported oil. While the interests of the sugar sector remained an important consideration during the various political regimes (like the second Brazilian Republic (1946–1964), and the dictatorial regime (1964–1985)), this was now seen as part of the Developmental State, a continuing feature of Brazilian governments across the various political regimes.

While there are differences there is continuity in how governments pushed the sugar cane sector since the 1930s; in the development and construction of motorways; in the creation and support of the State-owned company Petrobras after the discovery of oil in Brazil, in attracting and supporting of auto-assemblers into the country, and in the economic and research support to the modernization, also of the sugar producing sector. With this provision of recognizing continuity and path dependency, we can tell the story in terms of six stages. Given the importance of the ideology and practice of the Developmental State, the main criterion to identify the stages is how they are linked to the successive political regimes; so we will include brief characterizations of these regimes when discussing the stages.

2. The story, stage 1. The first Brazilian Republic (1889–1929)

The foundation of the Brazilian Republic on November 15, 1889 marks the beginning of the entanglement of indigenous resources, national development and agrarian elites which were knit together by the emerging use of ethanol fuel. At first, sugar mills and the government experimented with different blends of anhydrous ethanol and gasoline to be used as automotive fuel. Over time, there was institutionalization of the production and the creation of a market for the emerging ethanol fuel.

There is a prehistory: The production of sugar was initiated during the period in which Brazil was a colony of Portugal, and the production was based in the Northeast. Its importance receded after the 17th century, but by the 19th century the government introduced dedicated efforts to modernize the sugar sector [9]. In 1875, the then Imperial Government decide to subsidize the sugar producing activities by giving special financing conditions to entrepreneurs who aimed at establishing big central sugar mills. While not achieving the objective of constructing a large number of central sugar mills, the new policy induced a separation between the agricultural phase of sugar cane plantation, and the industrial phase of sugar production [10].

The separation of these two phases was part of the industrialization trend of the Brazilian First Republic and allowed the emergence of new dynamics within the sector. First, the separation between agricultural and industrial phases favored the state of São Paulo and the interests of the agrarian oligarchies, like sugar cane and coffee planters [11,12].[3] Second, it afforded alliances between sugar industrialists and Public Research Institutes, as the Campinas Institute of Agronomy (Instituto Agronômico de Campinas – IAC) [9]. New alliances were forged as part of the efforts to overcome the sugar cane mosaic virus crisis of the early 1920s. The strategy was successful and led to the development of more resistant sugar cane varieties. More than that, it was responsible for pushing the modernization of the sector within the state of São Paulo through the development of sugar cane crops that were better adapted to the Brazilian soil [9,10].

Already earlier, at the dawn of the 20th century, there were local experiments independent from federal measures and regulations which were using ethanol, as a by-product from the production of sugar, cachaça and ethanol for chemical ends, as a fuel for cars, tractors and trucks owned by these same mills. Those experiments were driven by local entrepreneurs, sometimes supported by local governments, that sought independence from imported gasoline, which was difficult to obtain at the beginning of the 20th Century [13]. Some of these experiments were reported at the 3rd National Agricultural Congress in 1922, which defended the expansion of the use of ethanol as an automotive fuel in the form of blend with gasoline, called álcool-motor [10].[4] Also in 1922 President Epitácio Pessoa made a public speech in which he highlighted the necessity to invest in álcool-motor as a substitute of gasoline because of the growing imports of gasoline and the need to support the sugar industry that was going through an overproduction and market reduction crisis [14].

In a subsequent initiative in 1923, the government tasked the *Estação Experimental de Combustíveis e Minérios* (EECM)[5] to start conducting studies on the use of ethanol as a fuel to partially substitute gasoline in explosion engines [15]. One of the results of these researches was the adaptation of the engine of a Ford Model T, that ran a 230 km race fueled by ethanol 70° G. L in 1925 [14]. There were general concerns about basing the country's industrialization on non-renewable energy sources [13,16,17], which led experimentation to occur in parallel to governmental initiatives.

There were more demonstrations that regular cars could run on ethanol blends. In 1927, the first commercial álcool-motor fuel blend was launched in Recife under the name of USGA – *Usina Serra Grande*

[2] In our case study, we will use the general idea of multi-level perpective, with interactions between the levels, rather than the specific version articulated by Geels [5] and now widely used in sustainability transition studies.

[3] We note that the industrialists of São Paulo played a central role in the early development of transportinfrastructures in Brazil because of their interest in reducing the transport costs for products that would be exported.

[4] Álcool-motor was the generic name given to fuel blends of anhydrous ethanol and gasoline before the 1970s enactment of Proálcool. Anhydrous ethanol is now commonly understood as ethanol with only 0.4 volume percent water, while the azeotropic mixture of 95.5 volume percent ethanol is called "hydrated ethanol". Earlier, there was some variety in the specification of anhydrous ethanol, for example 100° Gay-Lussac [16], or 99.7° Gay-Lussac at 15° Celsius [66], but also simply as higher than 96° Gay-Lussac [36]. The volume percentage of ethanol is measured with the alcoholmeter of Gay-Lussac, and expressed in degrees Gay-Lussac (GL), with 1° GL equal to one volume percent at a temperature of 15° Celsius. For information about álcool-motor see [13,16,36,66,67].

[5] The *EstaçãoExperimetal de Combustíveis e Minérios* was created in 1921 and had the mission to "investigate and promote the best industrial process for the use of fuels and minerals from the country". [15].