FUTURE SRJ
FUTURE STUDIES RESEARCH JOURNAL: TRENDS AND STRATEGIES

PROFUTURO: FUTURE STUDIES PROGRAM
Scientific Editor: James Terence Coulter Wright
Evaluation: Double Blind Review, pelo SEER/OJS
Review: Grammatical, normative and layout
Received in: 09/09/2014 **Approved in:** 10/22/2014

FUTURE RESIDENTIAL WATER HEATING PROSPECTS IN BRAZIL: A SCENARIO BUILDING GROUND ANALYSIS

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ABSTRACT

In Brazil, electricity is the prime energy carrier for bath shower heating purposes. However, since analyses indicate that expansion of the country´s electricity generation capacity shall spruce from an increased non-renewable sources' stake in detriment to that of hydroelectricity, high electricity consumption rates that spring from home end uses of the kind have drawn the attention of those who are involved with local energy planning. Furthermore, massive use of electric showers in a short timeframe largely drive electricity demands to culminate in peak loads. For water heating purposes, this context has favoured an alternative to electricity, deemed feasible from both an efficiency and energy infrastructure standpoint: promote fuel gas consumption (liquefied

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petroleum gas and natural gas in particular). A scenario methodology is herein employed to map electric shower use related variables and players and assess the future behaviour of the core elements that condition resorting to this technology. Thereafter, strategies and opportunities to promote the rational consumption of the country´s power sources ground on the increased use of fuel gases for residential water heating purposes are discussed.

KEY-WORDS: Energy scenarios. Electric showers. Fuel gases. Brazil. Residential end uses.

PERSPECTIVAS FUTURAS DO AQUECIMENTO RESIDENCIAL DE ÁGUANO BRASIL: UMA ANÁLISE A PARTIR DA CONSTRUÇÃO DE CENÁRIOS

RESUMO

Eletricidade é a principal forma de energia utilizada no aquecimento de água para banho no Brasil. O elevado consumo elétrico decorrente desse uso final, entretanto, tem atraído a atenção daqueles envolvidos no planejamento energético do país na medida em que análises indicam que a expansão da capacidade de geração elétrica deve ocorrer a partir da maior participação de fontes de energia não renováveis em detrimento da hidroeletricidade. Além disso, a utilização maciça de chuveiros elétricos em um curto intervalo de tempo contribui significativamente para a formação de picos de demanda elétrica. Diante desse cenário, a promoção do consumo de gases combustíveis (mais especificamente, gases liquefeitos de petróleo e gás natural) para o aquecimento de água tem se apresentado como alternativa viável, do ponto de vista da eficiência e infraestrutura energética, à eletricidade. Neste trabalho,

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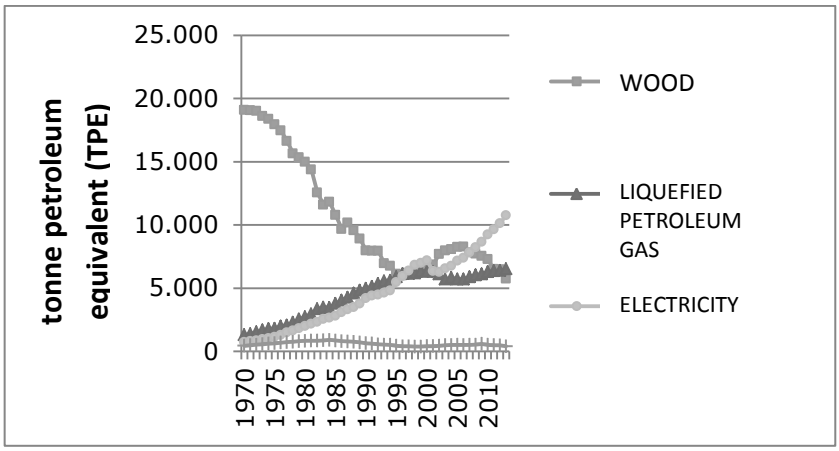
utiliza-se uma metodologia de cenários para mapear as variáveis e atores relacionados à utilização de chuveiros elétricos e avaliar o comportamento futuro dos principais elementos que condicionam a utilização dessa tecnologia. A partir disso, discutem-se estratégias e oportunidades para promover a racionalização do consumo dos recursos energéticos do país a partir da maior utilização de gases combustíveis para o aquecimento residencial de água.

PALAVRAS-CHAVE: Cenários energéticos. Chuveiros elétricos. Gases combustíveis. Brasil. Usos finais residenciais.

1 INTRODUCTION

In 2012, electric power consumption at Brazilian homes totalled 117.646 GWh, a figure that corresponds to 23.6% of the total amount of electric energy that is used in the country (Energy Research Company [EPE], 2013). Over the last decade, this kind of energy´s share in the domestic segment´s energy matrix rampantly expanded. In 2003, electricity accounted for 31.3% of the energy consumed at Brazilian homes whilst in 2012, this figure neared 42% (Graph 1), pointing towards the gradual increased relevance of electric end use in comparison to that based on other energy sources such as natural gas, liquefied petroleum gas (LPG) and wood.



Graph 1: Brazilian residential energy matrix evolution during 1970-2012

Note: Kerosene, piped gas and natural gas are not represented given the bleak historical contribution of these sources of energy to the residential segment.
Source: Prepared by the authors as of EPE (2013)

Assorted authors have centred their analyses on Brazil´s domestic consumption of electricity profiles. As of data gathered across the State of São Paulo, Jannuzzi and Schipper (1991) state that at the sampled homes, the end uses that most demand electricity are refrigeration and water heating (33% and 23% respectively).

In their study, Almeida, Schaeffer and Rovere (2001) present the share different electric consumption end uses have in the total amount the residential

segment consumes in Brazil, on a per region basis. For the most part, the survey´s data suggests that for the same consumption profile Jannuzzi and Schipper (1991) found that on average, water heating features as the second ranked end use that most consumes electricity at Brazilian homes (20.7%), only falling short of refrigeration (34,1%).

Finally, data of the most recent version of the Electro-domestic Appliance Ownership and Consumer Habits Survey (Eletrobras, 2007) corroborate the findings both of the previously mentioned studies presented. According to this survey, showers on average account for 24% of the residential consumption of electricity in Brazil.

If one takes into account the latest data on the share showers - 24% (Eletrobras, 2007) – hold in the residential segment´s total electrical consumption, i.e., 117.646.000 MWh (EPE, 2013) calculations reveal that this final use demands 28.235.000MWh per annum, an amount that is equivalent to 5.5% of all the electricity Brazil consumes.

The large volume of electricity used to heat water relates to the widespread use of electric showers in Brazil, a phenomenon that dates back to the 60´s and 70´s. During these decades, the country´s demand for electricity fell behind Brazil´s generating capacity growth rate, duly leveraged by the building of the Itaipú power plant. To ensure the consumption of the resulting surplus, the use of these appliances was encouraged (Martins, Abreu & Pereira, 2012). Electric showers are currently used at 73.1% of Brazilian homes. Throughout Brazil´s regions, this technology´s penetration varies to a significant extent particularly in light of local climatic conditions, namely: whilst in the South that at wintertime features the country´s lowest temperatures, the proportion of homes that use electric showers is remarkably high (98.6%), in the hot and damp Northern region figures are as low as 4% (Eletrobras, 2007).

Different authors suggest that as a result of several electric sector contexts, Brazil shall face structural process changes in its energy matrix. These shall be characterized by increases in the relative contribution of non-renewable thermic sources - particularly as of the burning of natural gas and other fossil fuels (eventually including the expansion of nuclear power generation) - in detriment of the generation of hydroelectric power. Castro, Brandão and Dantas (2010), Birol (2013), Santos, Rosa, Arouca and Ribeiro (2013) and Nogueira et

al. (2014) have extensively discussed and are deemed sound references for issues that determine the expansion of thermoelectric power generation in Brazil.

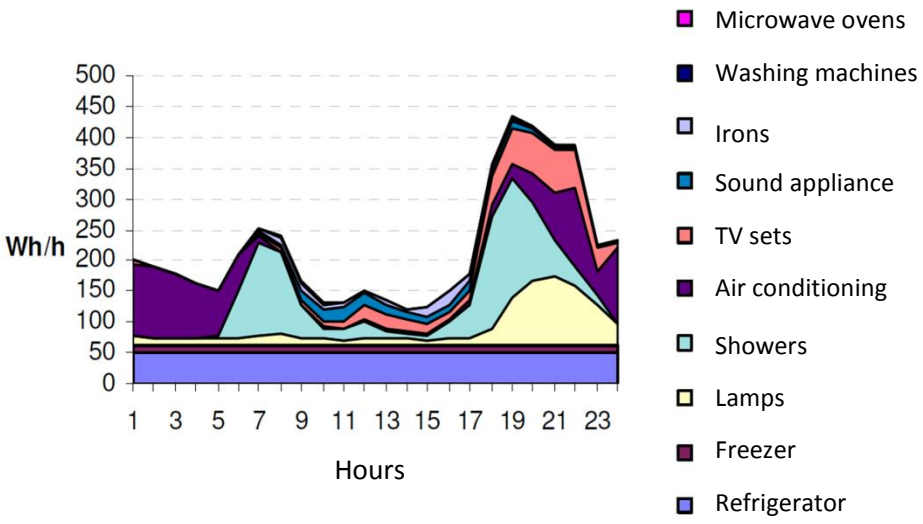
As an increased share of electricity consumed in Brazil is produced as of thermic sources, electrothermy (i.e., the use of electricity to generate heat, as is the case of electric showers) from an energy efficiency standpoint, accordingly becomes increasingly condemnable. Santos, Fagá and Santos (2013) illustrate this issue by comparing the global efficiency of heating water by using an electric shower that is powered by electricity generated by burning gas (37%) and a heater that uses gas directly to heat water at a home (72%). For the purpose of this comparison, the authors define the "global efficiency" concept as the efficiency of all processes – generation, transmission, distribution and conversion - involved in the transformation of primary energy into useful energy.

In addition to the high electricity consumption rate and energy efficiency related issues, Behrens and Consonni (1990) and Geller, Jannuzzi, Schaeffer and Tolmasquim (1998) also discuss the fact that the massive use of electric showers during a relatively short timeframe – usually between 18h00 and 21h00 – contributes to the increase of the electrical demand peak. During this period, the electrical demand posed by showers might come to account for approximately 60% of a home´s electrical demand (Naspolini, Militão & Rüther, 2010). Prado and Gonçalves (1998) suggest lower yet still very relevant shares: between 18h00 and 19h00, showers would represent 46.7% of the average residential electrical demand.

If one takes into account all of the economy´s sectors, Volpi, Jannuzzi and Gomes (2006) advocate showers are responsible for approximately 20% of the country´s demand peak. Furthermore, these authors estimate that each shower calls for the need to invest approximately US$ 1.000,00 (assumptions resting on the exchange rate during the period the study was published) to increase the electric generation capacity to power them (this figure´s current accuracy requires more refined research that literature does not offer. However, as of Graph 2 one notices that the electrical showers' aggregate demand determines the need for infrastructure to generate, transmit and distribute electricity which during the remaining hours of the day shall remain idle or

under-utilized. This idleness represents an economic inefficiency in the allocation of both capital and investments).

Graph 2 pictures the share different electro-domestic appliances have in the residential demand and demonstrates the relevance the electric shower demand imparts, both at the end of the day and during the morning.



Graph 2: Average curve of the Brazilian residential segment´s electrical consumption

Source: Eletrobras (2007)

Given the herein presented information, this study poses to understand the possibilities of energy consumption progress involving the residential heating of water in Brazil by resorting to a scenario construction methodology. Analyses focused on the energy mode that currently is most employed to power this energy service (electricity) and on its most direct alternative, i.e., heat generated via the burning of fuel gases (liquefied petroleum gases – LP gas and natural gas – NG). The herein presented results and analyses might subsidize planning strategies centred on promoting enhanced rationality when using the country´s energy resources.

2 METHODOLOGY

Scenarios can be built and classified in an assortment of ways (Börjeson, Höjer & Dreborg, 2006). Though far from ending discussions on the subject matter, there are some reviews that cast light on the challenge of accurately categorizing the diversity of building techniques and scenario interpretation modes (Börjeson et al., 2006; Souza & Takahashi, 2013). Given the absence of consensus involving the typology of this analytical tool (Börjeson et al., 2006), the authors to not intend to, per given nomenclatures, herein classify or define the type of scenario that was used.

Irrespective of the range of existing categories, the methodology henceforth presented enabled the investigation of different development possibilities of residential water heating modalities in Brazil and how decision makers might position themselves before such referrals to encourage the efficient and rational use of energy resources and infrastructure.

The grounding to develop the methodology was extracted from Buarque´s (2003) studies that comprises extensive contribution from authors such as Michel Godet and Kees van der Heijden. Simply put, the steps pictured in Figure 1 were executed throughout the study.

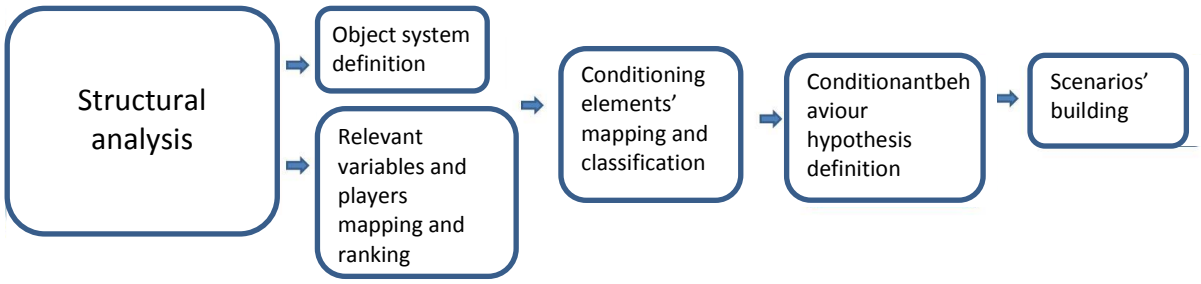


Figure 1: Scenario building process stages

2.1 STRUCTURAL ANALYSIS

The first stage of the scenario building process is the structural analysis of the system-object. Before exploring different future development possibilities and establishing how the analysed system-object might behave before each of

them – intrinsic activities of scenario construction itself – a robust knowledge structure must be built around the target of these developments.

As shall be seen throughout this section, the structural analysis of the system-object comprises sequential stages that when followed in an orderly manner not only enable the organizing of existing system-object information but also the mapping of gaps that knowledge on the subject matter of analysis may present and which shall have to be mitigated. Thus, this procedure proves to be vital to ensure subsequent analyses that are conducted during the scenario building process become more assertive and consequently reduce the level of uncertainty of the study´s findings.

Objectively, the structural analysis of the system-object that was prepared for this study´s purposes, followed the steps hereunder described.

- Definition of the system-object – Essential stage to ensure that the scenario building process effectively reflects the study´s key issue.
- Identification of the variables – Selection of the "determining and most relevant ... (elements) ...that explain the movement of the object of analysis" (Buarque, 2003, p. 50).
- Identification of the players – Selection of the agents who might influence the system-object.
- Ranking of variables – As of a square matrix (variable x variable), evaluation of each variable´s ability to influence others. Score "1" is assigned to situations where a variable listed in the "y" axis is capable of influencing a variable listed in axis "x". When no influence is verified, score "O" is assigned. The sum of line amounts indicates each variable´s influence power (Table1).

Table 1: Variables' structural analysis matrix example

	Variable 1	Variable 2	Variable 3	Variable 4	...	Influence Power
Variable 1	0	0	0	1	1	= 0+0+0+1+1
Variable 2	1	0	0	0	1	2
Variable 3	0	0	1	0	0	1
Variable 4	1	1	0	0	1	3
...	0	1	0	0	0	1

- Ranking of players – As of a square matrix (player x variable), evaluation of each player´s ability to influence variables. The analytical process is similar to that of the previous stage but in this case, each variable´s level of influence is taken into account. Thus, each stakeholder´s influence index is calculated as of the sum of the product between value "1" and the variable´s power of influence over which the analysed stakeholder/player is capable of exercising influence (Table 2).

Table 2: Stakeholder structural analysis matrix example

	Variable 1	Variable 2	Variable 3	Variable 4	...	
Power of Influence of the variable →	2	2	1	3	1	Power of Influence of the player ⇩
Player 1	0	0	0	1	1	= 0x2+0x2+0x1+1x3+1x1
Player 2	1	0	0	0	1	3
Player 3	0	0	1		0	1
Player 4	1	1	0	0	1	5
...	0	1	0	0	0	2

2.2 CONDITIONING ELEMENTS' MAPPING AND CLASSIFICATION

Future conditioners are the trends that are currently beginning to shape and suggest future pathways (Buarque, 2003).

Elected conditioners must be analysed in terms of their impacts, intensities and uncertainties. "Impact" is herein understood as the potential change the conditioning element might impart on the system-object. "Intensity" refers to the conditioning element´s current visibility. Finally, "uncertainty" expresses the level of reliability of the conditioner´s effective future occurrence. A value that pertains to each of these analytical criteria is assigned to conditioning elements ("1" having been used for a subtle relation, "3" for an average relation and "5" for a strong relation).

This methodology´s final procedure consists in the generation of a unique numeric index for each conditioner known as "density" that arises from the multiplication of the scores obtained from the analysis of the three mentioned criteria. Density – in as much as it synthetizes information on conditioner impact,

intensity and uncertainty – identifies the most "critical" conditioners, i.e., those that must receive greater attention from parties interested in the system-object´s future developments.

2.3 CONDITIONER BEHAVIOUR HYPOTHESIS DEFINITION

During this stage, focus is only placed on the critical conditioning elements and future behaviour hypotheses are assigned to them. This consists in a thought exercise or brainstorming session that ponders the possible developments each conditioning element might come to pursue, based on the analysis of data that might ground the formulation of hypotheses. For each conditioning element, two or three behaviour hypotheses were ideated.

2.4 SCENARIO BUILDING AND KEY STAKEHOLDERS' MAPPING

This final stage comprises the selection of different combinations of conditioner behaviours, establishing assorted scenarios. Since the random combination of all behavioural possibilities would generate too large a number of alternative scenarios for analytical purposes, a subjective approach was employed whereby specific scenarios were built.

As of the set of constructed scenarios, stakeholders capable of promoting on each conditioner the needed changes for the trending scenario to closely resemble that intended by the study, were identified.

3 RESULTS

Next, the outcomes that resulted from the application of the above described methodology for the purpose of the study herein presented are discussed. One can well imagine the level of effort this first stage´s system-object definition exercise calls for, since it is by no means obvious when it comes to a study that involves energy planning aspects and technological substitution as a subject matter, fields of study that are intrinsically complex and notorious for their multidisciplinarity. Special attention was devoted to ensuring that the

myriad of themes associated with the field of knowledge the study comprised did not interfere with the same´s objectiveness but rather, enriched analyses. Therefore effort centred on seeing to the system-object on one hand focused on the study´s overall objective and on the other, ensured the contribution of variables that stemmed from different theoretical frameworks.

3.1 STRUCTURAL ANALYSIS

The "residential heating of water as of electrical showers" was defined as the study´s system-object. The identification of determining variables', players and conditioning elements processes consisted in the review of specific literature and in the organizing of meetings where the brainstorming method was employed by the study´s technical team. After several discussion sessions when each researcher´s perception of the system-object´s behaviour in the short, mid and long term were shared and debated, final lists containing variables, players and conditioning elements of the future were prepared that shall accordingly be hereinafter presented.

All in all, 23 variables and 17 players were analysed as pictured in Charts 1 and 2, respectively.

Chart 1: Description of the selected for analyses variables

Variable	Description
Price of electricity	Represents the price one pays for consuming residential electricity
Price of the alternative final sources of energy	Refers to the price of energy sources that are alternatives to that of electricity that one can use to meet the residential demand for water heating purposes.
Price of the electric shower (appliance, installation and maintenance).	Represents the amount paid to purchase the appliance, install and maintain it.
Price of the alternative heating system (appliance, installation and maintenance).	Relates to the amount paid for the purchasing, installation and maintenance of residential water heating systems that pose as an alternative to the use of electric showers.
Price of the electric shower´s infrastructure (building and maintenance)	Costs involved in the building and maintenance of the construction work required to operate electric showers.
Price of alternative heating systems' infrastructure (building and maintenance)	Costs involved in building and maintaining the required building infrastructure (facilities) to operate alternative residential water heating systems *versus* that of the electric shower.
User´s buying power	Associated with a family or residence´s income being committed with periodic or extensive expenses.

Continues

Continuation

Types of infrastructure	Refers to technical aspects that pertain to the infrastructure needed to

	install and operate the different residential water heating technologies.
Types of technologies	Refers to the different residential water heating technologies that "compete" for the same consumer market.
Difficulty to retrofit infrastructure	Represents the technical challenges associated with the installation of residential water heating systems based on alternative sources of energy at homes where project assumptions were solely ground on the use of electricity for this particular purpose.
Comfort	Consists in the technical requirements associated with the comfort offered by residential water systems (hydraulic flow and water temperatures).
Usability	Variable associated with the friendliness of the interface between the residential water heating appliance and the final user.
Electric shower safety	Refers to the aspects that pertain to the appliance´s safety both in as much as the equipment´s intrinsic risks and those that result from its incorrect installation are concerned.
Safety of the alternative heating systems	Refers to aspects that pertain to the appliance´s safety, both as to the equipment´s intrinsic risks and in terms of the risks associated with its incorrect installation.
Energy efficiency	Efficiency of assorted residential water heating appliance technologies.
Perception of safety *versus* electric showersPercepção de segurança em relação ao chuveiro elétrico	Associated with the notion of safety end users have as compared to that of electric showersEstá associada à noção de segurança que o usuário final possui em relação ao chuveiro elétrico.
Perception of safety *versus* alternative heating systemsção de segurança em relação aos sistemas alternativos de aquecimento	Associated with the notion of safety end users have in relation to residential water heating systems. Está associada à noção de segurança que o usuário final possui em relação a sistemas residenciais de aquecimento de água.
Knowledge of technologiesConhecimento das tecnologias	Refers to access to information on the range of residential water heating systems that are available on the market. ere-se ao acesso a informações sobre as diferentes tecnologias de aquecimento residencial de água disponíveis no mercado.
Electric shower rulings Regulamentação dos chuveiros elétricos	Represents the technical requirements that the manufacturing and installation of electric showers must comply with according to the entities that define this activity´s rules. a os requisitos técnicos exigidos para a fabricação e instalação de chuveiros elétricos exigidos por órgãos reguladores da atividade.
Alternative heating system rulingRegulamentação dos sistemas aslternativos de aquecimento	Represents the minimum technical alternative to electric shower residential water heating systems' manufacturing and installation requirements the activity´s ruling entities demand all comply with.a os requisitos técnicos mínimos para a fabricação e instalação de sistemas residenciais de aquecimento de água alternativos ao chuveiro elétrico exigidos por órgãos reguladores da atividade.
Access to and availability of electricity à eletricidade e disponibilidade delaa eletricidade Perception of safety *versus* electric showersPercepção de segurança em relação ao chuveiro elétrico	Not only refers to access (in terms of being connected to the electric power network) but also to the capacity (financial) end users have to fund the electric consumption needed to meet the residential demand for hot water. Refere-se não apenas ao acesso (no sentido de estar conectados à rede elétrica), mas também à capacidade (financeira) de os usuários finais custearem o consumo elétrico necessário para o atendimento da demanda residencial de água quente. Associated with the notion of safety end users have as compared to that of electric showersEstá associada à noção de segurança que o usuário final possui em relação ao chuveiro elétrico.

Continues

Continuation

Access to other sources and	Not only refers to access (in terms of being serviced by the fuel gas

their availability o a outras fontes e disponibilidade delasa outras fontesPerception of safety *versus* alternative heating systemsção de segurança em relação aos sistemas alternativos de aquecimento	distribution network) but also the capacity (financial) end users have to fund the non-electric consumption needed to meet the residential demand for hot water. Refere-se não apenas ao acesso (no sentido de ser atendido pela rede de distribuição de gases combustíveis), mas também à capacidade (financeira) de os usuários finais custearem o consumo energético não elétrico necessário para o atendimento da demanda residencial de água quente. Associated with the notion of safety end users have in relation to residential water heating systems. Está associada à noção de segurança que o usuário final possui em relação a sistemas residenciais de aquecimento de água.
Climatic characteristicsCaracterísticas climáticas Knowledge of technologiesConhecimento das tecnologias	Refers to the local climate´s effects (particularly temperature and seasonality) on the hot water consumption habits. e-se aos efeitos do clima local (principalmente temperatura ambiental e sazonalidade) sobre os hábitos de uso de água quente. The insertion of this variable in the herein discussed analyses intends to reflect Brazil´s climatic diversity and the consequent influence this poses on the residential demand for hot water across the country´s different regions. A inserção desta variável nas análises apresentadas busca refletir a diversidade climática do Brasil e a sua consequente influência sobre a demanda de água quente residencial nas diferentes regiões do país. Refers to access to information on the range of residential water heating systems that are available on the market. ere-se ao acesso a informações sobre as diferentes tecnologias de aquecimento residencial de água disponíveis no mercado.
Electric shower rulings Regulamentação dos chuveiros elétricos	Represents the technical requirements that the manufacturing and installation of electric showers must comply with according to the entities that define this activity´s rules. a os requisitos técnicos exigidos para a fabricação e instalação de chuveiros elétricos exigidos por órgãos reguladores da atividade.
Alternative heating system rulingRegulamentação dos sistemas aslternativos de aquecimento	Represents the minimum technical alternative to electric shower residential water heating systems' manufacturing and installation requirements the activity´s ruling entities demand all comply with.a os requisitos técnicos mínimos para a fabricação e instalação de sistemas residenciais de aquecimento de água alternativos ao chuveiro elétrico exigidos por órgãos reguladores da atividade.
Access to and availability of electricity à eletricidade e disponibilidade delaa eletricidade	Not only refers to access (in terms of being connected to the electric power network) but also to the capacity (financial) end users have to fund the electric consumption needed to meet the residential demand for hot water. Refere-se não apenas ao acesso (no sentido de estar conectados à rede elétrica), mas também à capacidade (financeira) de os usuários finais custearem o consumo elétrico necessário para o atendimento da demanda residencial de água quente.
Access to other sources and their availability o a outras fontes e disponibilidade delasa outras fontes	Not only refers to access (in terms of being serviced by the fuel gas distribution network) but also the capacity (financial) end users have to fund the non-electric consumption needed to meet the residential demand for hot water. Refere-se não apenas ao acesso (no sentido de ser atendido pela rede de distribuição de gases combustíveis), mas também à capacidade (financeira) de os usuários finais custearem o consumo energético não elétrico necessário para o atendimento da demanda residencial de água quente.

Continues

Continuation

Climatic	Refers to the local climate´s effects (particularly temperature and

characteristicsCaracterísticas climáticas	seasonality) on the hot water consumption habits. e-se aos efeitos do clima local (principalmente temperatura ambiental e sazonalidade) sobre os hábitos de uso de água quente. The insertion of this variable in the herein discussed analyses intends to reflect Brazil´s climatic diversity and the consequent influence this poses on the residential demand for hot water across the country´s different regions. A inserção desta variável nas análises apresentadas busca refletir a diversidade climática do Brasil e a sua consequente influência sobre a demanda de água quente residencial nas diferentes regiões do país.

Chart 2: Description of the selected for analyses players

Players	**Description**
National Electric Energy Agency (*Aneel*)	Public entity accountable for ruling the Brazilian electric system.
Other energy sources ruling agencies	Refers to federal and state public entities accountable for controlling and supervising natural gas and LPG distribution activities.
Government – energy policies	Government sectors amongst other functions in charge of activities that pertain to the organization of the country´s energy sector such as planning the expansion of the supply of electricity and the adoption of energy efficient and consumption reduction measures. e.g.: Ministry of Mining and Energy.
Government – other policies	Government sectors capable of planning and implementing tributary or fiscal policies that might interfere in the system-object under study.
National Electric Energy Preservation Program (*Procel*)	Founded in 1980 by the federal government, *Procel´*s objective is to promote the rationalization of the production and consumption of electric energy.
National Rationalization of the Use of Petroleum and Natural Gas By-Products Program (*Conpet*)	Founded in 1990 by the federal government, *Conpet´*s objective is to promote the rational use of crude oil and natural gas's by-products.
Civil construction builders and developers	Comprise companies responsible for the project, building and sale of real estate.
Installer and labour	Comprise the professionals involved in the installation and maintenance of residential water heating appliances.
Designer	The professional that is in charge of defining the topography of the different residential water heating systems.
Consumer	Refers to those who shall use the residential water heating systems.
Electric shower suppliers	Refers to the companies that manufacture or import electric showers to address the residential market´s needs.
Alternative heating system suppliers	Refers to the companies that manufacture or import gas heaters or other water heating technologies for residential use.
Brazilian Technical Standards' Association (*ABNT*)	*ABNT* is a non-profit civil society entity certified as the single National Normalization Forum accountable for preparing rulings in Brazil.
Electric energy generator and transmitter	Comprises companies in charge of generating and transmitting electricity across the country. Special attention is given to *Eletrobrás*'s role, a state-owned company that holds significant market share and that easily directly interfaces with the government.

Continues

Continuation

Electric power distributor	Companies responsible for the distribution and direct supply of

	electricity to end users.
Distributor of other types of energy	Constitute companies in charge of the distribution and sale of alternative sources of energy (to that of electricity) utilized for the heating of water, such as natural gas and LPG.
National Metrology, Quality and Technology Institute (*Inmetro*)	*Inmetro* is a federal entity that is linked to the Ministry of Development, Industry and Foreign Trade (*MDIC*) whose mission is to formulate and execute the national metrology, industrial normalization and quality certification of industrial products policies.

In suit, Tables 3 and 4 present the ranking of variables and players prepared per procedures discussed in the previous section.

Table 3: Ranking of variables

Variables	Power of influence
Types of technologies	15
Types of infrastructure	13
User buying power	11
Climatic characteristics	9
Alternative heating system certification	9
Electric shower certification	8
Comfort	7
Usability	7
Electric shower safety	6
Alternative water heating system´s safety	6
Access to electricity and it´s availability	5
Access to other sources of energy and their availability	5
Knowledge of technologies	5
Difficulty in retrofitting infrastructure	5
Price of electricity	5
Price of alternative final energies	5
Price of alternative water heating systems (appliance, installation and maintenance)	5
Energetic efficiency	4
Alternative water heating system´s perception of safety	4
Electric shower´s perception of safety	4
Price of electric showers (appliance, installation and maintenance)	4
Price of alternative water heating systems´ infrastructure (construction and maintenance)	3
Price of electric shower´s infrastructure (construction and maintenance)	3

Table 4: Ranking of players

Player	Power of influence
Procel	70
Builders and developers	68
Conpet	63
Designer	62
Government – energy policies	61
Alternative water heating system suppliers	53
Electric showers' suppliers	52
ABNT	52
Inmetro	52
Government – other policies	51
Consumer	28
Distributor of other types of energy	27
Installer and labour	26
Electric power distributor	19
Other types of energy ruling agencies	15
Electric energy generator and transmitter	10
Aneel	10

3.2 CONDITIONING ELEMENTS

Eleven conditioning elements were defined as of the analysis of information that was generated during the study´s structural analysis stage. A detailed description of these elements is henceforth presented. The result of the ranking of conditioners analysis and of the selection of those deemed most critical (featuring greater densities) to the definition of the future development possibilities of the system-object are presented in Table 5.

- **Valuing water:**
  - The concern different sectors of society express in relation to the rational use of water resources tends to influence the choice for a given residential water heating system. With the technologies that are currently offered in Brazil (and also widespread across the world), gas fuelled heating systems might represent greater consumption of water when compared to electric showers, particularly in function of the greater flow of water that their showers utilize. In a context that values the rational use of water,

technologies that present comparatively high water consumptions shall become less attractive to the consumer market, public agents and other related sectors.

- Furthermore, one must take into account the volume of water that is discarded until the hot water effectively reaches the showerhead. Electric showers are sources of heat at the end point of hot water usage. On the other hand, for safety reasons, gas fuelled heaters are installed in ventilated areas, almost always far away from the bathrooms where the hot water shall be used. The water that remains stored in the portion of the pipeline between the showerhead and the heater is usually discarded since it´s not hot enough. However, these volumes tend to be less significant in relation to that consumed during a bathing session.

- **Relative price of electricity versus it´s substitutes**:
  - This is a theme that involves major uncertainties given the range of factors that influences the price of both electricity and fuel gases. The assumption is that the relative price of the source of energy influences the choice of different residential water heating systems.
- **Implementation of the white (time-of-use) tariff**:
  - The prime purpose of discriminatory charging systems is to inhibit the consumption of electricity at peak hours, penalising consumers with higher tariffs during three hours of the day when the demand for electricity increases, namely between 18h00 and 21h00 (Eletrobras, 2007). This measure may impart two important effects: make the use of electric showers less attractive and consequently increase the commercial appeal of water heaters based on other forms of energy or promote changes in the usage pattern of electric showers to new market conditions, shifting the use of the appliance to times of the day when electricity is cheaper.

- **Valuing of comfort**:

- The raise in overall income that occurred during the past couple of years enabled lower income population levels to have access to improved quality products and services. If initially the financial surplus is usually used to address the till then supressed demand for items that are considered pretty basic such as electro-electronic appliance and mobile phones for instance, a secondary trend might be the seeking of better energy services that offer greater comfort. Sheltered by this context, residential water heating systems that promote end user comfort might capture a larger portion of the market despite representing higher costs and often implying in the consumption of more water.

- **Fuel gases' supply – final energy:**
  - This conditioning element refers to the infrastructure or facilities one needs to ensure fuel gases can be used as final energy by the residential sector. Initially one must take into account the existence and extension of the distribution infrastructure for these kinds of energy sources. In contrast with the status of LP gases that features a bulk distribution network covering almost all of the country´s territory, that of natural gas is limited to the extent this hinders increased shares of this alternative at the residential sector (in Brazil, LP gases' pipeline infrastructure is also poor and concentrated in a handful of closed condominiums located at prime regions of the country´s major metropolitan areas. However, the scarcity of pipelines primarily impacts the residential use of natural gas since other bulk modes – via compressed natural gas (CNG) or natural liquefied gas (LNG) – are still deemed non-attractive for small scale use).
  - The absence of new gas pipeline network projects, a finding the Decennial Pipeline Transportation Network Expansion Plan – *PEMAT* 2022 (EPE, 2014) reveals, suggests this status shall remain unaltered during most of the timeframe this study analysed.
  - The provisioning of fuel gases as end energy also depends on the existence of internal residential networks to allow for the use of this source in end use appliances, such as water heaters. In this case, the incorporation of internal projects at new residential units might play an important role in the process of extending the availability of fuel gases as

final sources of energy given the known challenges involving the installation of networks at homes that have already been built.

- **Offer of fuel gases – primary and secondary energy:**
  - As the level of dissemination of the habit picks up, the consumption of fuel gases for the residential heating of water can promote a significant increase in the demand for these sources of energy. Currently, approximately 30% and 20% of NG and LP gases consumed in the country respectively is imported (EPE, 2013). The increase in the internal production of fuel gases and/or safeguarding of foreign supplies is a mandatory condition to ensure, from a balanced supply/demand standpoint, the sustainable expansion of their very consumption.
- **10% electricity savings by 2030 target (*PNEf*):** The National Energetic Efficiency Plan – PNEf (MME, 2011) foresees a reduction in consumption of electric energy target of 10% for the year 2030 ground on the adoption of assorted energetic efficiency actions. As previously mentioned, electric showers account for a significant share of the country´s consumption of electricity. Depending on the effort public agents devote to meeting the target this plan proposes, electric showers might end up being targets of actions centred on the reduction of this form of energy.
- **Absence of water heating systems project and execution skills:** Hardly ever professional courses adequately address the competencies one needs to design projects, install and maintain gas fuelled water heating systems. The lack of specialized labour might hinder the very election of such systems.
- **Public, commercial and residential buildings' labelling program:** The Energetic Efficiency Label on buildings is part of the Brazilian Labelling Program (*PBE*) that was jointly developed by the state-owned company *Eletrobrás* and the National Metrology, Quality and Technology Institute (*Inmetro*). The label´s objective is to promote energetic efficiency at buildings. Should labelled residential real estate become more valued by the market, penalizing the use of electric showers might stimulate the use of alternative residential water heating systems such as those powered by fuel gases.
- **Under sizing of the electric energy transmission and distribution network:** The demand for electric power´s growth rate has consistently

exceeded the expansion capacity of Brazil´s distribution and transmission network and this has caused regular system overloads, primarily during peak hours. This phenomenon tends to value actions centred on the substitution of electric energy consumption, particularly that powering showers, for other sources of energy.

- **Future of the electric matrix:** The evolution of the electric power generation matrix might influence the coining of public policies focused on the final uses of energy. Should the share of fossil fuel based thermoelectricity become significant, tolerance involving electric shower electrothermy for instance, shall tend to decrease given previously discussed factors.

Table 5: Ranking of conditioning elements

	Conditioning elements	Intensity	Impact	Uncertainty	Density
Critical conditioning elements	10% savings target in electricity by 2030 (*PNEf*)	5	5	5	125
	Valuing of water	5	3	5	75
	Supply of fuel gases – primary and secondary energy	3	5	5	75
	Supply of fuel gases – final energy	5	5	3	75
	Relative price of electricity *versus* its alternatives	3	3	5	45
	Future of the electric matrix	5	3	3	45
	White tariff implementation	5	3	1	15
	Public, commercial and residential buildings' labelling program	1	5	3	15
	Under-sizing of the electric energy transmission and distribution network	5	3	1	15
	Enhanced valuing of comfort (hot water)	3	3	1	9
	Lack of competence in designing and executing water heating system projects	3	3	1	9

3.3 CRITICAL CONDITIONERS' BEHAVIOUR HYPOTHESES AND FUTURE SCENARIOS

The behavioural hypotheses of critical conditioning elements are presented in Chart 3 whereby the "most expected" behaviour of analysed conditioners is highlighted.

Conditioners	**Behaviour Hypotheses**		
10% savings target in electricity by 2030 (*PNef)*	Non-compliance	**Partial compliance**	Full compliance
Valuing of water	Consumer habits remain unchanged (perception of hydric scarcity is not widespread across society)	**Consumer habits partially change (perception of hydric scarcity is partially widespread across society)**	Radical change in consumption habits (perception of hydric scarcity is widespread across society)
Supply of fuel gases – primary and secondary energy	Projections of supply increases do not materialize	Projections of supply increases partially materialize	**Supply increases materialize (consequent growth of fuel gases market)**
Supply of fuel gases – final energy	Infrastructure is not expanded to support supply increases	**Infrastructure expansion is restricted to large consumer centres**	Infrastructure expansion fulfils supply increase needs
Price of electricity *versus* its alternatives	Reduction	**Maintenance of current proportion**	Increase
Future of the electric matrix	Maintenance of the current matrix (predominantly hydroelectric)	**Matrix configuration change with hydroelectric share reduction**	Substantial increase in thermoelectric generation as of fossil fuels

Chart 3: Hypotheses of critical conditioning elements' future behaviour

4 CONCLUSION

As of the contrast between the trend scenario pictured in Chart 3 and the image of the future that addresses this study´s purposes, attempt was made to identify the stakeholders or players capable of promoting, on appropriate conditioners, the changes deemed necessary to ensure gas powered water heaters become increasingly popular in the residential sector, shaping enhanced rationality in the use of energy at Brazilian homes.

In the technological transformation of residential water heating systems where one employs as starting point electric showers and seeks to substitute these for gas powered ones, most of the top influencers are concentrated in the governmental arena (particularly federal), namely: *Procel*, *Conpet*, government and its vocation in the formulation of energy policies, *ABNT*, *Inmetro* and others. In addition to these players, amongst those most influent one also comes across real estate builders and developers, designers and the suppliers of alternative heating systems.

Given the absence of signs of significant shifts in the current course, a neutral behaviour was assigned to some conditioning elements in as much as impacting the increase of fuel gas consumption for residential water heating purposes is concerned. This is the case, for instance, of conditioners that pertain to the meeting of the *PNef´*s targets, the availability of fuel gases as final energy and the prices of energy sources.

Should the intent be to modify the future behaviour of these conditioning elements and thus induce a more favourable environment for promoting the rationalization of the use of the country´s energy resources, some kind of interaction with the most relevant players herein identified might prove to be necessary. To this effect, *Procel*, *Conpet* and the government – particularly at the directly centred on energy policies bureaus such as the Ministry of Mining and Energy (*MME*) – arise as core and influential players in defining the future behaviour of these critical conditioning elements. Furthermore, players deemed less influential within this study´s context, such as the National Electric Energy Agency (*Aneel*) and the ruling agencies of other types of energies, might make marginal contributions. In addition to formulating and implementing structural policies capable of, for instance, directly impacting the price of fuel gases and electricity or of planning the expansion of the fuel gas transportation (and

distribution) infrastructure, these players are directly or indirectly responsible for determining the level of compliance with targets set by the country´s *PNEf*.

In an ample context that goes beyond the frontiers of energy sector actions, the federal and state governments are for instance able to alter the prices of the different kinds of energies this study analysed (electricity, LPG, and natural gas) via tributary policies.

On the other hand, the availability of fuel gases as primary and secondary energy reveals a tendency to behave favourably when it comes to heating systems based on gas (according to official data (EPE, 2013b), thus, both the supply of LP gases and that of NG is expected to significantly increase in the upcoming decade). The same trend is observed in the case of the evolution of the electric matrix, which, as discussed in the introduction of this study, shall probably count on the gradual increase of fossil fuel based thermic generation shares.

The valuing of water as a natural resource of often uncertain availability indicates the need to include measures to reduce hydric consumption in gas heating promotion strategies. In this case, actions such as the adoption of hydric efficiency as an assumption for residential hot water network projects, in addition to the use of equipment that reduce the flow and of low flow showerheads, might be efficient when it comes to right sizing the hydric consumption of these heating systems.

As of the results exposed in the study, findings reveal that residential heating based on electric showers is a theme that is influenced by variables that arise from a vast range of arenas, varying from technical (types of technology and infrastructure, comfort and usability), regulatory (electric shower and alternative heating systems rulings), climatic to even market (user buying power) aspects.

Leaving the trend scenario behind where electricity remains the core technology and heading towards that desired whereby gas heaters are widely used in Brazil shall hardly be possible without the extensive and well-articulated action of influential government (and non-government) players. On the other hand, so that these players' actions are truly effective, they must take into consideration the subject matter´s multidimensional characteristic.

This is undoubtedly a matter of public policy redefinition, of leaving concepts and energy directives that are strongly embedded in Brazil´s society truly behind. The negative externalities of electric showers when configuring the peaks of load curves (placing an excessive burden on infrastructure investments) and on the energetic inefficiency of substituting the direct use of fuel gases for indirect transformation processes (increasingly generating electricity at gas fuelled thermoelectric stations and then consuming electricity produced in electrothermy) represent important disadvantages that can (and should) be gradually eliminated from Brazil´s final energy use profile.

The identification of key variables, influential players and critical conditioning elements enables the composition of a map over which public policies may be designed that may come to change the scenario of the final use of energy at residential environments. Not all of the most feasible suggestions and credible public policies that might come to be implemented were tested in this study. This task thus comprises the scope of this study´s continuation. To this effect, hope rests in soon being able to publish these outcomes.

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