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(Instituto Escolhas)



Angra 3:
Is it worth
the cost?

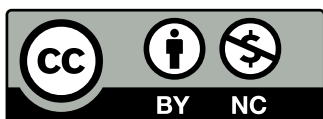
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Discussion Paper
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Organized by: **Instituto Escolhas**
Editorial Coordinator:
Saete Cangussu and Sergio Leitão
Text Editor:
Saete Cangussu and Sergio Leitão
Translation: **CIPÓ Platform**
Art Editor: **Brazz Design**
Cover Photo: © **Divulgação PAC**

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Instituto Escolhas produces studies and reviews on
Economics and the Environment in order to enable
sustainable development.





Construction site of the Angra
3 Nuclear Power Plant
© Source: PAC

On March 21, 2001, ten days after an earthquake registering 9.0 on the Richter scale, followed by a tsunami with waves of up to 15 meters that hit the Fukushima Nuclear Power Plant in Japan, causing the meltdown of three reactors and leading to the evacuation of 100,000 people--a situation that persists to this day--physicist José Goldemberg, 91, stated the following during an interview given to *Exame* magazine:

"In Brazil, nuclear energy is unnecessary. We do not need it. Although it is attractive, this type of generation should be the last option, restricted to countries that lack other options, such as France. When Angra 3 is ready, the energy generated will be less than the energy production potential of the sugarcane bagasse, which in São Paulo alone totals two million kilowatts. That is the equivalent of the energy produced by two nuclear reactors."

At that time, Brazil faced the imminent resumption of the construction of

"In Brazil, nuclear energy is unnecessary. We do not need it. Although it is attractive, this type of generation should be the last option, restricted to countries that lack other options, such as France."
José Goldemberg, physicist

the Angra 3 Thermonuclear Plant (Usina Termonuclear Angra 3 - UTN), which started in 1981 and has been suspended since April 1986 due to the combination of the financial crisis experienced by the country and concerns surrounding the risks that are intrinsic to nuclear energy. In the early hours of the 26th of that month, the world was shocked by the explosion of reactor number 4 of the Chernobyl Power Complex--in what

was then the Soviet Union, and currently within the national territory of Ukraine--sending radioactivity into the atmosphere and creating a circle of contamination that persists to this day.

Fukushima and Chernobyl were preceded by another extremely serious nuclear incident: the partial meltdown of reactor number 2 of the Three Mile Island Nuclear Generating Station in the United States, on March 28, 1979. At that

ANGRA 3: 47% MORE EXPENSIVE THAN ITS “TWIN” ANGRA 2

General information on Brazilian nuclear power plants and their construction sites

Feature	Angra 1	Angra 2	Angra 3 (*)
Installed Capacity (MW)	640	1350	1405
Construction start (year)	1972	1976	1981
Start of operations (year)	1985	2001	2026 (**)
Time to complete construction (years)	13	25	45 (**)
Construction cost (R\$ billion)	8,4	17,2	25 (**)
Rate/Reference price (R\$/MWh)	230,33	230,33	480 (**)

Source: TCU with data from MEE/Aneel/Eletronuclear

(*) Under construction

(**) Planned

time, the Angra 1 (626 MW) and Angra 2 (1,350 MW) plants, which together make up the Almirante Álvaro Alberto Nuclear Power Plant in the municipality of Angra dos Reis in the state of Rio de Janeiro, with a rated capacity of 1,976 MR, were in the initial stages of construction. The Federal Government hopes that Angra 3, with 1,405 MW of rated capacity, will join them in the future.

Angra 1 began running in 1985 and, during its first fifteen years of operations, was repeatedly halted due to a variety of reasons, including minor accidents, which earned the plant the nickname "Firefly Plant" (1). During that time, it operated with a capacity factor of merely 25%, only gaining momentum from 2000 onwards, until it finally reached 69% in 2004. Meanwhile, Angra 2, which was inaugurated only in 2001, by 2004 was operating with a capacity factor of 83% (2). A high capacity factor is one of the main comparative advantages in nuclear energy generation.

Angra 1 cost R\$ 8.4 billion. Angra 2,

with double that capacity, cost R\$ 17.2 billion. Angra 3, the "twin" of Angra 2, is budgeted at R\$ 25 billion.

The worst nuclear incidents in history inhibited, but did not bury, the desire on the part of Brazilian governments--ranging from that of Luiz Inácio Lula da Silva to that of Jair Bolsonaro--to complete the Angra dos Reis Nuclear Power Plant by building the third reactor and to expand the station that is the source of that energy, which is still under analysis yet whose possibility of completion has already been announced by the Ministry of Mines and Energy (Ministério de Minas e Energia - MME).

This information was provided by its Secretary for Energy Planning and Development, Reive Barros, on September 26, 2019, who stated that at least six new reactors are set to be built by 2050, preferably located in the Northeast region, in an investment estimated at US\$ 30 billion.

The resumption of construction at Angra 3 after 1986 was initially decided

by the National Council for Energy Policy (Conselho Nacional de Política Energética - CNPE) through Resolution No. 3/2007, yet the work was only restarted in April 2011, a little over one month after the Fukushima incident--when, according to data from the Federal Court of Accounts (Tribunal de Contas da União - TCU), construction of the reactor was only 10% complete. The budget was set at R\$ 9.95 billion, and the reactor was set to become operational in 2016.

The total budget includes the sum of R\$ 6.1 billion approved by the the National Bank for Economic and Social Development (Banco Nacional de Desenvolvimento Econômico e Social - BNDES) in 2010. That was expected to be the source of funding needed to complete construction; however, when additional funding was required, it ended up coming from the Caixa Econômica Federal Bank. With more than R\$ 3.8 billion from Caixa, total investments reached R\$ 9.9 billion, which is--in theory--enough for the plant to start operating. The tariff rate would be R\$ 240 per megawatt/hour (MWh) in updated 2018 figures. The original sum estimated in September 2009 was R\$ 148.65 MWh.

This last figure was used for the signing of the Reserve Energy Contract (Contrato de Energia e Reserva - CER) between Eletronuclear and the Chamber of Electric Energy Commercialization (Câmara de Comercialização de Energia Elétrica - CCEE) on August 26, 2011. The possibility of directly contracting nuclear energy as reserve energy, doing away with auctions, was assured by Law No. 12.111/2009. An-

STATE-OWNED BANKS LOANED NEARLY R\$ 10 BILLION TO COMPLETE CONSTRUCTION

Recent BNDES and Caixa funding to complete Angra 3

Organization	Year	Sum (R\$ billion)
BNDES	2010	6,1
Caixa	2015	3,8
Overall		9,9

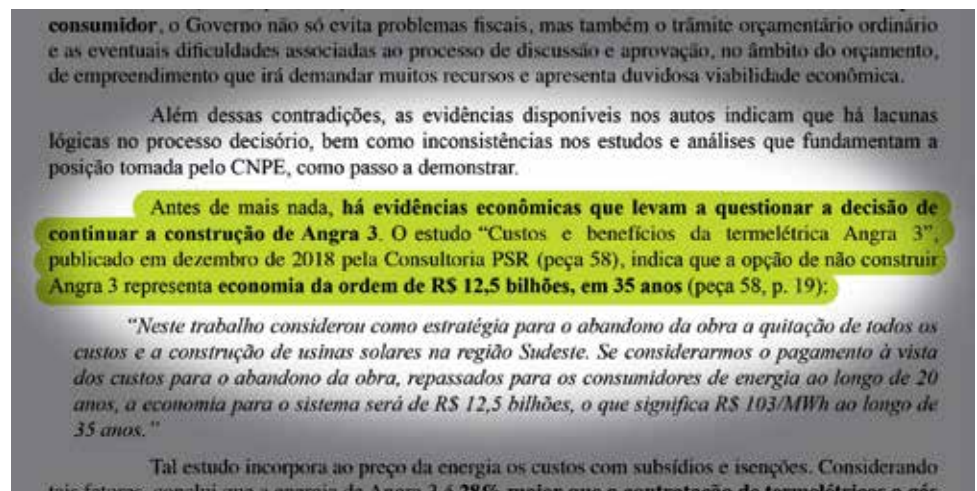
Source: Escolhas/PSR

“Resumption of work on Angra 2 should be treated as an option in the context of the Brazilian Energy Policy, and not as grounds for settling contractual obligations signed in previous years precisely to enable building of the venture, whose construction has dragged on for decades.”
Report from the Federal Court of Accounts (TCU).

Angra 3's energy was deemed reserve energy following a recommendation made by the Energy Research Company (Empresa de Pesquisa Energética - EPE) through a 2009 Technical Note

With the legal framework structured and funding secured, it seemed that the end of construction was simply a matter of executing the timeline. However, reality was far from that! In 2015, construction at the site was once again suspended, with around 67% of work complete on average in public works, equipment procurement, and assembly, amidst reports of corruption involving cartel formation in the bidding process through which the consortia responsible for resuming construction were chosen. Expenditures with the project until that point were estimated at approximately R\$ 7 billion, or R\$ 8.3 billion by late 2018.

On October 23, 2018, backed by conclusions drawn the previous month by an Inter-Ministerial Working Group (Grupo de Trabalho Interministerial - GT) created through a CNPE resolution aimed at "carrying out research and analysis and submitting recommendations to the National Council for Energy Policy on the economic viability of the Angra 2 Nuclear Power Plant project, as well as sugges-



ting other measures to make the venture viable,” according to what is stated under the Federal Court of Account’s (TCU) report, the MME published CNPE’s Resolution No. 14, in which it sets forth the conditions deemed adequate for enabling completion of the plant.

In the report "Measures for the Viability of the Angra 3 Thermonuclear Plant" (freely translated), the Working Group, composed of representatives from the MME; the then Ministries of Finance and Planning; the Institutional Security Office (Gabinete de Segurança Institucional - GSI) of the Presidency of the Republic; the

Special Office of the Program for Investment Partnerships (Programa de Parceria de Investimentos - PPI)--currently housed by the Ministry of the Economy--of Eletrobras; Eletronuclear; and EPE, concluded that the tariff rate set by the reserve energy contract would not suffice to ensure the venture's economic viability.

According to the TCU auditing report that established the grounds for Ruling 208/2020 of the control body, with unanimous votes, determining that the Federal Government provide evidence that project completion is the best option from the energy standpoint, calculation of the new rate was undertaken by the

EPE based on the discounted cash flow model, taking into account the plant's 40-year life cycle.

The cost of the energy generated would fall between R\$ 400 and R\$ 560 per MWh in order to cover investments, operations, maintenance, compensate investors, and decommission¹ the plant at the end of its life cycle. According to the TCU report, the Working Group sugges-

¹ According to the International Atomic Energy Agency (IAEA), decommissioning means taking all necessary measures to deactivate a nuclear installation at the end of its life cycle, taking all precautions to protect the health and safety of workers and of the population in general, as well as the environment.

ted R\$ 480 as a reference value (July 2018 figures), estimating that the impact on consumers' electricity rates in the Regulated Contracting Environment (Ambiente de Contratação Regulada - ACR)² would be 1.26%. Additional investments required for completion of the plant would be in the order of R\$ 15.5 billion.

During the 60 days it was granted to submit other recommendations, the Working Group concluded that a private partner was needed to enable the plant's completion, although it was unable to reach a consensus regarding the ideal model for such a partnership, even after having submitted two options. In the first one, suggested by Eletronuclear, the private partner would provide funding and become the plant's minority shareholder in the state-owned venture. The second one would be an Engineering, Procurement and Construction (EPC) contract through which the contracted party would finance itself so as to carry out the construction and, at the end, would be an owner of part of the contract to sell energy generated at Angra 3. The

"There are other energy sources at lower costs that deliver the same quantity of energy."

TCU report

Working Group's suggestion was that the PPI be tasked with defining what the ideal proposal would be. In turn, the PPI contracted BNDES so that the state development bank would provide an expert opinion on the best path forward.

² Regulated Contracting Environment (ACR): Market segment in which purchases and sales of electrical energy are carried out among sales and distribution entities after bids are placed, notwithstanding specific cases foreseen under the legislation, according to specific trading-related rules and procedures.

The Escolhas/PSR STUDY SHOWS THAT ENERGY GENERATED BY ANGRA 3 IS THE MOST EXPENSIVE OPTION

Energy cost comparison between Angra 3 and the several alternatives available

Source	Cost (R\$ MWh)
Combined-cycle gas-fired thermal plant (seasonal) - Northeast	346
Combined-cycle gas-fired thermal plant (flexible) - Southeast	216
Open-cycle gas-fired thermal plant (flexible) - Southeast	412
Combined-cycle LNG thermal plant (seasonal) - Southeast	166
Hydroelectric Plant (Usina Hidrelétrica - UHE)	286
Wind plant – Northeast	195
Wind plant – Southeast	244
Small Hydroelectric Center (Pequena Central Hidrelétrica - PCH) – Southeast	285
Biomass plant – Southeast	168
Solar plant – Northeast	297
Solar plant – Southeast	328
Angra 3	528

Source: Escolhas/PSR

According to the *Valor Econômico* newspaper, in an article published on March 12, 2020, the bank's expert opinion was submitted to Eletronuclear, Eletronuclear's financial controller, while the latter would, in turn, submit it to the PPI Special Secretariat for deliberation,

of investments already made.

The TCU's auditing report, under item 89, is clear on the focus that should anchor the Brazilian state's decision on this matter: "Resumption of Angra 3 should be treated as an option in the context of the Brazilian Energy Policy, and not as grounds for settling contractual obligations signed in previous years precisely to enable building of the venture, whose construction has dragged on for decades. Moreover, the audit failed to verify information or alternative research sufficiently detailed for this case, in addition to concerning reviews and scenarios on potentially cancelling the project, as well as the supply of the same quantity of energy provided by similar sources."

Following its main guideline of producing research papers and promoting high-level discussions on issues essential to sustainable development, Instituto Escolhas recognized the issue that needed to be addressed and drafted the study. In order to more efficiently obtain arguments, figures and answers, Escolhas formed a partnership with the well-respected energy consulting company PSR so as to

COSTS TO CANCEL PROJECT REACH R\$ 11.92 BILLION

Expenditures required to cancel construction of Angra 3

Cost	Sum (R\$ million)
Fine – Termination of energy reserve contract	2.310,40
Early cash settlement	6.915,60
Discharge	650
Termination of national contracts	190
Termination of contract with Areva (equipment)	1.000,00
Socio-environmental compensations	270
Contingency reserve	174,4
Tax exemptions	414,3
Overall	11.924,70

Source: Escolhas/PSR – with Eletronuclear data

examine the situation of Angra 3 from the standpoint of its cost, *vis-à-vis* other energy source options available in the market.

The in-depth paper, mentioned in items 128 to 181 of the TCU report, showed that the option of completing Angra 3 is the most expensive among all of the sources available in the market.

The TCU report states: "This paper, which the audit mentions as a reference, finds that the cost of completing Angra 3 is 28% higher than contracting open-cycle natural gas-fired thermal plants in the Southeast (R\$ 528.00/MWh and R\$ 412.00/MWh, respectively). It adds that "the cost of energy attributed to both Angra 3 and to other sources takes into account not only the price of the power generated, but also, for instance, subsidies and exemption costs."

These figures feature in another study produced by Escolhas/PSR, titled "What are the real costs and benefits of Brazil's electric power generation sources in Brazil?". Using a unique methodology, the paper estimates the overall cost of energy generation in Brazil by assessing and appraising the attributes of five components of each generation

source foreseen under the 2026 Ten-Year Energy Plan (PDE).³

As mentioned in the comprehensive report produced by the TCU experts, the Escolhas/PSR study signals that, if Angra 3's construction site were discontinued and replaced with solar generation in the Southeast region, maintaining the same proximity to the electrical load center--where consumer demand is highest--which is the focus of the nuclear plant,

"If resuming this construction is related to the Brazilian government and state-owned companies' nuclear programs, that should be made clear in another way, such as a government policy."
Sergio Leitão, Executive Director of Instituto Escolhas

R\$ 12.5 billion would be saved over the course of 35 years of Angra 3's concession, discounting all the costs required to decommission the site once the debts have been paid off, and taking into consideration investments needed to offset the solar source's intermittency.

At this time, when a potentially irreversible decision is about to be made, we find it appropriate to publish this Discussion Paper (DP) with the aim of engaging with interested parties and experts' standpoints in regards to this subject, as well as disseminating available data which may help Brazilian society to position itself adequately, while further expecting the Federal Government not to submit a decision without having first shared its evaluation as broadly as possible, as recommended by the TCU.

Furthermore, at the time this Working Paper was being drafted, the coronavirus pandemic was causing widespread havoc within the Brazilian economy, and it has thus become imperative to reevaluate construction costs, particularly when there are other less costly options available with the same results.

To Sergio Leitão, Executive Director of Instituto Escolhas, this discussion has become necessary for the government to be able to clearly set out its intentions in resuming construction of Angra 3, gi-

ven that--from both the energy sector and consumers' standpoints--it does not make sense. "From the standpoint of power generation, [Angra 3] is not justified." "If resuming this construction is related to the Brazilian government and state-owned companies' nuclear programs, that

³ http://www.escolhas.org/wp-content/uploads/2018/11/Quais_os_reais_custos_e_benef%C3%ADcios_das_fontes_de_gera%C3%A7%C3%A3o_el%C3%A9trica_no_brasil-SUM%C3%81RIO-EXECUTIVO.pdf

should be made clear in another way, such as a government policy," he states.

Since this is an issue that has not yet been officially defined, the DP additionally addresses the Federal Government's intention to expand the Brazilian nuclear program by building six new reactors, totalling 6,600 MW by 2050.

Angra 3's energy cost is R\$ 528

The Inter-Ministerial Working Group that studied the economic viability of resuming construction of Angra 3 decided to suggest a reference price (for the bid that will choose Eletrobras' partner in the project) for the plant's energy, which is the mean of the highest and lowest figures found by the EPE in discounted cash flow valuations--R\$ 400 and R\$ 560 MWh. This sum of R\$ 480, based on September 2018 figures, is R\$ 58, or 12.08% lower compared to the R\$ 528 expenses verified by the Escolhas/PSR study in its comprehensive survey of every cost related to both the nuclear plant and other energy sources.

This methodology takes into account investment and operating costs (Levelized Cost of Energy - LCOE) related to generation, infrastructure and distribution services; subsidies; incentives; and environmental costs. The paper draws on the 11 alternative energy-based LCOEs previously estimated by Escolhas/PSR in the "What are the real costs and benefits

of electricity generation sources?" study produced by Instituto Escolhas, and which includes Angra 3's LCOE estimation based on the R\$ 480 rate defined by the CNPE for the reactor's energy, excluding sums corresponding to the Transmission Use-of System charges (TUST), as well as network losses.

The decision to use the CNPE figure stems from the large disparity between construction costs and tariff rates of nuclear plants around the world. According to the Escolhas/PSR study, data from the defunct 2018 Lazard consulting firm's report showed that investments in nuclear energy fell between US\$ 6,500 and US\$ 12,250 per kWh installed, while those of the LCOE fell between US\$ 112 and US\$ 189.

Once TUST values and losses were calculated and included in the stage pertaining to estimating the final price of energy, Angra 3's LCOE was at R\$ 453, losing only--among all modalities previously calculated by PSR--to the flexible, open-cycle gas-fired thermal power plant installed in the Southeast region, whose LCOE is R\$ 794.

The following stage in calculating the final rate--which corresponds to generation services--namely, the flexibility of the gas-fired thermal power plant and its benefits for the modulation, seasonality and robustness of the system, ensures the Southeast's flexible thermal power plant

a cost reduction of R\$ 517 compared to the LCOE, whereas Angra 3's reliability lowers its cost by R\$ 7.⁴

In this second stage of calculation, Angra 3's energy ends up being the most expensive at R\$ 446 per MWh, whereas flexible energy in the Southeast falls to third place at R\$ 277 MWh, lower than the R\$ 294 recorded for the combined-cycle gas-fired thermal plant in the Northeast. Solar generation in the Southeast is basically stable, losing R\$ 1 compared to the R\$ 171 LCOE per MWh.

In the stage used to assess infrastructure costs, while Angra 3 mostly absorbs TUST, as well as losses that had been removed from the LCOE estimation (R\$ 18 MWh), there is an increase in the prices of solar and wind energy, in addition to most gas-fired thermal plants. Finally, subsidies and incentives absorbed to compose the final cost burden Angra 3 with R\$ 4 per MWh due to subsidized loans from BNDES and Caixa, even though renewable sources are even further burdened, particularly solar energy, which absorbs R\$ 102 to its cost in the Southeast, and R\$ 135 per MWh in the Northeast.

The final result, which--according to the Escolhas/PSR study--yields a R\$ 528 per MWh cost to Angra 3, stems mainly from the nuclear plant's capital costs, as well as its fixed operating costs. On the other hand, when it comes to the solar alternative in the Southeast, the region home to the Angra dos Reis Nuclear Power Plant, the levelized cost nearly doubles due to subsidies, incentives and infrastructure costs absorbed. Nonetheless, its energy is priced at R\$ 328 per MWh, R\$ 200 lower than the nuclear plant that the Brazilian government plans to build in 2026, four and a half decades

SUM STILL NEEDED TO COMPLETE CONSTRUCTION VARIES ACCORDING TO SOURCE AND TIME OF CONSTRUCTION

Funding still needed to complete Angra 3, according to information source

Source	Month/year	Sum (R\$ billion)
O Estado de S. Paulo (1)	Jul-17	17
Eletronuclear	Mar-18	13,8
Ministry of Mines and Energy (MME)	Oct-18	15,5

Source: Escolhas/PSR

⁴ Modulation is the capacity a generator has to meet the hourly load profile demand over the month; seasonality is the same capacity to meet the monthly demand over the year; and robustness is the capacity to meet demands exceeding the economic dispatch.

after its construction began.

Based on the calculations above and on Eletronuclear's own calculations, which conclude that cancelling construction would lead to costs nearing R\$ 11.92 billion, as well as on the R\$ 15.5 billion sum (see the table below for other available estimates) calculated by the MME for completion of the plant, the Escolhas/PSR study, helmed by Technical Director Bernardo Bezerra, found that if we only take into account all sums involved, disregarding additional arguments for completing or cancelling construction, replacing its energy system with solar generation in the Southeast would entail savings amounting to R\$ 12.5 billion over the 35-year span of the nuclear plant's contract, even if we consider cancellation costs disbursed.

This sum represents a difference of R\$ 528 minus R\$ 328, with the R\$ 12 billion sum that the government would need to disburse to seal off the construction site and pay off its outstanding debts already accounted for, since this amount would be collected at an Extended National Consumer Price Index (Índice Nacional de Preços ao Consumidor Amplo – IPCA) cost plus 5.19%, which was the original NTN-B (National Treasury notes, series B) cost at the time the paper was produced.

The study also points out that Angra 3-produced energy would be 28% higher than the second most expensive option: flexible gas-fired thermal plants in the Southeast. The preference for solar energy is justified by its positive attributes, which are similar to those of nuclear energy. In other words: it does not emit CO₂; it poses low annual production variability; and it would also be located in the Southeast. On the other hand, solar energy's disadvantages are its intermit-

tency, which raises costs with operating reserves⁵ and with power requirements, expenses already included when calculating its price, under the category "system infrastructure costs" (R\$ 55 MWh).

Since the assessment considers that solar energy would be contracted for 20 years, which is the useful life of photovoltaic panels, plus an additional 15 years to be contracted later on with the same current price, the study finds that calculations were based on conservative numbers "since they fail to consider a potential cost reduction in solar energy investments after the 20-year operating period."

and, on June 28, 2019, photovoltaic solar energy startled the market after it was sold at the new energy auction held by the Brazilian Electricity Regulatory Agency (Agência Nacional de Energia Elétrica - Aneel) at an inconceivable average price of R\$ 67.48 per MWh. The TCU report also stresses that Angra 3's energy rate will be 131.38% more expensive than the average rate of every new energy auction held from 2008 to 2018, which was R\$ 207.45 per MWh.

When it complains about the "absence of a specific and transparent paper on the decision to resume or cancel Angra 3," the control agency's 200-plus page

"In addressing sources individually, the [Escolhas/PSR] study fails to consider the energy system's joint operations." Ministry of Mines and Energy

The TCU shows that Angra 3 is the most expensive energy reserve

The TCU report--whose ruling was based on questioning the legitimacy of completing constructions for Angra 3--points out, under item 115, that the CNPE-approved price for Angra's energy is unprecedented in all nine energy reserve auctions (Leilão de Energia de Reserva - LER) held from 2008 to 2016. In these auctions, the average price that came closest to the R\$ 480 reais per MWh of the nuclear plant was R\$ 354.92 (updated based on to the December/2018 IPCA), determined by the 833.80 MW of power contracted in the solar energy auction held on August 28, 2015.

This 2015 LER figure has been constantly outdated in the past five years

report identifies several "non-compliances" that support its arguments. One of them concerns the fact that the fixed rate for the new plant is 108.39% higher than R\$ 230.33, the price that used to be charged for its "sisters" Angra 1 and Angra 2's energy rates.

The TCU report continues: "In regards to the Angra 3's aim of benefiting the energy sector, it is worth recalling that the CNPE resolution no. 3 of June 25, 2007 set forth as a criterion, upon defining the plant's energy rates, that these would need to 'correspond to rates commonly seen in current energy contracting auctions stemming from new energy generation ventures'," further stressing that the Council's policy at that time was to require that Angra 3 plant's energy rates not differ from other energy reserve procurements,

⁵ Operating Reserve (OR) is the surplus generation used by the National Electrical System Operator to offset disparities between the system's energy load and generation.

DEBT SERVICES COST R\$ 67.4 MILLION EACH MONTH TO ELETRONUCLEAR

Detailed debt service of Eletronuclear to build the power plant

Creditor	End of grace period	Monthly payment (R\$ million)
BNDES	Oct-17	30,9
Caixa	Jul-18	24,7
Eletrobras	Dec-18	9,8
Eletrobras/CCEE	Feb-18	5,2
Overall		67,4

Source: TCU

in accordance with the tariff modicity policy sought by the energy sector.

The TCU auditors were surprised by the change in the CNPE's stance, which was based on the grounds that maintaining parity with energy reserve auctions would consequently lead to prices too low to cover costs. Experts question the new criterion introduced by the Council, based on an "international comparison of energy rates compiled from nuclear ventures," citing as its source of information the Inter-Ministerial Working Group's report, which proposed measures to enable resumption of construction.

"This criterion has questionable accuracy due to differences in local costs as well as challenges in comparing ventures," states the TCU report. For the authors of the paper, the CNPE's reassessment of the criteria whereby it changes its decision to pursue tariff modicity, "evidences the Council's shift of priorities," where it replaces its "downplaying of the impact of rates on customers" with the goal of completing construction.

The document emphasizes that Aneel estimated the impact of the Angra 3's new energy rate on consumers to be 1.35%, though potentially reaching 1.8% if the R\$ 560 per MWh rate is introduced, the price limit calculated by the EPE for the Inter-Ministerial Working Group. The report then questions the EPE's pricing methodology due to technical shortcomings in data previously calculated and

delivered to the company, and it asks that these calculations be revised.

The TCU also refers to item 260 of the report, which brings another serious finding outside the scope of its audit: the "increasingly unstable investments made for the necessary maintenance of operations of the Angra 1 and Angra 2 plants, which stem from Eletronuclear's deficitary financial situation, as well as from Aneel's nonexistent oversight." Eletronuclear's effective breach is directly related to the nonperformance of Angra 3's construction schedule.

With--contrary to what had been expected--the plant failing to generate cash flows since 2016, in addition to commitments due to expire, the energy provider's financial situation quickly worsened. According to the TCU report, recurring debts from loans incurred alone resulted in the company spending R\$ 67.4 million by the end of 2018, after the last grace period expired, of which R\$ 30.9 million were spent with BNDES since October 2017.

Nevertheless, the control agency's main focus entails the plant's energy rates as well as a decision made to resume its construction. After mentioning the option proposed by the Escolhas/PSR study (see the paragraph above), the TCU report complains about the "absence of participation and of sector-specific agents in the decision-making process to resume Angra 3's construction," in addition to the

fact that the burden of the plant's new costs falls solely on consumers.

It then suggests that the MME should--following the ruling approved in the entity's plenary sitting--find another funding source for the plant, while deeming the plant a "priority in the Brazilian nuclear program." The reasoning behind this is that, according solely to the standpoint of energy generation, "there are other energy sources with lower costs that deliver the same amount of energy."

In light of so many different arguments, the control body intends for the government to carry out a public inquiry to hear what energy sectors have to say before deciding whether or not to resume the plant's construction.

In other words, the TCU aims for the very same thing that Instituto Escolhas and other segments of society wish for: a comprehensive discussion that makes it clear to Brazilian society the reasons why the decision will be made, in addition to costs related to said decision.

MME and Eletronuclear question the Escolhas/PSR study

Both the MME and Eletronuclear criticized the Escolhas/PSR study that compares energy costs generated by several sources to those of Angra 3, arguing that the paper's findings contain methodological inconsistencies and fail to adequately appraise nuclear generation's benefits.

"In addressing sources individually, the study fails to consider the energy system's joint operations," states the Ministry. The body claims that if said scope were accounted for, the paper "would need to acknowledge that operations with high availability and a high nuclear source capacity factor would enable, for instance, water economy in hydroelectric plant reservoirs," thereby allowing the latter to have a generation reserve able to deal with the variability of intermittent renewable



Bernardo Bezerra, PSR's technical director

sources, such as wind and solar energy.

The MME further states that a benefit of nuclear generation is that it enables an "increased flexibility in gas-fueled energy generation, as well as an enhanced reliability for the entire Brazilian energy system." The Ministry also claims that the issue of pricing non-controllable sources' variability is still under discussion, a potential additional expense that nuclear energy simply does not have. "When it includes sums without providing evidence in any way whatsoever of the costs related to several sources, and fails to consider the advantages of an integrated operating system, the study runs the risk of becoming mere hearsay, and of being little more than a qualitative evaluation," argues the MME.

Eletronorte, in turn, claims "that there are several methodological inconsistencies in the study, which puts forward ungrounded technical factors and weights." According to the company that holds a state-owned monopoly over nuclear generation in Brazil, the paper's methodology is not "backed by any legal regulation or academic methodology."

To illustrate the claim of technical inconsistencies in the Escolhas/PSR study, the state-owned company makes a comparison between Angra 3's energy costs and those of the flexible gas-fired thermal

plant located in the Southeast region. "The paper haphazardly increased Angra 3's rate from R\$ 453 per MWh (excluding taxes) to R\$ 528 per MWh, a 16.5% increment, while lowering the price of gas in the Southeast from R\$ 794 per MWh to R\$ 412 per MWh, a 48% drop," it states, pointing out that during the initial stages

"Nuclear energy does not make sense anywhere in the world if solar and wind energy are developed."

Roberto Schaeffer – professor at Coppe/UFRJ

of the work, "before treatment," Angra 3's energy rates were 40% cheaper than those of its gas-fueled competitor.

The paragraph above on the Escolhas/PSR study describes the numerous stages involved in calculating rates across the wide host of sources, explaining how each one's set of attributes for generating and providing energy to the Brazilian National Integrated System (SIN) contributes to the final energy price they supply, based on their leveled costs.

In response to the MME, engineer

Bernardo Bezerra, PSR's Technical Director, explained that the reservoirs' elevation effect generated by nuclear energy--in the case at hand, by Angra 3--was taken into consideration, and further noted that solar and wind energy sources "also contributed to reservoir elevation" due to their low annual variability (seasonal aspect).

Bezerra further stated that the variability effect of non-controllable sources was assessed in the study "in item 'dynamic probabilistic reserve,'" and that this cost was duly distributed across all non-controllable sources. The probabilistic reserve is one of the items that comprise each source's contribution to the system's infrastructure costs.

On questions raised about the paper's methodology, Bezerra stressed that its methodological, theoretical and quantitative information can be found in the books available at Instituto Escolha's homepage (www.escolhas.org), adding that "all selected and quantitative attributes

are thoroughly examined" there.

Regardless of objections made to the Escolhas/PSR paper, both the MME and Eletronuclear strongly support investments to complete Angra 3 and for nuclear energy as a whole in the coming years, emphasizing that decisions concerning future developments after the third plant is concluded in Rio de Janeiro will still be conditional upon the conclusions of the 2050 National Energy Plan (PNE 2050), which is currently under its final stages of development by the EPE.

“To dismiss the importance of nuclear energy for the country, as well as the need to complete Angra 3, is the same thing as closing the doors to a future of energy safety and low carbon emissions. We cannot afford this luxury,” states the nuclear state-owned company. According to it, only hydroelectric and thermal plants, “particularly natural gas and nuclear plants,” are able to provide the consistent base energy that the SIN network’s energy safety requires.

In the comparison between gas and nuclear generation, the state-owned company says that, even though investments to build a nuclear plant are much higher than those needed for a gas-fired thermoelectric plant, the fuel of the former is not only cheaper, but also less prone to market volatility and currency variations. Eletronuclear also points out that nuclear power plants operate with a capacity factor higher than 90%, in addition to having a useful life ranging from 60 to 80 years, as opposed to the 15 to 20-year span for natural gas-fired thermal plants.

In regards to the R\$ 480 rate set for

“Dismissing nuclear energy for cheaper renewables is an interesting idea; however, it turns into something entirely different if it is a strategic matter.”

Renato Queiroz – professor at UFRJ and member of the GEE

Angra 3’s energy, the company emphasizes that, because it is a reference price for the international bid expected to select its minority partner--thereby removing, in its evaluation, the need to change the Constitution, since monopoly is not broken when construction is finally comple-

ted--competition between the interested parties should lower this sum. “Regardless, construction of Angra 3 will have a positive impact on consumers’ electricity bills because it will replace more expensive energy generated by diesel oil and fuel oil-fired thermal plants,” he assesses.

“Nobody is able to justify nuclear power for energy purposes”

The sentence above was stated by electrical engineer Roberto Schaeffer, a professor with 30 years of experience comprising the Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering (Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia - Coppe)/Federal University of Rio de Janeiro (UFRJ) Energy Planning Program, and who holds a master’s degree in nuclear energy and a PhD in energy planning. The statement applies to the current energy scenario under which the development of new renewables--solar and wind energy--alongside the search for

greenhouse gas-free alternative generations, is causing an unprecedented global energy transition. We should also note that nuclear power plants do not emit greenhouse gases (GHG).

“It [nuclear energy] does not make sense anywhere in the world if solar and



Roberto Schaeffer – professor at Coppe/UFRJ

wind energy are developed,” he underscores. Schaeffer believes that nuclear plants’ inflexibility makes them clash against renewables, unlike open-cycle natural-gas fired thermal plants and these plants’ flexibility. According to the Coppe/UFRJ professor’s assessment, in 2007/2009, when the decision to resume construction of Angra 3 was made for the first time, it was “reasonable” since renewables’ prices were very high, something that, in his words, “melted” over the past decade.

The main proof that nuclear energy’s time has passed, according to Schaeffer’s evaluation, is that the flow of new constructions is significantly lower than the need to replace plants that are becoming obsolete. The International Atomic Energy Agency’s (IAEA) latest statistics, for December 2018, show that 55 new nuclear generation reactors were being built around the world, whereas the number of operating units, 451, has basically remained the same in this century’s first two decades.



Clarice Ferraz – professor at UFRJ and member of the GEE

“Basically, the United States has not built any new reactors since 1985,” he cites as an example. The Americans had 98 reactors in operation in December 2018, amounting to 99,061 MW of installed capacity, but only two under construction, with an output of 2,234 MW. In 2016, nuclear energy accounted for 19.3% of the country’s energy generation.

To the expert, the hold that nuclear energy still has over the world stems from the persuasive power of the sector’s main international companies. Schaeffer suspects that, specifically in regards to Brazil, the main “lobby” comes from China and its ability to offer cheap financing not only to complete Angra 3, but also for a potential expansion program already suggested by the MME.

He also finds that the current, trendy argument used by defenders of nuclear energy, according to which investment in the sector is justified as a means of ensuring that nuclear industry workers as a whole keep being trained, “makes sense.” Nevertheless, he argues that, rather than building energy generation plants solely to enhance workers’ technical

skills, investments in Research and Development (R&D) for new technologies in this field should be made instead. “Particularly since Angra 3’s reactor is a 1980s technology,” adds Schaeffer.

Questioned on whether the current Minister of Mines and Energy (MME), Bento Albuquerque, an admiral and a former General Director of the Brazilian

“Nuclear energy may be an excellent base energy; however, it is expensive, and there is no way to include it in the base and keep energy cheap.”

Clarice Ferraz – professor at UFRJ and member of the Energy Economic Group (GEE)

Navy’s Nuclear and Submarine Program--the sector in charge of developing Brazilian nuclear submarines--has something to do with the new boost that Angra 3 has garnered in the current government, Schaeffer says it is possible that he

ensured greater “sympathy” towards the project. Nevertheless, he points out that the minister has a background in nuclear energy, though not specifically in the energy sector.

The Coppe/UFRJ professor is optimistic when it comes to developing technologies able to overcome renewables’ intermittency, like what we are seeing in offshore wind plants in Europe, as well as with the development of powerful vehicle batteries that would, in addition to run these cars, also be able to power grids whenever said vehicles were idle. “I am not against nuclear energy. However, I am against its use for energy purposes,” he concludes.

Building in the name of technology

Keeping and expanding previously procured technologies for a wide host of uses, as well as stopping investments already made from going to waste, are the main arguments posed by economist Renato Queiroz, professor and member of the Energy Economics Group (Grupo de Economia de Energia - GEE) of the Federal University of Rio de Janeiro, to

complete Angra 3, in spite of deeming it a costly construction and acknowledging renewables’ progress, as well as their more affordable prices.

“The subject of nuclear energy is just like, for instance, eggplants: some

PEAK OF NEW PLANT CONSTRUCTIONS BETWEEN 1966 AND 1985 – AND OF CONNECTIONS, BETWEEN 1970 AND 1990

Construction start, connection to energy matrix and reactors in operation per five-year period (1954 to 2018)

Period	Construction start (in units)	Connection to energy matrix	Reactors in operation
1954 to 1955	9	1(*)	1
1956 to 1960	42	14	15
1961 to 1965	38	35	48
1966 to 1970	127	42	84
1971 to 1975	152	93	169
1976 to 1980	136	86	245
1981 to 1985	82	131	363
1986 to 1990	39	85	416
1991 to 1995	11	30	434
1996 to 2000	20	23	435
2001 to 2005	13	20	441
2006 to 2010	50	12	441
2011 to 2015	32	29	441
2016 to 2016	12	23	451

Source: AIEA Data

(*) The first commercial nuclear plant connected to the energy matrix was the so-called Obninsk Nuclear Power Plant, in the city of Obninsk, in the former Soviet Union (today, Russia). It only had 5W of power and operated until 1959, after which time it was used solely for research purposes.

love it, while others hate it,” compares Queiroz. He believes that a strategic outlook must be taken into consideration, and even though he sees advantages in nuclear generation, such as its potential to operate indefinitely close to the installed rated capacity, he also perceives problems like elevated costs and the issue of what to do with tailings (replaceable radioactive fuel rods).

At the Angra Nuclear Power Plant, these rods are stored in special pools and, according to Eletronuclear, are currently not treated as tailings, but rather as a fuel reserve that may be reused in the future, a technology still under development.

In spite of being in favor of Angra 3's completion, the economist believes that developing new renewables is an option for the future, thereby ruling out another nuclear power plant program, such as the one currently under development by the Brazilian government. A former EPE employee, Queiroz sees hydroelectric

reservoirs as a potential foundation for solar and wind plant expansion, thereby foregoing new nuclear power plants. “Dismissing nuclear energy for cheaper renewables is an interesting idea; however, it turns into something entirely different if it is a strategic matter.”

When looking ahead, though, he finds that the strong military presence in Brazil's current government is something that fosters the development of a new nuclear energy program within a context that includes every other venture related to said source, such as the nuclear submarine program.

Nevertheless, Queiroz also points to potential bottlenecks in securing a partner willing to invest solely in Angra 3. To this end, the project to build six new plants may be an encouragement to complete the suspended construction site, even though, as he recalls, the need to carry out a new bid for these plants' scheduling is no guarantee that Angra

3's partner will be the supplier of the unit reactors to be built later on.

It only makes sense to those who have no other options

In a podcast recorded with two other Energy Economics Group (Grupo de Economia de Energia – GEE) members, professors Clarice Ferraz and Ronaldo Bicalho, on whether Angra 3 should or should not be completed, in addition to building new plants in Brazil, Queiroz's standpoint was something of a point of balance between Ferraz--decidedly against--and Bicalho--in favor--although wary of the venture's success in light of Brazil's current scenario.

Ferraz, an economist, was adamant: “I do not favor more nuclear plants in the Brazilian energy matrix.” To her, the nuclear agenda is tied to a national sovereignty agenda. “However, I do not see national sovereignty on the agenda, and I do not see a reason to include this source

in the agenda," she adds. Ferraz believes that renewable sources, that is to say, solar, wind and biomass energy, are fully capable of meeting the expansion needs of the Brazilian energy matrix.

In her expert assessment, new investments in nuclear generation only make sense today for societies that have no

gy still has a place in the global energy transition, as well as in Brazil, although he doubts that the current Brazilian administration will have the efficiency required to undertake the project, whether in regards to complete Angra 3, or to build new plants.

In Brazil's agenda, the nuclear sour-

ce would carry out the role of helping to recover hydroelectric plant reservoirs, thereby enabling them to do a "backup" of their renewables. "If I could choose a solution, it would be nuclear, reservoirs, renewables and a little bit of fossil fuel," he states. Gas would be the fossil fuel.

The issue, according to Bicalho's evaluation, is that there is now a clash between two sides within the Brazilian government. On one hand, we have the MME, with Minister Bento advocating in favor of the nuclear solution under a development strategy encompassing every cornerstone of the former Brazilian nuclear program, including commercial uranium enrichment and nuclear submarines; and on the other, the Ministry of the Economy, which perceives gas as the priority and has an ally in Aneel.

"Managing efforts at this time [to redefine the energy matrix] is key; however, I do not think that we will be able to achieve this. I think that neither [Minister] Bento will see his nuclear plants nor will [Minister] Paulo Guedes see his gas program

"Managing efforts at this time is key; however, I do not think that we will be able to achieve this. I think that neither [Minister] Bento will see his nuclear plants nor will [Minister] Paulo Guedes see his gas program in motion."

Ronaldo Bicalho – professor at UFRJ and member of the GEE

other way of decarbonizing their energy production, as is the case of Japan, which tried to say 'no' to nuclear energy after Fukushima, but is now backpedalling on its decision. "Does it make sense for Brazil? No," she both asks and answers.

Still, according to Ferraz, Brazil does not need nuclear energy, because the country has an abundance of other resources, which it can use to solve two issues that the country faces: decarbonization and its need to build stocks. "We only need hydro, solar, wind and biomass energy, and no other energy," she concludes. To her, nuclear energy can be an excellent base energy; however, it is expensive, and there is no way to include it in the base and keep energy cheap.

On the other hand, Bicalho, also an economist, believes that nuclear ener-

WATER SCARCITY HAS A PRICE

Even though the "Electric sector: how to price water in a scarcity scenario" study produced by Instituto Escolhas in 2019 did not examine the issue of nuclear plants potentially being built in the São Francisco River's basin, it does signal what could happen in the realm of costs, without accounting for other socio-environmental issues.

Based on the 2026 Ten-Year Energy Plan (PDE 2026), which foresees construction of 16 gas-fired and biomass-fueled thermal plants for the region of the basin known as "Old Frank," currently home to 13, the paper estimated that in regards to water scarcity scenarios like the one seen in São Francisco during most of the 2010s, plants with cooling towers could end up halting energy generation. This, in turn, would lead to expenditures of up to R\$ 100 million to contract energy solely to fulfill contracts, taking into account only dry season months, as well as the conservative estimation whereby free market energy rates do not exceed R\$ 50 per MWh.

The Escolhas study also stresses that, even though this R\$ 100 million cost applies to generation companies, the lack of energy that they would be expected to produce will put pressure on the energy system's operating costs as a whole, consequently indirectly impacting consumers' pockets.

in motion," he finds. In his opinion, what is absent is an engaged state that helps to pass required legislative measures in the National Congress, in addition to carrying out necessary regulatory changes.

Rates for what is yet to be done

The President of Thymos Energia, João Carlos Mello, supports both the completion of Angra 3 and the expansion of the nuclear source at the Brazilian energy matrix's base, although he recognizes that the plant's energy reference price is high. Thus, he suggests a possible answer: all expenditures until now would be taken on by the organization responsible for those expenditures, in other words, the Brazilian state, whereas the tariff rate would be set in accordance with the investments needed to complete Angra 3's construction, a sum he estimates at R\$ 10 billion.

"What was already paid is paid for, so we need to see from now on," he explains. According to his calculations, the fixed rate would therefore amount to approximately R\$ 250 per MWh, thereby enabling competition with other sources like natural gas and LNG. "It is better to spend



Anivaldo Miranda – President of the São Francisco River Basin Committee (CBHRSF)

is set forth, the President of Thymos finds that nuclear energy does have a place in Brazil due to new renewables' intermittency, which "should enter the market on

"We need consistent energy," assesses the expert, who believes that nuclear energy and gas-fired thermal plants running on Pre-salt gas would be optimal answers to tackle insecurities related to structural rainfall scarcity in regions home to the country's main hydroelectric reservoirs.

In spite of seeing nuclear energy as an important alternative for the country, Mello distinguishes the solution proposed for Angra 3 from investments in new plants, arguing that if the decision to build these plants is made, then they should use modern technologies that enable the construction of smaller plants, "like the English are doing."

Given the challenges in financing new nuclear power plants, which is a global issue, Mello admits as a possibility the option that has been proposed by the British whereby investments in nuclear power are cleared, thus allowing the state to guarantee loans and also

"São Francisco is already seeing significant degradation in the volume and quality of its waters."

Anivaldo Miranda – President of the CBHRSF

R\$ 10 billion than to throw away R\$ 12 billion," he argues, referring to costs needed to cancel construction. Mello points out that Angra 3's technology "is not so modern," which would be another reason to ignore past tariff expenditures.

Once the key issue of energy pricing

a large-scale basis in the coming years because they are cheap and clean," and also due to the "complicated" outlook of hydroelectric plants and reservoirs which, pressured by water reserves' decline curve trend, are ideally the best options to deal with intermittency.

encouraging private banks to assume financing risks, which are deemed very high. The choice made by the United Kingdom is much like a prepaid plant, for which consumers pay a tariff for posterior rate rebate. "As a public policy, I can make a prepayment that will be compensated further ahead," says Mello.

When the issue concerns where potential new nuclear plants should be built, the expert argues that Brazil's Northeast would be a good option since the region has substantially developed its wind and solar energy, thereby enabling alternatives to these sources' intermittency to be built in the region itself, as well as making infrastructure costs more affordable.

is still pending, although authorities have signalled that it is certain to take place. According to Eletronuclear, EPE's PNE 2050 must be published "for us to be able to know what level of increase in installed capacity the country will need in the coming decades, as well as what will be the role of nuclear energy within this context."

Through its Secretary for Energy Planning and Development, Reive Barros, though, the MME has already made a number of public statements, admitting that six new nuclear power plants, totalling 6,600 MW of power, are included in the PNE 2050, and also offers recommendations that they should be built in the Pernambuco state municipality of Itacuruba,

that the main cause of distress among residents are disturbances inflicted upon the community's daily life after they were forced to move.

The technology that will be used in these new plants is yet to be decided, so we are consequently unable to determine how much water will be needed from the river to cool down the reactors. Eletronuclear states that closed-loop systems "used in rivers in Europe" would enable substantially low amounts of water, ranging from 0.015 to 0.06 m³/s per 1,100 thousand MW-powered reactor, the quantity needed to replace evaporated liquid in cooling towers.

The state-owned company does not verify the location of the potential new nuclear power plant. Eletronuclear itself claims to be assessing locations for the plants, for which it identified 40 adequate sites throughout the country, taking into account, among other things, the availability of water for cooling reactors. When the issue was being discussed, the São Francisco River's banks in the states of Pernambuco, Alagoas (estuary) and Minas Gerais were the most widely discussed options.

At the regular Angra 1 and Angra 2 plants, both of which use seawater, the required volume of water is 40 m³/s and 77 m³/s, respectively, according to 2004 Eletronuclear data (3). The volume used up by Angra 3 would therefore be the same as that of Angra 2, generating a total water discharge of 194 m³/s into the ocean site known as *Saco Piraquara de Fora*.

The President of the São Francisco River Basin Committee (Comitê da Bacia Hidrográfica do Rio São Francisco - CBHRSF), Anivaldo Miranda, dubs the plan to build the nuclear plant in Itacuruba or anywhere else along the banks of the river "malicious," as well as "an idea entirely out of context." "São Francisco is already seeing a significant degradation in the volume and quantity of its waters,"

The EPE's PNE 2050 needs to be published "for us to be able to know what level of increase in installed capacity the country will need in the coming decades, as well as what will be the role of nuclear energy within this context."

Eletronuclear

In regards to the potential choice of São Francisco River's banks to house these plants, he points out that the affluent's continuous decrease changed the river's status from an energy river to one envisioned to meet other demands. Questioned whether there would be enough water to cool down the reactors, he replies: "That is no longer my field of expertise."

"An idea entirely out of context"

The decision to build new nuclear power plants in Brazil after Angra 3's completion

more specifically on the São Francisco River's left banks, with funding estimated at US\$ 30 billion.

Itacuruba is currently a resettlement of the original city, which was flooded by the 1980s-built Itaparica hydroelectric plant reservoir. In 2014, filmmaker Isabela Cribari produced an alarming short documentary called "De Profundis," in which she examines the city's high rates of depression and suicide, deemed the highest, in proportional terms, in the entire country. The documentary suggests



Angra Nuclear Power Plant, Almirante Álvaro Alberto Nuclear Power Plant, Rio de Janeiro, Brazil

he argues. In regards to Itacuruba, attention must also be paid to the population's hardship portrayed in the documentary, and to risks of these people suffering yet another trauma.

Miranda stressed that, after the 2013/2014 water shortage crisis, at which time the São Francisco River's affluent flows waned, the National Water Agency (Agência Nacional de Águas – ANA) was forced to lower Sobradinho lake's defluent flows, the main water flow regulator for both the middle and lower São Francisco River, from the minimum flow of 1,300 m³/s to 500 m³/s, to meet strictly essential needs (human, livestock and irrigation uses).

Today, in spite of a favorable water supply scenario, Sobradinho's flow rate required to fill the reservoir is estimated at nearly 800 m³/s, which on March 17, 2020 exceeded the 60% volume level for the first time since June 10, 2012.

According to Miranda, the São Francisco River's diminished water flow stems from several factors that reach well beyond factors like rainfall levels. Among them, we can point to the intensive use of its waters for irrigated agriculture in western Bahia state, which, as a result, undermines the Urucuia aquifer, deemed the main guarantor of the river's continued existence during dry spells (May to November).

"São Francisco does not have a plan B, so we need to tackle degradation risks at all costs, under the risk of breaking Brazil in two," he urges, while further stating that building new nuclear plants would only lead to more elements being added to this degradation process, not only due to the introduction of another major water consumer, but also due to risks inherent to nuclear power plants that people face. "Nuclear is over," he says.

A concern evidenced by statistics

AIEA's statistical examination of the period ending in December 2018, the latest available, makes it utterly impossible to

avoid comparing the growth rate of new nuclear generation units worldwide to the three worst incidents that tarnished the industry's track record, even though there are no conclusive papers on this comparison.

The three events took place on March 28, 1970 in the Three Mile Island Nuclear Generating Station in the United States; on April 26, 1986 in Chernobyl, Ukraine (at the time, part of the former Soviet Union), the worst in history; and on March 11, 2011 in Fukushima, Japan.

Ever since the first commercial electric generation nuclear power plant was built in 1954 in the Russian city of Obninsk (at the time, part of the Soviet Union), with only five MW of installed capacity, the world has seen a boom in new plants between the second half of the 1960s and the first half of the 1980s, particularly during the period from 1966 to 1980, when construction started for 415 plants.

In the five years that followed the Three Mile Island incident, pursuant to decisions that had already been made, 82 additional construction sites commenced, though this represented 60% of the 136 construction sites already started in the previous five-year period. From 1986 to 1990 the number of new construction sites dropped to 39 in a swiftly decreasing pace since 1987, the year after the Chernobyl incident.

In the following 15 years, activity in the industry remained low, amounting to 44 new construction sites in the period, until a strong acceleration took place from 2006 to 2010, thereby suggesting a regain of confidence and leading to the construction of 50 new nuclear power plants. Nevertheless, the Fukushima incident happened the following year, resulting in an abrupt deceleration in that same year, after which only four new plants, or 25% of the overall number for 2010, were built.

That year, several countries either gave up on or postponed their new projects, while Germany simply decided to shut down all its nuclear plants. In spite of a relative surge witnessed in 2013, when ten new plants started to be built, numbers remain extremely low if we measure them against the golden age standard. Furthermore, there are currently no indications that any type of strong acceleration may take place in the coming years, enough to--taking into account age-related plant decommissioning--expand the overall number of plants in operation worldwide far beyond the range of 440 to 450, a figure that has stayed the same since the beginning of this century.

As previously stated by experts heard in this paper, nuclear generation now seems to be an alternative to decarbonization in countries with no other less costly option at hand. Even the United States, the nation home to the largest number of nuclear power plants in operation, currently only has two new plants under construction.

France, who holds the record in nuclear participation in its energy matrix (71.7% in 2018), only has two new plants under construction, as opposed to the 58 currently in operation. The country has been in a heated internal struggle against Germany within the European Union to try to make the EU deem the nuclear source a "green energy", something that the Germans, who are willing to shut down, until December 2022, their seven plants still operating at the end of 2018, are not willing to accept.

Even the United Kingdom, which is trying to set a financial figure that enables construction of new plants, in 2018 had only one plant under construction to add to its current 15 in operation. In turn, after Fukushima, Japan actually announced that it would shut off its reactors indefinitely. However, the country has been gradually reactivating its 39 plants

due to pressures resulting from elevated natural gas import prices to replace the nuclear plants.

Of the 55 new reactors that were under construction when the 2018 AIEA report was being concluded, including Angra 3's halted construction, China (11); India (7); Russia (6); South Korea (5); and the United Arab Emirates (4) accounted for 60%, or 33 units. The United Arab Emirates; Bangladesh (2); Belarus (2); and Turkey (1) are the new countries to join the club of nuclear power producers, a group comprised of 30 nations, not including this last group of countries mentioned.

Although--as UFRJ professor Queiroz pointed out--nuclear plants are loved by some and hated by others, the statistics clearly show that nuclear plants' glory days are long gone, and that incidents and costs generated, boosted by safety measures introduced after each one of these incidents, undoubtedly justify society's fears in regards to the ever-present possibility of a new serious incident, in addition to concerns about this type of venture's cost-benefit.

The recent success of HBO's hit miniseries "Chernobyl" reignited, in the minds of people across the globe, the horrors of radiation and the risks that nuclear power plants will always entail.

It is now up to us to decide whether we wish to extend these risks to Brazil, at costs exceedingly higher than those offered by other cheaper and less risky options, if we bear in mind only energy-related considerations. ●

REACTORS UNDER CONSTRUCTION FAIL TO REPLENISH WORKING STOCKS

Reactors in operation and under construction in the world as of December 31, 2018

Country	Reactors in operation	Installed capacity (MW)	Reactors under construction	Planned Capacity (MW)
Argentina	3	1633	1	25
Armenia	1	375	0	0
Bangladesh	0	0	2	2160
Belarus	0	0	2	2220
Belgium	7	5918	0	0
Brazil	2	1884	1	1340
Bulgary	2	1966	0	0
Canada	19	13554	0	0
China	46	42858	11	10982
Czech Republic	6	3932	0	0
Finland	4	2784	1	1600
France	58	63130	1	1630
Germany	7	9515	0	0
Hungary	4	1902	0	0
India	22	6255	7	4824
Iran	1	915	0	0
Japan	39	36974	2	2653
South Korea	24	22444	5	6700
Mexico	2	1552	0	0
Netherlands	1	482	0	0
Pakistan	5	1318	2	2028
Romania	2	1300	0	0
Russia	36	27252	6	4573
Slovakia	4	1814	2	880
Slovenia	1	688	0	0
South Africa	2	1860	0	0
Spain	7	7121	0	0
Sweden	8	8613	0	0
Switzerland	5	3333	0	0
Turkey	0	0	1	1114
United Arab Emirates	0	0	4	5380
United Kingdom	15	8923	1	1630
Ukraine	15	13107	2	2070
United States	98	99061	2	2234
Overall	451	396911	55	56643

Source: AIEA Data

Observations:

See book "Bomba atômica! Para quê" ("Atomic Bomb! For what?", *freely translated*) by journalist Tania Malheiros, page 75 (Editora Lacre).

See "Nuclear Energy for Electricity Generation: Historical Analysis, Nowadays Situation and Future Perspective." Doctoral thesis by Sara Tania Mongelli for the Institute of Energetic and Nuclear Research (Instituto de Pesquisas Energéticas e Nucleares), a self-administered public entity bound to the University of São Paulo – 2006.

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Podcast: GEE Energy: Does Brazil Need to Build New Nuclear Power Plants?

Renato Queiroz, Clarice Ferraz and Ronaldo Bicalho – Energy Economics Group

<https://www.youtube.com/watch?v=yEpQmBJzMzM>

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