

UNIVERSIDADE DE SÃO PAULO
ESCOLA DE ARTES, CIÊNCIAS E HUMANIDADES
PROGRAMA DE PÓS-GRADUAÇÃO EM SUSTENTABILIDADE

JOÃO MARCOS MOTT PAVANELLI

**Transições energéticas no Brasil e na Nigéria: estruturas conceituais para
mudanças institucionais na indústria elétrica**

São Paulo
2022

JOÃO MARCOS MOTT PAVANELLI

**Transições energéticas no Brasil e na Nigéria: estruturas conceituais para
mudanças institucionais na indústria elétrica**

Tese de doutorado apresentada ao
Programa de Pós-graduação em
Sustentabilidade da Escola de Artes,
Ciências e Humanidades da Universidade
de São Paulo – EACH-USP.

Área: Ciências Ambientais

Orientador: Prof. Dr. Alexandre Toshiro
Igari

São Paulo
2022

Autorizo a reprodução e divulgação total ou parcial deste trabalho, por qualquer meio convencional ou eletrônico, para fins de estudo e pesquisa, desde que citada a fonte.

Ficha catalográfica elaborada pela Biblioteca da Escola de Artes, Ciências e Humanidades,
com os dados inseridos pelo(a) autor(a) □
Brenda Fontes Malheiros de Castro CRB 8-7012; Sandra Tokarevicz CRB 8-4936

Mott Pavanelli, João Marcos

Transições energéticas no Brasil e na Nigéria:
estruturas conceituais para mudanças institucionais
na indústria elétrica / João Marcos Mott Pavanelli;
orientador, Alexandre Toshio Igari. -- São Paulo,
2022.

135 p: il.

Tese (Doutorado em Ciências) - Programa de Pós-
Graduação em Sustentabilidade, Escola de Artes,
Ciências e Humanidades, Universidade de São Paulo,
2022.

Versão corrigida

1. Análise Institucional Multinível. 2. Mudança
Institucional. 3. Transições Energéticas. 4. Geração
Elétrica. 5. História da Indústria Elétrica. I.
Igari, Alexandre Toshio, orient. II. Título.

Tese submetida à Banca de Doutorado, de autoria de João Marcos Mott Pavanelli, sob o título “Transições Energéticas no Brasil e na Nigéria: Estruturas conceituais para mudanças institucionais na indústria elétrica”, apresentada à Escola de Artes, Ciências e Humanidades da Universidade de São Paulo, como parte dos requisitos para obtenção do título de Doutor em Ciências pelo Programa de Pós-graduação em Sustentabilidade, na área de concentração Ciências Ambientais, aprovado em _____ pela comissão examinadora constituída pelos doutores:

Prof. Dr. Alexandre Toshiro Igari
Presidente
Escola de Artes Ciências e Humanidades da Universidade de São Paulo – EACH-USP

Prof. Dr. Célio Bermann
Instituto de Energia e Meio Ambiente da Universidade de São Paulo – IEE-USP

Profa. Dra. Tânia Pereira Christopoulos
Escola de Artes Ciências e Humanidades da Universidade de São Paulo – EACH-USP

Prof Dr. Sergio Villamayor-Tomas
ICTA, Autonomous University of Barcleona

Profa. Visitante Flavia Mendes de Almeida Collaço
Parque Tecnológico da Universidade Federal do Ceará – UFC

De forma simbólica, dedico esta tese ao Theo Pavanelli de Oliveira, que representa, no instante desta publicação, as gerações vindouras e a esperança de mudança.

AGRADECIMENTOS

Aos membros da seção de pós-graduação, em especial ao Fabiano Gomes Teixeira Prado, ao Marcus Oliveira, à Kelly Masaharu da Silva e à Vanessa de Lima Tavares.

À biblioteca da Escola de Artes, Ciências e Humanidades da Universidade de São Paulo.

À CAPES.

À Fox Fellowship da Universidade de Yale, especialmente à Julia Muravnik do MacMillan Center e Ozan Say do *Office of International Students and Scholars*.

À Gestão pedagógica do IEMA Rio Anil, em especial à Jequélia Caldas, Thássica Muniz, Andressa Freire e ao Olivar Pinheiro Júnior, Larissa Araújo Martins e Marcelo Rocha.

Ao MacroAmb, especialmente ao G3: Anelise Gomes, professor doutor Paulo Sinisgalli, Pedro Jacobi, Pedro Torres e ao G4: doutora Lira Lázaro, doutores Andrea Lampis e Guilherme Pedroso.

À banca: às professoras doutoras, Flávia Mendes Collaço, Tânia Christopoulos e aos professores doutores Célio Bermann e Prof. Dr. Sergio Villamayor-Tomas – Também aos respectivos suplentes: doutor Nilton Bispo Amado, professora doutora Sylmara Lopes Francelino Gonçalves Dias e professores doutores Ildo Sauer e André Simões.

À Silvia Mandai, minha amiga e com quem compartilhei bons momentos acadêmicos, discussões e um ano frente à representação discente do Programa de Pós-Graduação em Sustentabilidade.

Aos amigos: Felipe Campos, Tomás Marques, Alexander Bakri e Valério Rodrigues de Souza Neto. Às amigas Carolina Girotti, Raiana Schirmer Soares e em especial, Camila Espezio de Oliveira. Também às amigas Erika Vieira Sang, Yusra Ghani, Amanda Souza e Juliana de Menezes Cardoso e aos amigos Arthur Siqueira, Raphael Laffin e Toni Pereira.

Às professoras doutoras Emily Erikson, Maria Sylvia Machionne Saes e Wânia Duleba. Aos professores doutores Norbert Edomah, Guilherme Grandi, Dib Karan, Glauco Machado, José Mauro Hernandez, Marcelo Pereira de Souza, William Vance e Daniel Esty.

Aos entrevistados que participaram dos estudos presentes nos capítulos 2 e 4 desta tese: Élio Vicentini, Luciano Pelegrina, professor doutor José Goldemberg, André Kozen, Olapegba, Justin Tinsey e Anthony Idigbe.

Aos meus familiares, Luís Claudio Pelegrina Pavanelli, Ana Camila Hollo Mott Pavanelli, Ana Victória Mott Pavanelli de Oliveira, Paulo de Oliveira e aos meus primos Juliano Pelegrina, Rafael Farah e Camila Nicoletti Del Arco Farah.

À Thalía pelo companheirismo na fase final da tese, pelas riquíssimas, produtivas e intermináveis discussões e pelo esmero e consideração nas revisões e sugestões que formaram o documento final da tese.

Finalmente, ao professor doutor Alexandre Toshiro Igari, orientador, amigo, rigoroso e amável cientista e um símbolo de inspiração de conduta, sem o qual este trabalho jamais existiria.

RESUMO

PAVANELLI, João Marcos Mott. **Transições energéticas no Brasil e na Nigéria: estruturas conceituais para mudanças institucionais na indústria elétrica**. 135 f. Tese (Doutorado em Ciências) – Programa de Pós Graduação em Sustentabilidade, Escola de Artes, Ciências e Humanidades da Universidade de São Paulo, São Paulo, 2022.

As fontes que compõem a oferta elétrica dos países são resultantes de escolhas por diferentes possibilidades, disputadas por diferentes agentes, considerando, para além de aspectos biofísicos, econômicos e sociais, a relação de tais aspectos com as instituições, entendidas como regras formais e informais que servem de guias para a interação entre os agentes. Instituições, portanto, são também objetos de disputas e delimitam as estratégias das organizações de um setor, podendo favorecer ou dificultar a expansão de certas fontes de geração elétrica em detrimento de outras. Diante de acordos multilaterais para redução e substituição de fontes fósseis, emerge a importância de compreender cenários de transições energéticas para fontes renováveis mais limpas. Este projeto procurou descrever conjuntos de variáveis sociais, econômicas e biofísicas que influenciaram a reprodução e mudança das instituições ao longo de trajetórias históricas de indústrias elétricas do Brasil e Nigéria, com o intuito de explicar as escolhas por fontes de geração e modelos de governança em diferentes períodos. A metodologia apresenta uma triangulação de métodos composta por: a) revisão sistemática da literatura para elaboração de *frameworks*; b) pesquisa histórica e construção de narrativas cronológicas; e c) entrevistas em profundidade com especialistas para confrontação dos resultados. Os resultados apresentam diferentes *frameworks*, que articulam variáveis institucionais, indicando que mudanças decorrem de: i) crises internas e externas, e ii) alterações em dotações sociais, econômicas e biofísicas. Estes momentos foram identificados nas narrativas históricas como antecessores de acirramentos de disputas e redistribuição no balanço de poder entre agentes e seus interesses nas arenas sociais.

Palavras-chave: Análise Institucional Multinível. Mudança Institucional. Transições Energéticas. Geração Elétrica. História da Indústria Elétrica.

ABSTRACT

PAVANELLI, João Marcos Mott. **Energy transitions in Brazil and Nigeria: frameworks for institutional change in the electricity industry**. 135 p. Thesis (Doctorate in Science) – Post-graduate Program in Sustainability. School of Arts, Sciences and Humanities from the University of São Paulo, São Paulo, 2022.

The countries' source of electricity supply is resultant of disputes between different agents among different possibilities, considering, beyond the biophysical, economic, and social aspects, their relationship with the institutions, considered in this study to be formal and informal rules that guide social interaction. Institutions, therefore, are the object of disputes and delineate organizations' strategies in an economic sector, favoring or hindering the expansion of one source to others' detriment. In front of multilateral agreements for the reduction and substitution of fossil fuels, it emerges the importance of comprehending renewable and cleaner energy transition scenarios. This study described a set of social, economic, and environmental variables that influenced the institutional reproduction and change throughout the Brazilian and Nigerian electricity industry's history, with the objective of explaining choices for electricity generation sources and governance modes in different periods. The methodology presents a methods triangulation composed of: a) systematic literature review for the frameworks' elaboration; b) historical research to build historical narratives and; c) in-depth interviews with specialists to confront the results. Results present different frameworks articulating institutional variables that indicate that the institutional changes elapse from: i) internal and external crises; and ii) alteration in social, economic, and environmental agents' endowments. Those moments were identified in the literature as predecessors for dispute stirring in social arenas and power redistribution among agents and their interests.

Key-words: Multilevel Institutional Analysis. Institutional Change. Energy Transitions. Electricity Generation. History of Electricity Industry.

RÉSUMÉ

PAVANELLI, João Marcos Mott. **La Transition Énergétique au Brésil et au Nigeria : Structures Conceptuelles pour le Changement Institutionnel au sein de l'Industrie Électrique**. 135 p. Thèse (Doctorat en sciences) – Programme du troisième cycle en développement durable. École des Arts, Sciences et des Sciences Humaines de l'Université de Sao Paulo, Sao Paulo, 2022.

Les sources d'approvisionnement électrique des pays sont le résultat d'un choix parmi différentes possibilités entre différents acteurs. Cette décision est prise non seulement en tenant compte des aspects biophysiques, économiques et sociaux, mais aussi des relations avec les institutions : celles-ci dénotant les règles formelles et informelles qui orientent l'interaction entre les agents. Les institutions font ainsi l'objet de disputes et délimitent les stratégies d'organisation dans un secteur, ce qui peut favoriser ou entraver l'expansion de certaines sources de génération d'énergie électrique au détriment d'autres. Face aux accords multilatéraux qui visent à réduire et remplacer les sources d'énergie fossiles, il émerge l'importance de comprendre les circonstances des transitions énergétiques vers des sources renouvelables davantage propres. Ce projet cherche à décrire des groupes de variables sociales, économiques et biophysiques qui ont influencé la reproduction et le changement des institutions des industries d'énergie électrique au Brésil et au Nigeria à travers l'histoire, expliquant ainsi les motifs qui ont menés aux choix des sources de génération d'énergie électrique et les modèles de gouvernance dans ces pays pendant différentes périodes. La méthodologie présente une triangulation des méthodes composé par : a) la révision systématique de littérature afin d'élaborer les structures conceptuelles ; b) la recherche historique et la construction de la narrative chronologique ; e c) des entretiens approfondis avec des experts afin de confronter les résultats de la recherche à la réalité du terrain. Les résultats présentent des différentes structures conceptuelles qui articulent des variables institutionnelles en indiquant que les changements institutionnels proviennent i) des crises internes et externes ; et ii) des changements des dotations sociales, économiques et biophysiques. Ces moments ont été identifiés dans les narratives historiques comme étant prédécesseurs de l'ascension des disputes, de la redistribution de l'équilibre du pouvoir parmi les agents ainsi que de leurs intérêts dans les arènes sociales.

Mots-clés : L'Analyse Intentionnelle Multiniveaux, Changement Institutionnel. Transition Énergétique. Génération d'Énergie Électrique. Histoire de l'Industrie Électrique.

RESUMEN

PAVANELLI, João Marcos Mott. **Transiciones energéticas en Brasil y Nigeria: marcos conceptuales para el cambio institucionales en la industria eléctrica.** 135 h. Tesis (Doctorado en Ciencias) – Programa de Posgrado en Sostenibilidad. Escuela de Artes, Ciencias y Humanidades de la Universidad de São Paulo, São Paulo, 2022.

Las fuentes que componen la oferta eléctrica de los países son el resultado de opciones por diferentes posibilidades disputadas por diferentes agentes, considerando, además de los aspectos biofísicos, económicos y sociales, la relación de tales aspectos con las instituciones, entendidas como reglas formales e informales que servir de guías para la interacción entre los agentes. Las instituciones, por tanto, también son objeto de disputas y delimitan las estrategias de las organizaciones de un sector, que pueden favorecer o dificultar la expansión de ciertas fuentes de generación eléctrica en deterioro de otras. Frente a los acuerdos multilaterales para reducir y reemplazar las fuentes fósiles, surge la importancia de entender los escenarios de transición energética para fuentes renovables más limpias. Este proyecto buscó describir conjuntos de variables sociales, económicas y biofísicas que influyeron en la reproducción y el cambio de instituciones a lo largo de las trayectorias históricas de las industrias eléctricas en Brasil y Nigeria, con el fin de explicar las opciones de fuentes de generación y modelos de gobernanza en diferentes períodos. La metodología presenta una triangulación de métodos compuesta por: a) revisión sistemática de la literatura para la elaboración de marcos; b) investigación histórica y construcción de narrativas cronológicas; c) entrevistas en profundidad con expertos para confrontar los resultados. Los resultados presentan diferentes estructuras conceptuales que articulan variables institucionales indicando que los cambios institucionales resultan de: i) crisis internas y externas, y de ii) cambios en las dotaciones sociales, económicas y biofísicas. Estos momentos fueron identificados en las narrativas históricas como antecedentes de la intensificación de las disputas y la redistribución en el equilibrio de poder entre los agentes y sus intereses en las arenas sociales.

Palabras clave: Análisis Institucional Multinivel. Cambio Institucional. Transiciones Energéticas. Generación Eléctrica. Historia de la Industria Eléctrica.

LISTA DE SIGLAS POR CAPÍTULO

Capítulo 1

IAD	<i>Institutional Analysis and Development</i>
OPEP	Organização dos Países Exportadores de Petróleo
MIDA	<i>Multidimensional Institutional Dynamics Analysis</i>

Capítulo 2

NES	<i>New Economic Sociology</i> (Nova Sociologia Econômica)
NIE	<i>New Institutional Economics</i> (Nova Economia Institucional)
NOI	<i>New Organizational Institutionalism</i> (Novo Institucionalismo Organizacional)
CNAEE	<i>National Counsel of Water and Electricity</i> (Conselho Nacional de Águas e Energia Elétrica)
CHESF	<i>The São Francisco Hydroelectric Company</i> (Companhia Hidrelétrica do São Francisco)
MME	<i>Ministry of Mines and Energy</i> (Ministério de Minas e Energia)
BNDES	<i>The National Bank of Development</i> (Banco Nacional do Desenvolvimento)
EPE	<i>Energy Research Company</i> (Empresa de Pesquisa Energética)
ANEEL	National Electricity Agency (Agencia Nacional de Energia Elétrica)
PROINFA	<i>Program of Incentive for Alternative Sources</i> (Programa de Incentivo à Fontes Alternativas de Energia Elétrica)
COP21	21st Conference of the Parties (21a Conferência das Partes)
AES	<i>Applied Energy Services Inc.</i>

Capítulo 3

IAD	<i>Institutional Analysis and Development</i>
CNAEE	<i>National Counsel of Water and Electricity</i> (Conselho Nacional de Águas e Energia Elétrica)
MME	<i>Ministry of Mines and Energy</i> (Ministério de Minas e Energia)
ANEEL	National Electricity Agency (Agencia Nacional de Energia Elétrica)
NOS	National System Operator (Operador Nacional do Sistema)

SIN	Interconnected National System (Sistema Interligado Nacional)
PROINFA	<i>Program of Incentive for Alternative Sources</i> (Programa de Incentivo à Fontes Alternativas de Energia Elétrica)

Capítulo 4

NREEEP	The National Renewable Energy and Efficiency Policy (Política Nacional de Eficiência e Energia Renovável)
IAD	Institutional Analysis and Development
NERC	Nigerian Electricity Regulatory Committee (Comissão Regulatório de Electricidade da Nigéria)
MIDA	<i>Multidimensional Institutional Dynamics Analysis</i> (Análise de Dinâmicas Institucionais Multidimensional)
PWD	<i>Public Work Department</i> (Departamento de Trabalho Público)
NESCO	<i>Nigerian Electricity Supply Corporation</i> (Corporação de Suprimento de Electricidade da Nigéria)
NDA	<i>Niger Dam Authority</i> (Autoridade de Represas do Niger)
IMF	<i>International Monetary Fund</i> (Fundo Monetário Internacional)
OPEC	<i>Organization of the Petroleum Exporting Countries</i> (Organização dos Países Exportadores de Petróleo)
ECN	<i>Energy Commission of Nigeria</i> (Comissão de Energia da Nigéria)
NEPA	<i>National Electricity Power Authority</i> (Autoridade National de Electricidade)
NNPC	<i>Nigerian National Petroleum Corporation</i> (Corporação Nacional Nigeriana de Petróleo)
SAP	<i>Structural Adjustment Program</i> (Programa de Ajuste Estrutural)
NGC	<i>Nigerian Gas Company</i> (Companhia Nigeriana de Gás)
FME	<i>The Federal Ministry of Environment</i> (Ministério Federal do Meio Ambiente)
REMP	<i>Renewable Energy Master Plan</i> (Plano Mestre de Energia Renovável)
COP	<i>Conference of the Parties</i> (Conferência das Partes)
SUCC	Special Unit Climate Change (Unidade Especial de Mudança Climática)
SURE	Special Unit on Renewable Energy (Unidade Especial para Energia Renovável)

NEPP	National Electric Power Policy (Política Nacional de Electricidade)
NIPP	National Integrated Power Project (Projeto Integrado de Electricidade)
EPSRA	Electric Power Sector Reform Act (Ato de Reforma do Setor Elétrico)
NBET	Nigerian Bulk Electricity Trading (Comércio de Eletricidade no Varejo da Nigéria)
PHCN	Power Holding Company of Nigeria (Companhia Holding de Electricidade da Nigéria)
Transcos	Transmission Companies (Companias de Transmissão)
Discos	Distribution Companies (Companias de Distribuição)
Gencos	Generation Companies (Companias de Geração)
COP21	<i>21st Conference of the Parties</i> (21ª Conferência das Partes)

LISTA DE QUADROS, TABELAS E FIGURAS POR CAPÍTULO

Introdução

Quadro 1	Resumo das principais similaridades e diferenças entre os <i>frameworks</i> apresentados nos capítulos 2, 3 e 4 desta tese.....	25
-----------------	---	----

Capítulo 2

Figure 1	Nested triangulation among Theories, Methods, and Sources.....	37
Figure 2	Integrative Analytical Framework for Institutional Dynamics.....	40
Table 1	Analytical Framework theoretical concepts and their empirical evidence in the Brazilian Electric Sector's History.....	42

Capítulo 3

Figura 1	IAD - <i>Institutional Analysis and Development framework</i>	65
Figura 2	Framework de análise institucional adaptado a partir do IAD	68
Quadro 1	Categorização dos eventos históricos de acordo com as variáveis propostas no <i>framework</i> de análise institucional (linhas), ao longo dos períodos da indústria de eletricidade brasileira (colunas).....	82

Capítulo 4

Figure 1	Representation of the IAD framework.....	94
Figure 2	Triangulation of Methods.....	96
Figure 3	Multidimensional Institutional Dynamics Analysis (MIDA).....	101
Figure 4	Installed capacity (MW) per source in Nigeria with y-axis in logarithmic scale.....	104
Table 1	Agents and interests, biophysical conditions, economic and social endowments, rules-in-use and the organizations responsible for crafting them: The Imperial Period (1896 - 1960).....	106
Table 2	Agents and interests, biophysical conditions, economic and social endowments, rules-in-use and the organizations responsible for crafting them: The Early Independence Period (1961 - 1970).....	107
Table 3	Agents and interests, biophysical conditions, economic and social endowments, rules-in-use and the organizations responsible for crafting them: The Military Regime Period (1971 - 1985).....	109
Table 4	Agents and interests, biophysical conditions, economic and social endowments, final rules-in-use, and the organizations responsible for crafting them: The First Reform Period (1986 - 1999).....	111
Table 5	Agents and interests, biophysical conditions, economic and social endowments, final rules-in-use, and the organizations responsible for crafting them: The Intensification Of The Privatization Programs (2000 - 2020).....	113

SUMÁRIO

1	INTRODUÇÃO	18
2	INSTITUTIONAL REPRODUCTION AND CHANGE: AN ANALYTICAL FRAMEWORK FOR BRAZILIAN ELECTRICITY GENERATION CHOICES	28
2.1	INTRODUCTION.....	28
2.2	THEORY.....	29
2.2.1	Baseline concepts: field, agents and institutions	30
2.2.2	Institutional theories and core analytical concepts	31
2.2.3	New Institutional Economics (NIE): Belief systems and Path dependence	32
2.2.4	New Organizational Institutionalism (NOI): Isomorphism	33
2.2.5	New Economic Sociology (NES): Social skilled agents and Crisis	33
2.3	METHODS.....	35
2.4	RESULTS.....	38
2.4.1	Integrative Analytical Framework for institutional reproduction and change in the Brazilian electricity sector	38
2.4.2	Historical analysis of reproduction and change of technological choices in the Brazilian electricity sector	40
2.4.2.1	1879-1903: Hydroelectric and Thermoelectric Decentralized Non-connected.....	45
2.4.2.2	1904-1933: Hydroelectric Centralized Non-connected.....	45
2.4.2.3	1934-1963: Hydroelectric Centralized Regionally Connected.....	46
2.4.2.4	1964-1992: Hydroelectric Centralized Inter-Regionally Connected.....	47
2.4.2.5	1993-2002: Hydroelectric Centralized Nationally Connected.....	48
2.4.2.6	2003-2016: Hydroelectric, Gas fueled thermoelectric and Eolic centralized connected and also Biomass thermoelectric distributed connected (sugarcane cogeneration).....	49
2.5	DISCUSSION.....	52
2.6	CONCLUSIONS.....	54
2.7	ACKNOWLEDGMENTS.....	55
2.8	REFERENCES.....	55
3	O DESAFIO DAS MUDANÇAS INSTITUCIONAIS NA ECONOMIA ECOLÓGICA: UM FRAMEWORK A PARTIR DO IAD DE OSTROM	59
3.1	INTRODUÇÃO.....	60
3.2	ADAPTAÇÃO DO <i>FRAMEWORK</i> : EXPANDINDO E DETALHANDO AS VARIÁVEIS DO IAD.....	66
3.3	APLICAÇÃO DO <i>FRAMEWORK</i> DE ANÁLISE INSTITUCIONAL À NARRATIVA HISTÓRICA DA INDÚSTRIA DE ELETRICIDADE BRASILEIRA.....	69
3.4	CONSIDERAÇÕES FINAIS.....	75
3.5	AGRADECIMENTOS.....	77
3.6	REFERÊNCIAS.....	77
	ANEXO.....	81
4	AN INSTITUTIONAL FRAMEWORK FOR ENERGY TRANSITIONS: LESSONS FROM THE NIGERIAN ELECTRICITY INDUSTRY HISTORY	86
4.1	INTRODUCTION.....	86

4.2	GRAPPLING A THEORETICAL FOUNDATION FOR ENERGY TRANSITIONS AND INSTITUTIONAL CHANGE.....	89
4.2.1	Fundamentals of Ostrom's IAD Framework.....	91
4.3	MATERIALS AND METHODS.....	95
4.3.1	Institutional Analysis and Development (IAD) framework and its adaptation in electricity industry analysis.....	97
4.3.2	Document Review.....	98
4.3.3	In-depth Interviews.....	99
4.4	PRESENTING THE MIDA: MULTIDIMENSIONAL INSTITUTIONAL DYNAMICS ANALYSIS.....	100
4.5	USING THE MIDA TO BUILD THE NIGERIAN ELECTRICITY INDUSTRY'S NARRATIVE.....	103
4.5.1	The Imperial Period (1896-1960).....	105
4.5.2	The Early Independence Period (1961-1970).....	106
4.5.3	The Military Regime Period (1971 - 1985).....	108
4.5.4	The First Economic Reform Period (1986 - 1999).....	109
4.5.5	The Intensification of the Privatization Programs (2000 - 2020).....	111
4.6	CONCLUSION.....	115
4.7	REFERENCES.....	116
5	CONCLUSÃO.....	125
	REFERÊNCIAS DA INTRODUÇÃO E DA CONCLUSÃO.....	129
	APÊNDICE A.....	133
	APÊNDICE B.....	134

1 INTRODUÇÃO

As transições energéticas estão presentes em agendas políticas, econômicas e científicas, principalmente pela importância associada à mitigação da emissão de gases relacionados ao aumento da temperatura média do planeta e seus impactos deletérios, com efeitos diretos e indiretos nas atividades humanas presentes e futuras (IPCC, 2022). Neste contexto, os combustíveis fósseis, responsáveis pela maior parte das emissões globais, recebem especial destaque e surgem grupos interessados em alterar a composição da oferta mundial de energia, em direção às fontes de fluxo¹.

Entretanto, nem toda transição energética na história da humanidade apontou (ou aponta) para a atual e desejada descarbonização, orientada a fontes mais limpas e renováveis de fluxo. Apesar de o termo “transições energéticas” ser empregado para fenômenos contemporâneos ligados às mudanças climáticas, mudanças de fonte, tecnologia e governança de recursos energéticos não são novidades. Historicamente, as sociedades sempre optaram por diferentes formas de apropriação e uso dos recursos energéticos.

A história do petróleo, por exemplo, é marcada por escolhas atreladas não apenas à sua disponibilidade dentro dos territórios, à maturidade tecnológica da infraestrutura da cadeia produtiva e aos interesses de agentes com poder econômico e político, mas também por disputas emergentes de contingências históricas, como crises, guerras e desastres naturais (SOLOMON e KRISHNA, 2011; YURGIN, 2020).

As trajetórias históricas do carvão e do petróleo, inclusive, exemplificam transições energéticas contrárias às desejadas, no sentido da manutenção da temperatura média global, a partir de quando a humanidade trocou as fontes de fluxo (biomassa, moinhos, barcos a vela) pelas fósseis, aumentando consideravelmente a demanda mundial por energia, após a Segunda Revolução Industrial (SCHNEIDER e JARZYNSKI, 2006).

De todo modo, a sociedade sempre dependeu e dependerá de fontes energéticas para desenvolver suas atividades, tendo aumentado sua quantidade absoluta demandada e as opções disponíveis para produzi-las e delas se apropriarem. Transições energéticas, neste sentido, são entendidas por Smil (2017a, 2017b)

¹ Fontes de fluxo são capazes de se renovar em um período relativamente curto de tempo, como as fontes solar, eólica, biomassa e hídrica, que se renovam em minutos, horas, dias, anos, contrapondo-se assim aos combustíveis fósseis, que possuem ciclos de renovação muito mais longos (medidos em eras).

quando uma fonte atinge pelo menos 10% do total da oferta energética. Tais transições perpassam dilemas de apropriação e uso de recursos energéticos e, portanto, são elementos de disputa nas arenas sociais.

Desde a primeira revolução agrícola e os primeiros assentamentos humanos, há cerca de dez mil anos, passando pela Revolução Industrial e suas máquinas a combustão, do século XVIII em diante, até a moderna e flexível eletricidade ao final do século XIX, a qualidade e quantidade dos energéticos possibilitaram (ou limitaram) o desenvolvimento das sociedades (SCHNEIDER e JARZYNSKI, 2006).

A eletricidade é um vetor energético capaz de realizar diferentes tipos de trabalho. Ela surge ao final do século XIX e expande sua participação na oferta global de energéticos durante todo o século XX. Em 2020, a eletricidade respondeu por cerca de 30% da oferta energética mundial. Projeta-se um avanço da oferta para regiões ainda sem acesso e o aumento da eletricidade na participação da oferta global de energia (IEA, 2021). A maior parte da oferta de energia elétrica ainda é proveniente de fontes fósseis, mesmo diante de acordos multilaterais para redução do seu uso e substituição por fontes mais limpas e renováveis (COP 21). Dito isso, a humanidade não está em curso para alterar seus hábitos de consumo de combustíveis fósseis.

Em verdade, o planeta testemunha o aumento da utilização absoluta de combustíveis fósseis ao longo do tempo. Os avanços das fontes de fluxo, principalmente a solar e eólica, não mudam a tendência de aumento absoluto do consumo de combustíveis fósseis. A explosão na demanda global de energéticos pressiona para que as demandas absolutas de combustíveis fósseis também aumentem. O resultado é que, embora a participação relativa das renováveis aumente na oferta global de energia, o uso absoluto de fósseis também aumenta, fenômeno que tem sido referido como *energy additions* ou adições energéticas (YORK e BELL, 2019).

Ao fim das contas, as renováveis mais limpas compõem apenas uma parte da crescente demanda energética global e não substituem o quantitativo existente de combustíveis fósseis. Neste contexto, qual o papel da mudança institucional para entender as transições (ou não transições) energéticas? Quais elementos estão presentes em momentos de mudança ou adição (10% do total da oferta) da fonte de geração ou governança de indústrias elétricas?

Para responder tais questões, esta tese parte da compreensão de que as transições energéticas se referem aos processos de mudança de fonte, tecnologia

e/ou governança de indústrias elétricas. Por sua vez, por governança, este estudo se refere às estratégias e interesses dos grupos dotados de poder, presentes em nível constitucional mais elevado, e que são responsáveis pelas decisões sobre o planejamento, investimento e execução da expansão da oferta de eletricidade, compreendendo que estas relações também são influenciadas por diferentes manifestações dos capitais sociais em cada contexto (como cultura, laços de confiança, capital humano disponível etc.). Os processos de reprodução e mudança das instituições, portanto, são dependentes de disputas e escolhas entre agentes contextualizados em uma trajetória histórico-social em curso.

A partir dessa premissa, apontamos, com casos brasileiros e nigerianos, que as escolhas por fontes que compõem a oferta de eletricidade desses países não foram somente determinadas pela disponibilidade dos recursos, como a infraestrutura disponível e as opções técnica e economicamente viáveis (SCHNEIDER e JARZYNSKI, 2006), mas também foram resultantes das próprias disputas pelo controle das instituições que guiaram a estrutura de incentivos desse setor econômico.

As instituições, desse modo, foram tratadas nesta tese como interfaces entre o mundo social e o mundo natural, fruto de escolhas entre diferentes opções e modelos (tanto de fonte e tecnologia de geração, como de governança), sendo a disponibilidade de recurso apenas mais um dos fatores estruturantes de tais alterações.

As disputas pelo controle das instituições se estruturam ao redor de interesses conflitantes de agentes e grupos, que se confrontam para melhorar suas posições na apropriação e controle dos diferentes tipos de capitais ambientais, sociais, políticos e econômicos que influenciam na distribuição de poder entre os agentes. Tais elementos em disputa são também estruturantes, ao interagirem ao longo do tempo para a formação, manutenção e mudança das instituições ou, simplificada, influenciam na composição de regras formais e informais que balizam a interação dos agentes em um setor econômico.

Smil (2015, 2016, 2017), Sovacool (2017) e outros (NEWELL, GEELS, SOVACOOOL, 2022) apresentaram casos empíricos de mudanças, tanto a longo prazo como a curto prazo, na configuração da oferta de recursos energéticos utilizados pelas sociedades, observando transições paulatinas (como a transição da biomassa para os fósseis) ou abruptas (o descomissionamento de carvão em Montreal, Canadá, e o caso da expansão do etanol, no Brasil) na composição das fontes de energia.

Entretanto, os autores não sintetizam as transições rápidas e lentas em uma

estrutura conceitual, apresentando os casos separadamente e focando em categorizar e descrever as variações absolutas e relativas de cada fonte ao longo do tempo. Sovacool (2017) ainda procura propor perfis de transições energéticas, aprofundando as questões de governança e justiça energética, mas apresenta uma abordagem de estudos de casos contextualizados em um momento do tempo.

A presente tese entende que transições energéticas, sejam elas paulatinas ou abruptas, ocorrem acompanhadas de mudanças institucionais. Instituições são aqui entendidas como as regras formais e informais que influenciam diretamente as ações dos agentes, seguindo as definições de Douglass North (1990). São as regras do jogo a priori, somadas às relações que emergem com o jogo sendo jogado. Ostrom (2008) ainda caracteriza como instituições cada tipo de regra empregada em cada nível hierárquico². A autora se refere a este conjunto de regras como regras em uso.

Para North (1990), as instituições, além de passarem por mudanças incrementais, resultantes da interação entre as regras vigentes e aquelas emergentes das relações entre os agentes do setor (*players*), também podem mudar abruptamente. O autor atribuiu as mudanças disruptivas a causas exógenas à sua análise e explica que as instituições não seriam necessariamente balizas que maximizam o resultado econômico das transações, mas sim elementos constituintes dos setores econômicos, sensíveis a elementos históricos e culturais, e recorrentemente estabilizados em equilíbrios econômicos subótimos.

As instituições vigentes e utilizadas como balizas para a interação social, em um dado momento, refletem o resultado de confrontos (históricos) entre grupos que disputam o controle dos recursos que lhes interessam. Esta disputa é travada, para além das instituições vigentes, também de acordo com parâmetros delimitados pelo ambiente biofísico e social.

É possível entender o aspecto biofísico aplicado para a geração elétrica, de uma perspectiva Ricardiana bastante ortodoxa, entendendo que a abundância de quedas d'água naturais em um território explicaria uma dominância de geração hidrelétrica, refletindo assim sua vantagem comparativa e passando a ser a opção preferencial de escolha no estabelecimento e expansão da oferta elétrica.

² Os níveis hierárquicos estão detalhados nos manuscritos que compõem esta tese, mas tratam fundamentalmente dos níveis: a) operacional (mercados); b) das ações coletivas (ambientes regulatórios); c) constitucional (ambiente de regramentos formais, leis); e d) meta constitucional (regras formais e informais que constroem o nível constitucional, e.g. COP, Parlamento Europeu, Acordos Internacionais etc.).

O mesmo pode acontecer se a expansão de um parque geracional elétrico ocorrer em um território que conte com uma rede de gasodutos já instalada, o que aumentaria a propensão de os incrementos ocorrerem via usinas de geração térmica a gás. Nesses dois casos, a disponibilidade de recursos naturais e a infraestrutura implementada incentivam a reprodução das instituições que balizam a expansão do setor elétrico, bem como as escolhas por fontes de geração.

Analogamente, diferentes tipos de capitais sociais (relações, cultura historicamente construída, humano) também são capazes de fomentar um conjunto institucional em detrimento de outro. Tais elementos sociais tendem a limitar as opções colocadas aos agentes e às coalizões que disputam o domínio sobre as instituições de um determinado setor econômico (ou campo social). Os agentes e coalizões dominantes de um campo tendem a produzir e reproduzir aquelas que fortalecem sua posição de domínio ao longo do tempo.

As instituições, quando formais e representadas por códigos, leis, portarias ou outras instâncias de restrição coercitiva, apresentam prescrições do que os agentes devem (ou podem) ou não fazer (NORTH, 2008; OSTROM, 2008), representando os limites formais de suas ações estratégicas (OSTROM, 2008).

A efetividade das instituições formais e sua reprodução ao longo do tempo dependem das regras informais que, por sua vez, derivam das interações históricas consolidadas entre indivíduos e grupos que interagem e se influenciam mutuamente no setor econômico. Essa diferença entre as preferências formais e informais afeta o custo e eficiência dos mecanismos de controle (coerção e incentivo).

As regras informais, como os costumes, as condutas, os códigos morais e a linguagem, dentre outros tipos e manifestações de instituições tácitas, também são fundamentais para que os indivíduos possam balizar suas interações, manifestar seus interesses e antever ações estratégicas. Tais regras informais contribuem no processo de legitimação dos capitais acumulados por agentes (na forma de dotações), conduzindo senso de normalidade para as decisões e transações em um setor econômico³.

North entendeu que parte deste aspecto informal das instituições é fruto de

³ Em seu limite, as regras informais definem as metaregras do jogo, ou seja, o que é plausível ou não, em um dado momento, de ser considerado como uma regra formal. Para mais detalhes, consultar a noção de “regras cognitivas”, trazida por Grief e Mokyr (2017), ao apresentar uma crítica ao individualismo do Sistema de Crenças proposto por North (1990). É salutar lembrar que Douglass North, em 2017, já havia falecido e não pôde oferecer uma resposta à crítica de Greif e Mokyr.

sistemas de crenças e ideologias (DENZAU e NORTH, 1994; NORTH, 2008), enquanto que, em uma crítica ao individualizado sistema de crenças de Denzau e North, Greif e Mokyr (2017) propuseram um conceito mais amplo, denominado regras cognitivas, que poderia ser interpretado como uma espécie de “meta-amparo” informal para as regras formais, entregando uma razão compartilhada socialmente para o simples seguir mecânico das regras.

De todo modo, as regras formais e informais interagem, legitimando o acúmulo de capitais sociais (COLEMAN, 1988), simbólicos e econômicos. Redes de influência dos agentes, controle dos elementos discursivos e liquidez para fazer investimentos e controlar os capitais financeiros delimitam um conjunto de variáveis sociais moduladas por vetores relacionais e historicamente construídos que influenciam retroativamente as regras formais e informais.

Nesta pesquisa este conjunto de variáveis é apresentado através do detalhamento dos atributos de comunidade, parâmetro adotado na proposição original de análise institucional de Elinor Ostrom (2008).

Identificar os elementos conceituais que influenciam as escolhas pelas regras formais e informais relevantes e como elas se desdobram, tanto ao longo do tempo, quanto pelos níveis hierárquicos das disputas, levados em conta os parâmetros biofísicos e os atributos de comunidade, contribuiu neste estudo para aumentar a especificidade dos casos onde as instituições influenciaram nas escolhas por fontes de geração em indústrias elétricas, além de oferecer uma abordagem oportuna para compreender alguns cenários em que ocorreram avanços ou retrocessos nas transições energéticas.

A presente tese também vislumbra propor estruturas conceituais (doravante referidas neste estudo como *frameworks*) que colaborem com o planejamento energético e que permitam ilustrar casos mais ou menos propícios, bem como instituições mais ou menos oportunas para eles, para a consolidação de fontes de geração alternativas (preferencialmente de fontes primárias de fluxo).

O ambiente institucional do setor elétrico brasileiro, caracterizado pela centralização do seu planejamento no Governo Federal, justifica a abrangência nacional do estudo, uma vez que o mesmo processo acontece na Nigéria. Esse recorte geográfico entende que a estrutura institucional permeia os níveis hierárquicos políticos federalizados (principalmente através de ministérios e agências de regulação) e delimita assim a governança e a ação estratégica dos agentes nos

demais níveis, como na consolidação e operacionalização da expansão de fontes alternativas.

Entretanto, o fato de ambos os países terem adicionado fontes térmicas, principalmente provenientes de gás natural, intensificando as participações fósseis em ofertas majoritariamente renováveis (hidroelétrica) após os anos 1990 e 2000, foi capaz de ilustrar dois casos de indústrias elétricas impactadas pela agenda liberal, guiada pelo modelo britânico de privatizações e desverticalizações (PINTO JUNIOR et al., 2007; VICTOR e HELLER, 2007). A Nigéria foi ainda mais influenciada por grupos e interesses voltados aos combustíveis fósseis, de nível metaconstitucional, explicada por sua participação como membro da Organização dos Países Exportadores de Petróleo (OPEP).

A presente tese foi desenvolvida na forma de compilado de artigos e apresentou três diferentes *frameworks* para aprofundar a compreensão de transições energéticas em casos das indústrias elétricas nacionais de Brasil e Nigéria. A motivação de realização da pesquisa foi aprofundar a compreensão de transições energéticas em indústrias elétricas (sejam elas de fósseis para fluxo, ou como nos casos aqui expostos, de fluxo para fóssil), entendendo que as dinâmicas institucionais possuem um papel importante na explicação e elucidação da reprodução e mudança das fontes e dos modos de governança de indústrias elétricas.

Os próximos capítulos (2, 3 e 4) apresentam as metodologias e resultados em forma de manuscritos, contendo estudos de casos dispostos em narrativas históricas analisadas por diferentes *frameworks*. Tais *frameworks* convergem no sentido de apresentar uma articulação de conceitos institucionalistas capazes de elucidar variáveis sociais, econômicas e biofísicas presentes em processos de mudança institucional. Os capítulos 2 e 3 tratam da indústria elétrica brasileira, enquanto o capítulo 4 apresenta o caso da indústria elétrica nigeriana.

O capítulo 2 é composto por um *framework* que utiliza as noções de crise e habilidade social para explicar a mudança institucional e foi inspirado em bases conceituais da Nova Sociologia Econômica, mais precisamente na produção de Fligstein e McAdam (2012). A reprodução institucional, por sua vez, é explicada por *path dependence* e isomorfismos, seguindo conceitos da Nova Economia Institucional de North (1990) e do Novo Institucionalismo Organizacional, de DiMaggio e Powell (1983). As principais mudanças de governança e fontes de geração na indústria elétrica brasileira foram analisadas através da identificação das mais relevantes crises

internas e externas e da ação estratégica de agentes em posições dotadas de prerrogativas decisórias, presentes em momentos antecipatórios às mudanças institucionais.

Já os capítulos 2 e 3 detalham os elementos que circundaram as crises nas indústrias elétricas de Brasil e Nigéria, respectivamente, com inspiração no *Institutional Analysis and Development* (IAD), de Elinor Ostrom (2005), decompõem as condições biofísicas e os atributos de comunidade em variáveis ambientais, sociais e econômicas, bem como procura identificá-las durante as trajetórias históricas.

Já a reprodução foi reduzida apenas a *path dependence*, noção atribuída à Douglass North (1990), sem assim perder poder explicativo. Com isso, foi possível reconhecer os elementos presentes nos instantes anteriores, ilustrando-os através de casos brasileiros e nigerianos de transições energéticas. O Quadro 1 apresenta as principais diferenças e similaridades dos três *frameworks* apresentados em cada um dos capítulos desta tese.

Quadro 1 – Resumo das principais similaridades e diferenças entre os *frameworks* apresentados nos capítulos 2, 3 e 4 desta tese

-	Capítulo 2	Capítulo 3	Capítulo 4
Descrição no Capítulo	<i>Integrative Analytical Framework for Institutional Dynamics</i>	<i>Framework</i> de Análise Institucional adaptado a partir do IAD	<i>Multidimensional Institutional Dynamics Analysis</i> (MIDA)
Principal Explicação para a Mudança	Crises internas e externas e ações estratégicas de agentes hábeis	Crises resultantes de mudança nas dotações ambientais, sociais e econômicas	
Principal Explicação para a Reprodução	Isomorfismos e <i>Path Dependence</i> (Dependência de Trajetória)	<i>Path Dependence</i> (Dependência de Trajetória)	
Origens Conceituais	Nova Sociologia Econômica, Nova Economia Institucional, Novo Institucionalismo Organizacional	Nova Economia Institucional	
Autores Inspiradores	Fligstein e McAdam (2012), North (1990), Dimaggio e Powell (1983)	Ostrom (2005), North (1990)	
Aplicação	Caso da indústria elétrica brasileira		Caso da indústria elétrica nigeriana

Entendimento das disputas	Agentes com prerrogativas, diante de crises, têm mais chances de fazer prevalecer seus interesses	Agentes acumulam dotações ambientais, sociais e econômicas que aumentam as chances de influência nas disputas
Grau de liberdade dos agentes	Foco na habilidade social para explicar os resultados institucionais de cada caso	Foco nos interesses, coalizões e estratégias dos agentes dotados de capital ambiental, social e econômico

Fonte: Elaborado pelo autor (2022).

Durante a elaboração do capítulo 2, atentou-se aos grupos e indivíduos com capacidades interpessoais de convergir interesses distintos diante de momentos de instabilidade institucional (referidos como crise), os quais são identificados por Fligstein e McAdam (2012) como agentes hábeis. Estes, diante de crises internas ou externas, demonstraram capacidade, na história da indústria elétrica brasileira, de propor novas instituições que impactaram as tecnologias e preferências de governança no país.

Já a emergência institucional no capítulo 2 é explicada através do sistema de crenças (os amparos metafísicos que o indivíduo utiliza para autojustificar o seguir mecânico das regras) e que, em um primeiro momento, costuma derivar de outros campos ou setores já institucionalizados. A reprodução institucional para este primeiro estudo identificou mecanismos isomórficos, como dito por DiMaggio e Powell (1983), entre as razões para a continuidade dos modelos de governança e fontes de geração ao longo do tempo: homogeneização das preferências entre entidades de classe, incluindo indicações por capital humano que executam ações e estratégias parecidas, pois são provenientes de organizações de ensino que disseminam ferramentas similares, barreiras de entradas e regras formais proibitivas para novos agentes e desafiantes e efeitos de mimetismo, em que, diante de incertezas, agentes tendem a copiar ações identificadas como sucessos.

As noções de *path dependence* de North (1990) colaboram tanto para entender a consolidação de instituições em um processo inicial de institucionalização de um setor ou indústria, como para entender a reprodução institucional, pois entende que as escolhas acordadas em determinado momento do tempo, sejam elas as mais eficientes ou não, tendem a perdurar e a influenciar as escolhas institucionais futuras.

É interessante salientar que, mesmo diante de lentes teóricas com evidentes conflitos ontológicos e epistemológicos, fora possível, no artigo apresentado no

capítulo 2, construir uma narrativa histórica para a indústria elétrica brasileira que identificasse os conceitos das diferentes escolas institucionalistas, articulando-os de modo a explicar os principais mecanismos de emergência, reprodução e mudança das instituições para o caso.

Já para os capítulos 3 e 4, houve um foco maior na decomposição das crises internas e externas, procurando por suas causas nas relações históricas entre os elementos biofísicos, sociais e econômicos. As disputas por poder (controle institucional), embora mantidas como elemento contingencial das resultantes institucionais, são agora explicadas não por habilidade social diante de crise, mas pela distribuição de dotações ambientais, sociais e econômicas, entre os grupos de interesses. A crise refere-se, nos capítulos 3 e 4, a uma alteração em uma ou mais dotações que podem resultar em reconfigurações das disputas nas arenas de ação e, conseqüentemente, podem abrir espaço para a emergência de interesses heterodoxos e para mudança das instituições.

Partindo desses fundamentos, foi possível focar em uma única escola como lente teórica: a Nova Economia Institucional, preservando as noções de *path dependence* de North (1990), como no capítulo 2, para explicar a reprodução, principalmente através dos mecanismos de *lock-in* (agora reduzidos apenas a *path dependence*, ao invés de detalhados em diferentes tipos de isomorfismos), mas se apoiando em Ostrom (1990, 2005, 2008) para desenvolver as explicações de mudança institucional. Essa adaptação resulta em um *framework* multinível, multitemporal e capaz de endogenizar a história para explicar as dinâmicas institucionais (com maior foco na reprodução e mudança).

Maiores detalhamentos sobre cada um dos *frameworks* dispostos dentro do Quadro 1 são encontrados em seus referidos capítulos 2, 3 e 4. A conclusão compõe o capítulo 5 desta tese, reunindo, organizando e analisando aspectos centrais dos resultados obtidos em cada um dos manuscritos apresentados, além das proposições de estudos futuros e dos limites teórico-metodológicos dos *frameworks* apresentados, seguida de uma seção contendo as referências deste capítulo introdutório.

2 INSTITUTIONAL REPRODUCTION AND CHANGE: AN ANALYTICAL FRAMEWORK FOR BRAZILIAN ELECTRICITY GENERATION CHOICES

PAVANELLI, J. M. M.; IGARI, A. T. Institutional Reproduction and Change: An Analytical Framework for Brazilian Electricity Generation Choices. **International Journal of Energy Economics and Policy**, v. 9, n. 5, p. 252–263, 2019.

ABSTRACT

Energy transitions will be shaped, among other aspects, by their Institutional historical trajectory. Institutions reproduce and change over time, and these processes have been investigated under different and sometimes confronting approaches. We proposed a framework which articulates different institutionalism approaches to understand the dominance of hydroelectricity in the Brazilian matrix. The framework articulates institutional processes to explain its reproduction and change over time. Findings point out that institutional path dependence and isomorphism have precluded the adoption of other technologies in Brazil. Contrarily, momentary external or internal crisis in the field rapidly fostered the emergence of electricity generation transition from almost fully hydroelectric to a hybrid matrix with thermal (fossil and biomass) and wind power. Crises presented an opportunity for strategic action of social skilled agents on institutional change. This analytical framework improves the integration of complementary theoretical approaches for understanding institutional dynamics in order to guide policymakers.

Keywords: Energy Transitions; Institutional Analysis; Brazilian Electricity Sector.

Declaration of Interest: None.

2.1 INTRODUCTION

Social-technical transitions have been explored under hybrid theories (SOLOMON and KRISHNA, 2011; ARAÚJO, 2014; KUCHARSKI and UNESAKI, 2018; GERMÁN et al., 2016). Neo-institutionalism has articulated politics, economics and sociology to unveil the complexity of social-technical transitions (Kucharski e Unesaki, 2018). In the electricity sector, social-technical transitions usually drive the replacement of fossil fuels by renewable sources. The Brazilian case is particular because it shows an empirical and relatively recent case where the electrical transition went backward: from hydroelectricity to thermoelectric fossil sources.

Brazil always relied on hydroelectric as the main source of electricity generation. Nevertheless, after an offer crisis between 2000 and 2002, the national matrix shifted towards a hybrid source configuration, incorporating fossil thermoelectric, which delivered stability and reliability to national matrix regarding eventual water shortage in rainy seasons.

To unveil and clarify energy transitions in Brazil we undertook an investigation under hybrid institutional theories, in order to understand the emergence, reproduction, and change of the generation choices throughout almost 140 years of electricity history in Brazil. For doing so we articulated three main branches of institutional theories: New Institutional Economics and New Organizational Institutionalism to explain institutional emergence and reproduction, and New Economic Sociology to tackle institutional change.

The resulting integrative analytical framework addresses key elements in the process of institutional evolution, and it is confronted with empirical evidence from the history of the Brazilian electricity sector. The electricity sector in Brazil, as seen, is a particular clean energy case given its historical reliance on hydroelectricity, which represents more than 65% of the Brazilian electricity matrix (BEN, 2014). This preference towards hydroelectricity, although obviously explained by the abundance of hydric resources, did not occur in other countries which present as much hydraulic potential as Brazil (IEA, 2014).

This paper aims to contribute to the research on institutional dynamics, particularly regarding their effects on Brazilian technological choices for electricity generation. The proposed analytical framework unveils the synergic contribution of path dependence and isomorphism on explaining institutions emergence and reproduction, as well as the effects of crises and the role of social skilled agents particularly to explain institutional change.

The next two sections are respectively dedicated to present the theoretical elements incorporated into the integrative analytical framework and to the methods. The latter sections present as results in the own analytical framework and the narrative of the historical institutional evolution of the Brazilian electricity sector, and lastly are presented discussion and conclusion.

2.2 THEORY

The present theoretical synthesis aims to introduce the main concepts from different or even concurrent research fields. Given the epistemological and ontological diversity of theoretical contributions, the reader might incur in some misinterpretations of concepts and assumptions which support the analysis. Furthermore, there is considerable variation on scope and scale in which the research branches undertake

institutional analyses. Therefore, it is appropriate to clarify in the next sections some key concepts extensively used in the present piece of work.

2.2.1 Baseline concepts: field, agents and institutions

The concept of field was introduced by Pierre Bourdieu (1980), and constitutes a broader perspective for understanding the symbolic conflicts among individuals and even organizations. The core idea is that field is the locus where agents struggle for symbolic gains. Elinor Ostrom (1990b; 2008) adopted an analog perspective in her investigation on common goods governance. She called arena the field where agents legitimate competing positions while struggling for power domination. Therefore, arena constitutes a field where incumbents and challengers recognize each other positions and stir their dispute.

Bacchiogga and Da Costa Ferreira (2014) stress the difference between the concept of field introduced by Bourdieu (1980) and the concept of arena proposed by Ostrom (2008), by indicating that in the field, differently from the arena, agents may not always be aware of the existence of any symbolic struggle. The present work understands the arena as a status of the field where agents recognize and stir their different and frequently confronting positions.

The organizational studies of DiMaggio and Powell (1983) presented the concept as “organizational field”, an instance which encompasses the set of relations among organizations. Neil Fligstein (2001) recognizes the challenge of limiting a field in empirical studies, but he considers a reasonable approach to circumscribe economic sectors, as the electricity sector, as fields.

The definition of agents is very similar among North (1990; 2008), DiMaggio and Powell (1983), Neil Fligstein (2001) and Elinor Ostrom (1990b; 2008). They converge in the sense that agents can be viewed as players, representing individuals as well as public, private, and non-governmental organizations. In this article, agents are presented as individuals, the government, regulatory agencies, investment banks and other public, private and non-governmental organizations.

Institutions are the collectively conceived norms⁴ and formal rules responsible for stabilizing the relationships among the agents in a given social field. They guide

⁴ Norms are viewed as “shared prescriptions known and accepted by most of the participants (agents) themselves, involving intrinsic cost and benefits” (OSTROM, 2008).

agents in their strategic social action. The emergence, reproduction, and change of the institutions are an outcome of power disputes among agents pursuing their own interests (FLIGSTEIN, 2001). When, why, how and by whom institutions rise, reproduce and change are then an important part of the puzzle for understanding their role in social life. The three theoretical approaches addressed in this article present complementary, and sometimes concurrent visions of these phenomena.

2.2.2 Institutional theories and core analytical concepts

New Economic Sociology (NES), when it first appeared in the middle 1980s, had plentiful interactions with New Institutional Economics (NIE), especially regarding the ideas of Douglass North and Elinor Ostrom. But some years later the interactions became less frequent and fruitful (NEE and SWEDBERG, 2008; NEE, 2005, 2018). This article intends to integrate different theoretical fields, (New Organizational Institutionalism - NOI⁵, NES, and NIE) for explaining the institutional processes (formation, reproduction, and change) which constrained technological choices in the history of the Brazilian electricity sector. We propose that these three theoretical approaches complement each other⁶ on understanding the complex process in which institutions evolve in social fields. This article presents a framework which integrates a) North's concepts of path dependence⁷ (1990; 2008) and belief systems (DENZAU and NORTH, 1994) in institutional formation and stabilization⁸, b) the effects of isomorphism on institutional reproduction, addressed by DiMaggio and Powell (1983),

⁵ Although authors have classified both DiMaggio and Powell (1983) and Fligstein (2001) in NES studies, Victor Nee and Richard Swedberg (2008) attributed the term "organizational new institutionalism" to refer the studies from of DiMaggio. Therefore, the present study chose to position NOI as indicated by Nee and Swedberg (2008) in order to present a clear distinction between a theory which explains institutional reproduction (NOI) from other selected to address institutional change (NES).

⁶ In this case, we depart from the arguments of Ostrom (2008) in which she states that the concept of "field" is very synergic among Bourdieu (1997), Fligstein (2001) and DiMaggio and Powell (1983).

⁷ The first agent to establish the forms of uses and functions of the resource will have the power to guide and influence the subsequent activities. The choice for the initial set of institutions (the early choices for dealing with the resource), as seen, is not necessarily the best or most efficient solution, but it is simply the mostly accepted one (NORTH, 1990).

⁸ It is important to note the difference between institutional stabilization and institutional reproduction. Institutional stabilization is associated to path dependence and the inertia of belief systems, and it is broadly used under North's approach, while institutional reproduction is associated to institutional homogenization processes, or isomorphism, according DiMaggio and Powell (1983). In this article both (stabilization and reproduction) are assumed as institutional reproduction, and the reason is that both are associated to the process of perpetuating institutions along time.

and c) the studies on institutional change, derived mainly from Fligstein (2001) and Fligstein and McAdam (2012).

2.2.3 New Institutional Economics (NIE): Belief systems and Path dependence

New Institutional Economics explains the role of institutions from the perspective of the transaction's costs in non-perfect market⁹. Contrary to neoclassical assumptions, markets under NIE perspective lack relevant information in their transactions and there is remarkable asymmetry on power and information endowments among agents. Improvements in information availability among economic agents would burden markets with transactions costs regarding information prospection, assurance, monitoring, and analysis. Institutions play a key role on dealing with information availability and the respective transaction costs, so, the conception, reproduction, and change of institutions would be constrained by their ability to deliver information and reduce transaction costs. This perspective, stressed by Williamson (1985), assumes that economic agents are capable of precisely evaluating the economic outcomes of each institutional environment and then selecting the most effective arrangements.

North (1990) expanded this theoretical scope and added psychological and social variables to the instrumental rationality of institutional emergence and selection. Davis and North (1971) and North (2008) theoretical perspective on institutional historical dynamics does not allow to conclude that NIE instrumental rationality necessarily conduces to independent and optimal decisions, since it would be sensible to socially constructed belief systems and to the prior trajectory of choices. Belief systems and historical path dependence on choices would, according to North, constitute key elements to institution formation and reproduction. Belief systems are shared pre-analytical views rooted in accumulated empirical experience and cultural heritage that generate most of the agents' modus operandi (1990; 2008). This symbolic framework shapes and selects the rules and norms responsible for stabilizing the relationship among social agents. The institutional change would then be coherent to changes in belief systems, mostly incremental and bounded to prior choices. Then, the concept of path dependence, predicts that an initial institution, once established in a field, would bound future institutional changes in historically conceived lock-ins. Belief systems and path dependence explanations regarding arise and the reproduction of

⁹ See Ronald Coase (1937) and Oliver Williamson (1985, 2007).

institutions are consistent to individuals as well as to organizations dynamics (GREENWOOD et al., 2008).

2.2.4 New Organizational Institutionalism (NOI): Isomorphism

In meso-level analysis, New Organizational Institutionalism (NOI) assumes organizations as the main agents which struggle for their self-interests in social fields. Specifically, DiMaggio and Powell (1983) stressed the phenomena of homogenization of the structure, processes, and institutions concerning strategic actions of organizations in competitive fields. The isomorphism on organizations and institutions would arise from mimetic, coercive or normative driven forces. When the competitive field is under non-diversifiable risks or uncertainties, players are constrained to mimic strategies that are considered the most successful ones. Dominant organizations are frequently imitated by others. Coercive isomorphism occurs when there is a marked power unbalance in the field, as the power of the state or the dominance of oligopolistic agents, which conceive and enforce the rules. In oligopolistic contexts, new players usually conform to present rules and there is little room for change. Finally, according to the normative perspective, shared academic background, as well as professional corporate relationships, induce the emergence of similar institutions in independent organizations or fields¹⁰.

NIE and NOI approaches complement each other on the explanation of origin and reproduction of institutions. Regarding institutional change, North (2008) attributes it mostly to external crisis phenomena, however, he also acknowledges that long-term change reflects the cumulative effect of internal short-term decisions by political and economic entrepreneurs (NORTH, 1990). DiMaggio and Powell (1983) focused on institutional homogenization process and did not noticeably contribute to clarify institutional change.

2.2.5 New Economic Sociology (NES): Social skilled agents and Crisis

The investigation on social induced institutional dynamics is a core interest of New Economic Sociology (NES). This perspective assumes that emergence,

¹⁰ This normative induced isomorphism could be interpreted as a short-term contribution to social belief systems, despite normative isomorphism and belief systems are theoretical constructs from clearly distinct research branches.

reproduction, and change of institutions have roots far beyond the comparative economic results of each possible institutional scenario. Institutions are understood as social-driven and field-endogenous outcomes, which emerge from the recursive relationship between the institutional set in force and the power balance among agents. Coalitions of social agents struggle for their interests, and the incumbents consolidate institutions which stabilize the relationships in the field. This set of institutions in force is favorable to the interests of incumbent coalitions and does not necessarily represent the optimal institutional arrangement to economic prosperity. Also, stabilization of relationships does not mean that all interests were met, but it just reflects the past and present power balance in the competitive field (FLIGSTEIN, 2001; FLIGSTEIN and MCADAM, 2012).

As well as North, Fligstein and McAdam (2012) claim that prevailing institutions are outcomes of historical and present power disputes in the field. But the NES authors add that short-term disturbs caused by skilled agents or external induced crises can disrupt the power balance in the field and foster the emergence of a suitable context for institutional change.

Social skilled agents are those capable of inducing cooperation among other agents in the field. In the words of Fligstein and McAdam (2012), "Social skill is the ability to empathetically understand situations and what others need and want, and to figure out how to use this information to get what you want". Social skilled agents can be positioned in incumbent coalitions and, in this scenario, they struggle to stabilize and reproduce institutions which reinforce their dominant position. On the other hand, these same social abilities can serve challenger coalitions and make emerge favorable conditions to disrupt the power balance and promote institutional change. As incumbents or challengers, social skilled agents tend to amplify their influence on institutional design when internal or external crises emerge in the field. Then, social skilled agents have cognitive, relational and political abilities to establish new coalitions and to conceive innovative institutions which meet emerging interests in the field. However, the institutions in force represent positive feedback to the present power structure in the competitive field, which contributes to persistent power and institutional stability.

The key role of social skilled agents is shaping power balance inside fields, however, most events which change the competing context are exogenous (FLIGSTEIN and McADAM, 2012). The destabilizing effect of external crises makes

institutions lose their role of assuring predictability to strategic action of the agents. In a crisis scenario, incumbent agents attempt to safeguard their status quo and allow incremental changes on current institutions, keeping them suitable to their strategic objectives. On the other hand, challengers rearrange coalitions and try to achieve more favorable competing for positions, striving for a new set of institutions, aimed to stabilize the field in this alternative state.

Institutional crises make agents more reluctant to perform economic transactions and are characterized as moments of low flow of assets and information because agents are no longer able to understand or comply with current institutions, and their actions cannot be well predicted by others.

External-induced institutional crises also emerge in moments of political rearrangement, which involve some relevant ideological change. These moments of change foster institutional reform and agents are not up to transact while the comprehension of the new institutional order is not clear.

Integrating different institutional theories is a challenging task. We are aware of the methodological, epistemological and even ontological contradictions among the theoretical perspectives which supported the analytical framework proposed in this article. However, each institutional theory contributed to explaining a particular aspect of the complex process of institutional emergence, reproduction, and change, to the point that complementarities or even synergies incorporated to the framework overcame the latent conflicts among the original institutional theories. This integrative concern is a permanent dilemma for understanding complex phenomena in interdisciplinary research.

2.3 METHODS

The investigation was conducted under a qualitative approach of nested triangulation (DENZIN, 1978; KRAUSE and DENZIN, 1989). Triangulation approach aims to identify convergences and divergences among different sources of information, which are gathered through varied methodological strategies (DENZIN, 1978; KRAUSE and DENZIN, 1989; FLICK, VON KARDORFF and STEINKE, 2004).

The upper-level triangulation (outer dotted line in Figure 1) consolidates the outcomes from the literature review (top circle in Figure 1), empirical evidence from document review (right circle in Figure 1) and from in-depth interviews with specialists

(left circle in Figure 1).

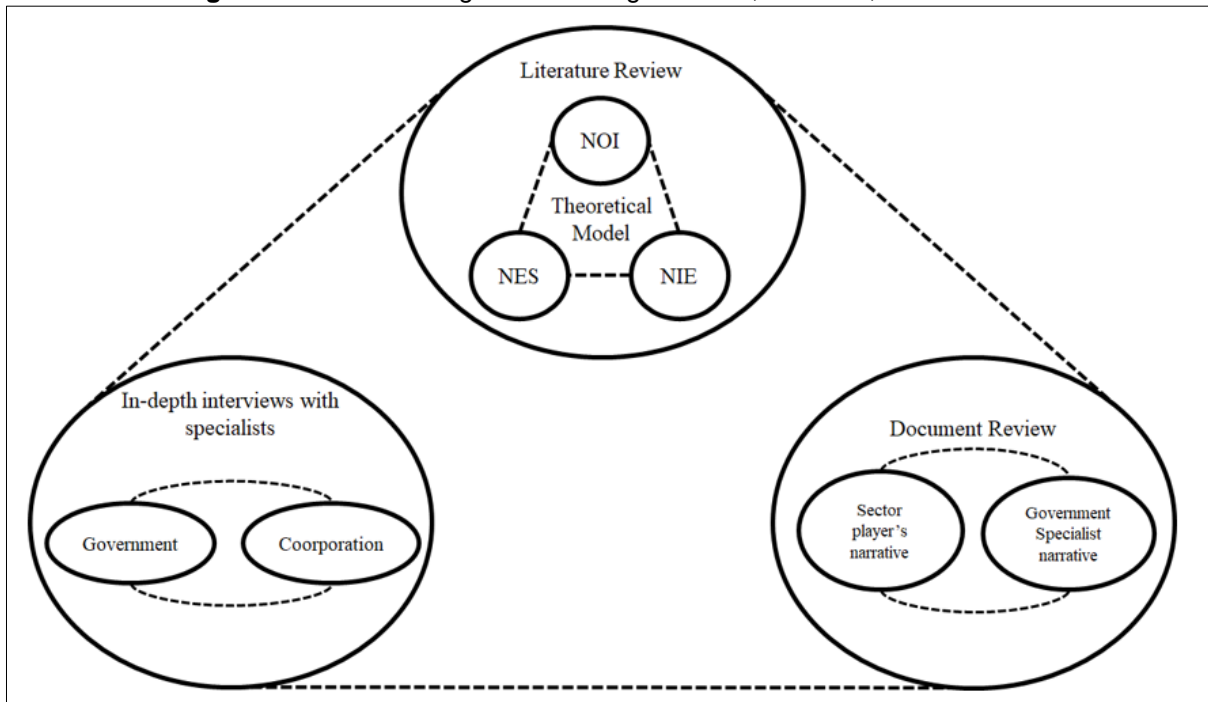
The nested lower level triangulation is represented inside each circle. Literature review on NIE, NOI, and NES (top circle in Figure 1) identified theoretical complementarities among these concurrent approaches of institutional research, as argued in the theory section. This triangulation of theoretical approaches supported the proposition of the Integrative Analytical Framework (Figure 2). The Analytical Framework was then confronted with empirical evidence.

The document review (right circle in Figure 1) consolidated a historical narrative of the Brazilian electricity sector trajectory, regarding the evolution of the institutions, the concentration of political and economic power and the technological changes of the Brazilian electricity matrix. The main documented narratives were achieved from two complementary sources: (i) an organization called “Memória da Eletricidade” (Memory of Electricity), supported by major national players (Eletrobras, Light, CEMIG, Itaipu Binacional), which preserves the history of the electricity sector (MEMÓRIA DA ELETRICIDADE, 2015)¹¹; (ii) two editions of the book “A Energia do Brasil”¹² authored by the former-Minister of Mines and Energy Antonio Dias Leite (1997, 2014); (iii) The book “reconstructing the Brazilian electric sector” from researcher and former Petrobras Director Ildo Sauer (SAUER et al., 2003) and his respective paper (SAUER, 2015). The triangulation of sources (DENZIN, 1978), from private funded documents and government specialists books, contributed to retrieve a more complete, consistent, and detailed historical narrative.

¹¹ For more information see: <http://portal.memoriadaeletricidade.com.br>. Further the historical compilation, the site presents a vast collection of pictures and documents (in Portuguese only).

¹² The energy of Brazil (translated by the authors of this paper). The minister remained in charge between 1969 and 1974, during the military regime.

Figure 1 – Nested triangulation among Theories, Methods, and Sources



Source: Authors supported by Creswell (2003), Denzin (1978), Krause and Denzin (1989) and Flick, von Kardoff & Steinke (2004).

In-depth interviews with specialists (left circle in Figure 1) were the last methodological approach inside the upper-level triangulation (outer dotted line in Figure 1). The nested triangulation among information sources was conducted between two different perspectives: government (hereafter specialists Gov1 and Gov2) and private sector corporations (hereafter specialists Corp1 and Corp2). From the government perspective we interviewed one senior acknowledged specialist with attested government background, a former secretary of environment (Gov1), and also one specialist (Gov2) from the most relevant Brazilian governmental research organization on energy, EPE – Empresa de Pesquisa Energética (Energy Research Company), which supports the planning and organization of the energy public offers and auctions. From the private sector corporations, we have interviewed one entrepreneur specialist from the photovoltaics distributed market (Corp1), and another specialist from a major multinational of energy distribution in São Paulo.

The nested triangulation process identifies the convergences and divergences among the integrative analytical framework and empirical evidence from diverse information sources, which present a plural set of perspectives regarding the historical phenomena and are gathered through complementary qualitative research methods.

2.4 RESULTS

2.4.1 Integrative Analytical Framework for institutional reproduction and change in the Brazilian electricity sector

An initial competitive condition stresses an interest under dispute among social agents, in this particular case, the technological choices for energy generation in Brazil. The dispute establishes the borders for institutional dynamics of a given social field. Agents recognize common and concurrent perspectives and form coalitions around their strategic objectives. The perspectives, objectives, and choices are influenced by present interests, as well as by historically shaped belief systems (“Douglass North” box in Figure 2).

The historical trajectory of choices in a social field reinforces dominant belief systems, which, in turn, foster the reproduction of choices according to a path dependent rationality (“Douglass North” box in Figure 2). Therefore, formal and informal institutions rise and are reproduced through a historical cognitive lock-in (“Technological Reproduction” in Figure 2).

Institutional reproduction and even homogenization is reinforced by mimetic, coercive or normative isomorphism drivers (“DiMaggio & Powell” box in Figure 2). Normative isomorphism points out professionalization as a substantial driver for homogenization of decisions among organizational agents. Shared formal education and professional allegiance legitimate belief systems, which, as argued by North (2008), modulate institutional dynamics.

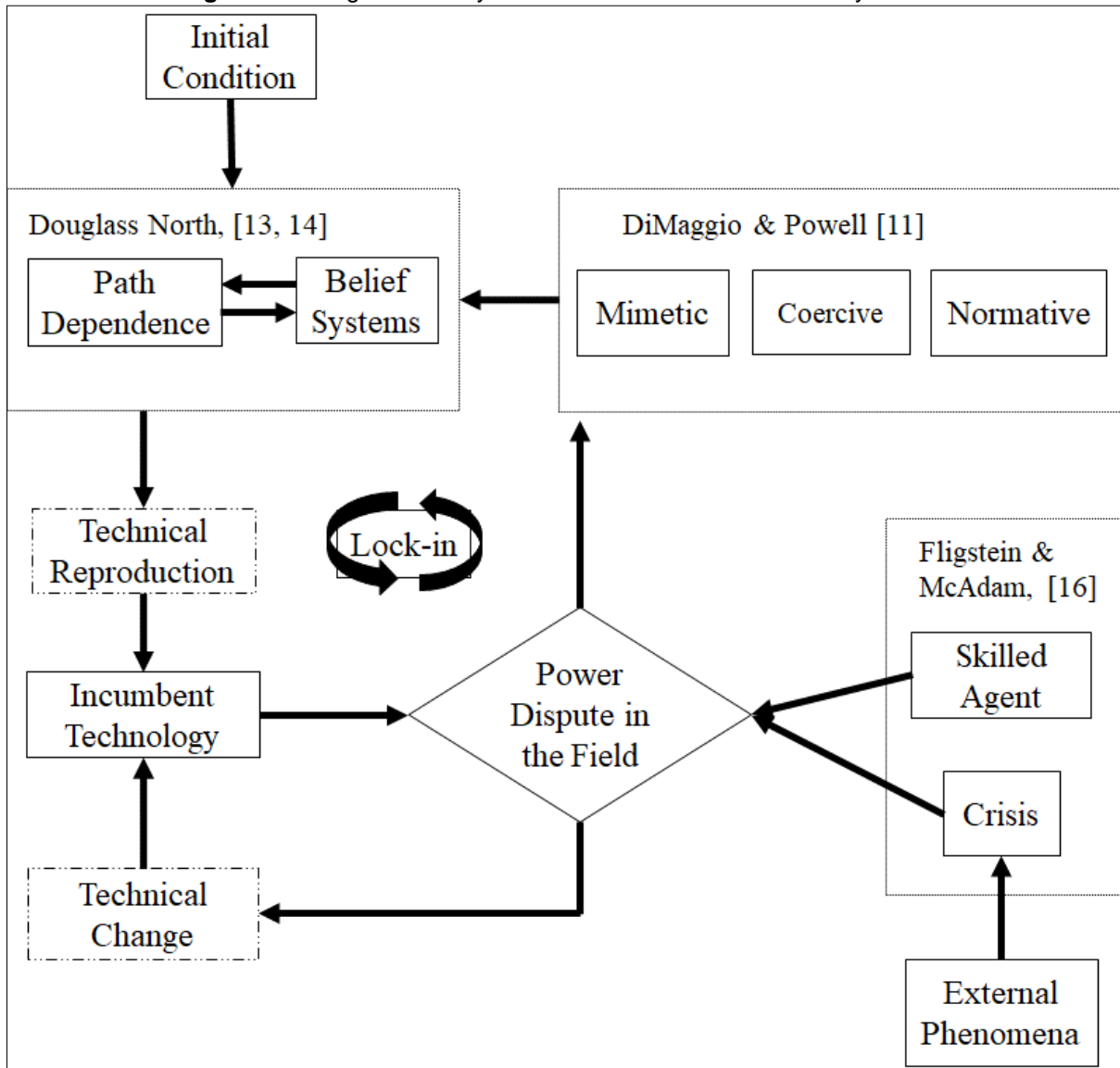
Mimetic isomorphism is the most obvious driver for institutional reproduction. In initial stages of technological development, when uncertainties are dominant, and in markets where firms share the same suppliers or clients, as the electricity sector, organizations tend to take similar decisions, which reinforce path dependence on institutional reproduction. Uncertainties and shared resources foster weaker competitors to mimitize incumbent decisions.

Government and sector agencies have regulatory power over other economic agents and constrain strategic actions through formal institutional enactment. The stricter the coercive institutions, the more isomorphic is the organizational behavior in the field. The level of power asymmetry among agents in the field (central diamond in Figure 2) is also a key element for coercive isomorphism (“DiMaggio & Powell” box in

Figure 2). Incumbent organizations also impose contractual or informal rules to other firms, which fosters institutional homogenization and reproduction.

Power dispute in the field consolidates incumbent and challenging coalitions around competing interests. Incumbent coalitions maneuver for the reproduction of institutions which favor the maintenance and improvement of their position in the field, while challenging coalitions struggle to change the power balance and reformulate institutions according to their own interests. Therefore, incumbent institutions, in this case the technological choice in the electricity sector (“Incumbent Technology” box in Figure 2), would be reproduced according the lock-in loop established by power dispute among agents (diamond in Figure II), isomorphic drivers (“DiMaggio & Powell” box in Figure 2) and historical recursive dynamics between path dependence and belief systems (“Douglass North” box in Figure 2). Substantive change on agents’ interests and strategic objectives could disrupt coalitions and give rise to new incumbent groups. The emergent power balance could then trigger a process of disruptive institutional change.

Skilled agents (“Fligstein & McAdam” box in Figure 2) present cognitive and empathic abilities which afford them a central role on coalition’s emergence, maintenance, and change. Skilled agents in incumbent coalitions deal with ongoing institutions and keep them compatible with coalition shared interests, mainly through incremental institutional changes. On the other hand, skilled agents in challenging coalitions struggle to increase their representativeness in the field, to the point they become incumbent and capable to trigger disruptive institutional change. In this case, institutional change is represented by the dashed “Technological Change” box in Figure 2. The internal efforts of Skilled Agents are often catalyzed by field crises driven by external events (“Fligstein & McAdam” box in Figure 2). These crises disrupt the ongoing coalitions, and the following field reorganization is a suitable scenario for Skilled Agent abilities on coalition emergence and change.

Figure 2 – Integrative Analytical Framework for Institutional Dynamics

Source: Elaborated by the author (2022)

2.4.2 Historical analysis of reproduction and change of technological choices in the Brazilian electricity sector

The historical narrative identified the shifts of mode (decentralized, centralized or distributed), sources (hydro, thermal - gas, oil, nuclear, biomass - wind, solar) and interconnectivity (locally connected, regionally connected, nationally connected) for Brazilian electrical generation (Table 1). The periods were divided following the previous division made by Electricity Memory (MEMÓRIA DA ELETRICIDADE, 2015).

The main events in each historical period (columns in Table I) were categorized according to the rationality of the Integrative Analytical Framework for Institutional Dynamics (Figure 2) and depict the phenomena of institutional emergence: a) path

dependence; reproduction: b) belief systems; c) Isomorphism; and change: d) External crisis; e) Internal crisis; f) Social skilled agent (Table 1).

Table 1 – Analytical Framework theoretical concepts and their empirical evidence in the Brazilian Electric Sector's History

ANALYTICAL FRAMEWORK CONCEPTS	DESCRIPTION	1879-1903	1904-1933	1934-1963	1964-1992	1993-2002	2003-2016
TECHNOLOGICAL CHOICE	Choices regarding mode (decentralized, centralized and distributed) and source (hydro, thermal - gas, oil, nuclear, biomass - wind, solar) and interconnectivity in the electricity sector.	Hydroelectric and Thermolectric Decentralized Non-connected	Hydroelectric Centralized Non-connected	Hydroelectric Centralized Regionally Connected	Hydroelectric Centralized Inter-regionally Connected	Hydroelectric Centralized Nationally Connected	Hydroelectric, Gas fueled thermal and Eolic Centralized Nationally Connected
SOCIAL SKILLED AGENT	An agent capable of translating different groups interests into widely acceptable institutions that guarantees predictability in strategic social action	Bernardo Mascarenhas, Arthur Thiré, and Dom Pedro II	Multinationals Light and Amforp	Getúlio Vargas and CNAEE	MME and Eletrobras	ANEEL, Fernando Henrique Cardoso	ANEEL, EPE, BNDES, Lula
EMERGENCE PATH DEPENDENCE	The first experience identified by most agents as successful marks the departing point of a historical trajectory of analog choices.	Early local hydroelectric and thermolectric experiences	Hydroelectric prevailed over thermolectric and multinationals outcompeted local companies	Nationalization of the electric sector and Hydroelectric growth financed by World Bank	Integration of Hydroelectric generation - frequency standardization in 60 Hz	Privatization of the electric sector and generation growth financed by private agents	Gas-fueled thermolectric brought stability to the national grid. Successful experiences with the wind in the northeast

REPRODUCTION BELIEF SYSTEM	Aggregated cultural, moral, academic, economic or technological preferences directly or indirectly expressed as organizational or political choices	Reliance on national local private capital for electricity generation	Reliance on large multinational private capital for scaling up electricity generation	The electric sector as strategic and controlled by the state	Military government reinforces the perspective of the electric sector as strategic and controlled by the state	The electric sector as a private business under the regulation of state agency (ANEEL)	Electric sector expansion through Public-Private Partnerships under the regulation of state agency
REPRODUCTION ISOMORPHISM	Institutional homogenization is driven by coercion, mimicry or shared an academic or professional background	Mimetic - local national private companies dominate electricity generation	Coercive - the golden clause favored multinational oligopolies for hydroelectric generation	Coercive - Nationalization and concentration of the electric sector (CHESF, Furnas, Eletrobras)	Normative - Lobby of engineering and construction companies specialized in dams	Coercive – ANEEL, MME and public energy auctions guide choices for energy generation sources	Coercive - ANEEL, MME, EPE and public energy auctions guide choices for energy generation sources
CHANGE EXTERNAL CRISIS	Event external to the electric sector that disturbed the ongoing institutional dynamics - Agents were no longer able to predict strategic social action	-	29's crash undermined multinational investments in Brazil	Military coup d'état	New liberal civil government - National Program of Privatization (PND)	-	Climate crisis fosters the choices for clean and renewable generation sources

<p>CHANGE INTERNAL CRISIS</p>	<p>Event internal to the electric sector that disturbed the ongoing institutional dynamics - Agents were no longer able to predict strategic social action</p>	<p>Lack of national private and public resources for generation expansion</p>	<p>Lack of resources for generation expansion</p>	<p>-</p>	<p>Insolvency crisis in the electric sector</p>	<p>Offer crisis - national blackouts</p>	<p>-</p>
---	--	---	---	----------	---	--	----------

Rows: the historical trajectory of empirical evidence. Columns: the relationship among events in a given period according to the Analytical Framework.

Source: Elaborated by the author (2022) with theoretical support from North (1990, 2008), DiMaggio and Powell (1983) and Fligstein (2001).

2.4.2.1 1879-1903: Hydroelectric and Thermoelectric Decentralized Non-connected

Brazil started electricity production in 1879¹³, when Pedro II, the last Brazilian emperor, lighted up six lamp bulbs, powered by a small locomotive, for illuminating the central train station in Rio de Janeiro city.

Early hydroelectric experiences were carried by Arthur Thiré in 1883, and by Bernardo Mascarenhas in 1889 in Minas Gerais state, which have supplied electricity through a two-kilometer transmission line (1879-1903 in Table 1). Brazilian private entrepreneurs were the major investors of early electrical expansion, through thermoelectric projects in southern and northern urban areas of Brazil. However, in the southeastern states of Rio de Janeiro, São Paulo and Minas Gerais, the expansion of generation was mostly through hydroelectricity. Southeastern industrialists achieved municipal concessions for exploiting the hydraulic potential of rivers, which sometimes were conditioned to the provision of public illumination.

Nevertheless, by 1900, the first expressive multinational, Light, established its operations in Brazil with a thermoelectric facility in the city of Sao Paulo. By 1901 Light has launched a hydroelectric mill in the state of Sao Paulo, and by 1904 started another hydroelectric in the state of Rio de Janeiro, mimetizing the successful hydroelectric models from Brazilian entrepreneurs.

Then, decentralized non-connected hydroelectric and thermoelectric production established the initial technological dispute in the Brazilian electric matrix. On the other hand, the power dispute between national and multinational investments would stir up, as described in the next section.

2.4.2.2 1904-1933: Hydroelectric Centralized Non-connected

The abundance of hydric resources (Gov1, Gov2, Corp1, Corp2) was a key reason for early expansion hydroelectricity instead of thermoelectricity (1904-1933 in Table 1). Multinationals as Light and Amforp concentrated the capital for expanding generation and outcompeted sparse national entrepreneurs. As Federal Government and private local entrepreneurs lacked resources for investments in generation expansion (Gov1), those multinationals pressed politicians to implement the Golden

¹³ Only some months after Edison had invented the electric lamp.

Clause in 1904. This norm fixed their returns in American dollars, reducing currency and exchange risks derived by Brazilian inflation fluctuations. The Golden Clause was a coercive institution which resulted from a growing power asymmetry in the field and favored the incumbent coalition of multinational companies (1904-1933 in Table 1). The electrical expansion was smooth until 1929 when the financial crash committed the global economy. Multinationals then lacked resources for investments in the expansion of electricity generation in Brazil (1904-1933 in Table 1).

2.4.2.3 1934-1963: Hydroelectric Centralized Regionally Connected

In 1934 the president Getúlio Vargas¹⁴ revoked the Golden Clause and gradually increased state influence in the electric sector, establishing the beginning of a new belief system: the electric sector as a strategic state issue that might be controlled by the Federal Government (1904-1933 in Table 1). Vargas implemented the Water Code and also a federal secretary for regulating hydroelectric generation (CNAEE)¹⁵, which reflected the Federal Government source preference.

Although multinationals still held significant influence in strategic decision in the electricity sector, the federal power increased substantially. In the mid-fifties, the Federal Government, with World Bank's financing (Gov1), concentrated the sector in two major national companies, CHESF, in the northeast, to explore the São Francisco basin, and Furnas, in the south, to explore the Paraná basin (1904-1933 in Table 1).

Nevertheless, along with the expansion of electric generation, both private and state agents reproduced hydroelectric power plants as the main technological option. Projects increased the size of the plants, which allowed electricity supply to larger areas. However, transmission lines remained regionally-connected.

In 1954 the Federal Government created Eletrobras, the largest public company of the Brazilian electricity sector, but it would effectively operate only after 1962. Eletrobras acquired assets from Light and Amforp with World Bank financing (Gov1),

¹⁴ Getúlio Vargas had taken office in 1930 by a *coup d'état*. He was a populist politician who had enough social skill to politically influence many economic and social fields.

¹⁵ In 1940 the first regulation for thermoelectric was implemented under the dispositions of the CNAEE and the Water Code. However, it did not launch expressive thermoelectric projects, exception made for Light's first centralized thermoelectric in 1954, with an expressive installed capacity (200MW), in São Paulo.

and it would hold most of the investments until 1990¹⁶. The Ministry of Mines and Energy (MME) was also created in 1962, and it would become responsible for regulating the national electricity production, centralizing regulation and becoming the federal organization for reinforcing coercive isomorphism to the field.

2.4.2.4 1964-1992: Hydroelectric Centralized Inter-Regionally Connected

Both Eletrobras and the MME were social skilled agents responsible for implementing, in 1964, the frequency standardization in 60 Hz (1964-1992 in Table 1). Frequency standardization was an unavoidable technical condition for the integration of the electric national grid and eventual connection of all centralized hydroelectric facilities in the national territory.

Brazilian military coup d'état (1964-1985) represented an external crisis on the Brazilian electricity sector. Nationalization took impulse and was not restricted to the electricity sector, it was rather a state policy for the named "strategic sectors" (e.g. oil, mining, energy). Nationalization has not changed the technological choices for electricity generation, remaining mostly hydroelectric¹⁷. However, both the centrality of the Federal Government in the electricity sector decision making and the national security (aimed under the political-military belief system) supported the investments towards grid standardization and integration. Eletrobras and MME were pivotal agents in the process of changing the model towards centralized connected hydroelectric plants (1964-1992 in Table 1).

The expansion of the centralized connected hydroelectric plants in this period would culminate, in 1984, in two of the largest hydroelectric facilities in the world: Itaipu and Tucuruí, with respectively 14 and 11 GW installed capacity. Nationalization of private assets and investments in new projects were largely financed by the World Bank (Gov1), which legitimated and reinforced the power balance and the institutions in the electricity sector. Furthermore, the legitimation of hydroelectric generation as the main national electricity source has consolidated specialized engineering and construction companies, which, in turn, constituted an important political lobby towards

¹⁶ Eletrobras still holds more than thirty percent of Brazilian generation assets (ELETROBRAS, 2015).

¹⁷ Only in 1985 Brazil has built its first nuclear power plant, with 657 MW installed capacity, which is owned, controlled and operated by Eletrobras. However, it did not threaten the dominant technological choice for central hydroelectric, remaining as a minor challenger technology until present days.

hydroelectricity expansion (Gov1). This reproduction lock-in around the hydroelectric technological path is also reinforced by the consolidation of engineering specialization in the Brazilian universities, fostering a normative isomorphism (1964-1992 in Table 1).

By 1985, an internal crisis arose: public and also private companies in the sector went through an insolvency crisis, mostly because of the unfavorable contractual financial returns imposed by the Federal Government at the moment (Gov 1). Then, in 1990, another external crisis broke out from the political sphere and impacted the electricity sector. The first elected Federal Government after the military period sanctioned the National Program of Privatization (PND), aiming to achieve investments from private actors (1964-1992 in Table 1). In the electricity sector, the necessity of investments for expansion of the national grid made the liberal-oriented Federal Government consider privatization as a promising solution.

2.4.2.5 1993-2002: Hydroelectric Centralized Nationally Connected

Between 1994 and 1998 the privatization of the electricity sector gained momentum, mainly under the presidential term of Fernando Henrique Cardoso, from 1995 to 2002. Public electrical companies were divided into generation, transmission and distribution categories, facilitating and accelerating the privatization program. Aiming to regulate and coordinate operations of public and private companies, by 1997 the Federal Government conceived its first regulatory agency in the electricity sector: the National Agency of Electricity (ANEEL). ANEEL would be independent of the state and less sensible to political pressure¹⁸. The regulatory agency shared with the MME all the regulation issues, consolidating itself as a major source for coercive isomorphism (1993-2002 in Table 1).

By the end of the 1990s, despite most of the Brazilian electric grid was interconnected, an energy supply crisis loomed at the horizon. In 2000, trying to anticipate an offer crisis, the president Fernando Henrique Cardoso launched the Priority Program of Thermolectric (PPT), fueled by natural gas supplied by Bolivia through recent pipelines infrastructures (Sauer et al., 2003). Nevertheless, PPT did not achieve its objectives in time and, between 2001 and 2002, Brazil suffered a series of

¹⁸ Although the executive power indicates its board composition, and the nomination must be assessed and approved by the national congress.

blackouts in major cities¹⁹. After the blackouts, gas-fueled thermoelectric brought stability to the national grid, supplying the electricity in dry periods when the levels of hydroelectric dams are lower. No other major internal crisis as the 2002 offer crisis has risen since then, and this internal crisis is held responsible for triggering the first disruptive change in terms of electricity generation source (1993-2002 in Table 1).

The offer crisis of 2002 consolidated thermoelectric incumbent role in the Brazilian electrical grid, and also opened room for centralized connected renewables, like wind power, and distributed connected small hydroelectric and biomass generation, as the bagasse cogeneration in sugarcane mills in São Paulo (Gov1)²⁰. These interconnected generation sources gained relevance in public auctions and assumed challenging positions in the sector. The system then started to operate mainly as centralized connected hydroelectric with centralized connected thermoelectric as a complement²¹.

2.4.2.6 2003-2016: Hydroelectric, Gas fueled thermoelectric and Eolic centralized connected and also Biomass thermoelectric distributed²² connected (sugarcane cogeneration)

In 2004, for financing the strategic planning of the electricity sector, the Federal Government enacted that one percent of the net profit from every company of the electricity sector might be destined to the Energy Research Company (EPE). EPE publishes yearly, since then, annual reports and ten-year outlooks and assessments for the electricity sector, and it got also responsible for the public auctions coordination.

¹⁹ A series of public measures was taken under Fernando Henrique Cardoso administration for stabilizing future supply crises derived from drought periods and empty reservoirs. Among them was short term energy rationing (throughout programmed shutdowns) and the creation of agencies for managing new inputs of electricity from thermoelectric.

²⁰ The incentives for renewables from small hydroelectric, biomass generation and wind power plants are part of a Federal program called Proinfa (Program of Incentive for Alternative Sources) (ELETROBRAS, 2015).

²¹ In present days, centralized thermoelectric takes around thirty percent of share in the total national matrix source composition (EPE, 2017).

²² Centralized generation and Decentralized Generation are differentiated, in general terms, by the size of the power plants and the geographical area supplied. When the national or regional grid is integrated, Centralized Generation becomes the dominant option due its scale gains. There is also Distributed Generation, which usually relies on small scale plants that generate electric energy for *in-loco* consumption. They can be connected or disconnected from the grid (ACKERMANN, ANDERSSON and SÖDER, 2001).

EPE aimed to be a reliable source of information and forecasting for electricity sector policymakers (Gov1). EPE and ANEEL are identified as social skilled agents capable to modulate the prices for generation for each source in order to foster competitiveness. Together, EPE and ANEEL would be responsible for most of the proposals and are therefore organizations capable of conceiving relevant institutions and promoting coercive isomorphism (2003-2016 in Table 1).

The expansion of gas-fueled thermoelectric centralized connected generation was consolidated as an incumbent technological choice. Thermoelectric is the second most representative source in the Brazilian electric matrix, with 27% (included central gas-fueled power plants and distributed biomass) of total installed capacity in 2016 (EPE, 2017). The main purpose of thermoelectric plants is supplying electricity when the water level in hydroelectric dams is more critical, reducing the risk of a new offer crisis. Despite the substantial operational costs, gas-fueled thermoelectric are accomplishing their strategic supplying role.

On the other hand, the expansion of fossil thermoelectric faces environmental contestation. Greenhouse gases from the energy sector are in the core of global concerns on climate governance. Brazilian emissions are mainly derived from land use change, and the hydroelectric-based matrix was historically an environmental global reference. However, the exhaustion of the hydraulic potential (Gov2, Corp1, Corp2) and the growing relevance of thermoelectric in the national electric matrix increased the projections of the electricity sector greenhouse emissions. In this scenario, Brazilian commitments on the reduction of energy greenhouse gases represent a new external-driven crisis on the electricity sector which might change power disputes and technological choices in the field. Brazil was among more than 190 countries in COP21, held in Paris, to pledge expansion in renewable and clean energy sources (2003-2016 in Table 1).

Centralized wind power plants assumed a relevant position in the national matrix since then, mainly in the northeast of Brazil, where it represents up to one-third of the total electricity generation (EPE, 2017). Eolic represented more than 10 GW, around 7% of the total installed capacity in Brazil (EPE, 2017). Furthermore, almost one century after the pioneer experiences on electricity generation in the state of Minas Gerais, the private investments in distributed small power plants (up to 5 MW of installed capacity) are relevant again in the national matrix, mainly from small hydroelectric and thermoelectric fueled with biomass from sugarcane bagasse (Gov1).

Biomass from sugarcane bagasse represented 6,09% of the total electric Brazilian generation in 2016 with 35.236 GWh²³ (EPE, 2017).

Other small scaled distributed sources are incipient yet and demand economic and technological support to consolidate as viable challenging technologies. Connected individual solar panels are expanding in the cities and are a promising complementary source. However, scaling up these distributed sources demands technological improvements in the distribution grid and close control of scale diseconomies regarding transaction and maintenance costs (Gov2, Corp1, Corp2).

Hydroelectric expansion through larger dams faces social and environmental constraints (FEARNSIDE, 1999; 2006) (Gov1). The hydric resources are seen as almost completely exploited (Gov2, Corp1, Corp2). However, hydroelectric dominance is predicted to resist for several decades more (Gov1). The Federal Government and private companies continue to prioritize centralized hydroelectric power plants for expanding the national installed capacity. Belo Monte power plant was launched in 2016, with more than 11 GW of installed capacity²⁴, figuring among the largest in the world. The role of EPE and ANEEL on planning and structuring public auctions for energy supply remains crucial for institutional and technological changes towards generation matrix' expansion.

From 2003 on, under the presidential term of Lula, state control over the expansion of the electricity sector had again a change of direction, marking a new belief system. Public auctions held the major instance of hiring electricity to the national grid. The auctions, though, were divided into new power plants and old power plants, with specific hiring conditions for each one. The most expressive change was that state and private corporations could establish partnerships in order to expand the electricity sector (2003-2016 in Table 1). The National Bank of Development (BNDES) represented a key actor for emerging public-private partnerships, since it controls substantial financial resources under low-interest rates, to finance long term and low return assets, as power plants and transmission lines. This arrangement relieves the direct public budget and keeps state control over the sector²⁵.

²³ From the total 27% of thermal participation this represents a bit more than 20% of total thermal national production.

²⁴ But only 4,6 GW operating due environmental and social pressures.

²⁵ However, given the central role of the public bank BNDES in the expansion projects, there is a substantial indirect public expenditure on subsidized interest rates.

Brazilian electricity sector then currently relies on hydroelectric centralized and connected; gas fueled thermoelectric centralized connected; distributed connected thermoelectric (the latter fueled with sugarcane bagasse); and centralized connected wind power plants.

2.5 DISCUSSION

The historical narrative for technological choices in the Brazilian electricity sector was developed with an emphasis on the institutional perspective. We pointed out three institutional aspects as determinants for the technological path which locked Brazilian matrix in a centralized hydroelectric generation: (i) the formal institutions that constrained the agent's choices; (ii) the internal and external crises; and (iii) the strategic action of social skilled agents.

The centrality of the macro and mesoscale social drivers on institutional emergence, reproduction, and change, supported by NIE and NOI, is modulated by microscale individual action of social skilled agents, who present cognitive and relational abilities to change (or halt) path dependence institutional trajectories during internal or external crises.

The historical evidence demonstrates that disruptive technological change in the Brazilian electricity sector demands more than technological development, economic payoffs, and political will. Breakthroughs which overcame tenacious institutional lock-in – here identified as a result of synergic interactions among path dependence, belief system and isomorphism – occurred mainly as result of the interaction between crises and strategic action of social skilled agents.

Energy transitions have usually taken long periods, even centuries, for arising and consolidating innovative patterns. From the discovery of petrol to its broad usage, it has taken more than a hundred years to surpass biomass as the dominant energy source (SOLOMON and KRISHNA, 2011). Brazil had a fast-moving transition from hydro to thermal electricity generation. However, the lock-ins on technological trajectories in electricity generation are beyond single theory analysis, they demand multidisciplinary approaches to enlarge the theoretical comprehension of such complex phenomena.

Single theory efforts on explaining the historical trajectory of technological choices in the Brazilian electricity sector stressed path dependence as the main driven

force which constrained agents toward hydroelectric choice, as shown in studies by Araújo (2014) and also by de Césaris (2009) has also relied on path dependence approach, and pointed out the importance of refining an analytical frameworks which address the institutional reproduction and change.

Ince, Vredenburg and Liu (2015), also under a single theory approach, applied NOI theories to analyze Norway's renewable expansion. They pointed out isomorphism influence on institutional reproduction in the Norwegian electricity sector. The authors observed that the introduction of renewable sources in the Norwegian electricity sector was undertaken under coercive and mimetic isomorphism fostered by incumbent European's countries. On the other hand, applying hybrid theories to conceive a theoretical model, a study tackling energy transitions in Japan concluded that political, social and economic aspects must be integrated into an interdisciplinary approach towards institutional analysis (KUCHARSKI and UNESAKI, 2018).

The recognized work of Hoffman (1999) also laid on DiMaggio and Powell (1983) isomorphism theoretical approach but relied on complementary theoretical contributions for explaining the inertia in the USA chemical industry during 1960-1993 period. Hoffman expressed concerns regarding the suitability of isomorphism theoretical approach on explaining institutional change process. He aimed to introduce "[...] the "old" institutional concept of change into the neoinstitutional literature". Hoffman (1999), as well as the present study, sees organizational fields as arenas of political confrontations and proposes three institutional categories of analysis: organizational field, situated institutions²⁶, and disruptive events. Those categories carry on similarities to some categories we articulated in this work, respectively power dispute in the field, dominant institutions (incumbent technology) and internal/external crises. The main advance in the analytical framework presented in our work is the recognition of the micro level role of social skilled agents in the process of institutional change. Our work, as well as Hoffman's, presents a proposal of an analytical framework which incorporates and integrates contributions of different and even conflicting academic fields in the assessment of historical institutional change process.

²⁶ We interpreted Hoffman (1999) "situated institutions" much as what North (1990) and Ostrom (2008) call norms and informal constraints: "Institutional beliefs and perceptions are influenced by this field-level competition but are situated within individual organizations or populations of organizations. Therefore, to fully appreciate the complexity of institutional dynamics, one must analyze both the specific institutions that lie at the center of an issue-based field and the competing institutions that may lie within the individual populations." (HOFFMAN, 1999).

2.6 CONCLUSIONS

The evolution of institutions in the history of the Brazilian electricity sector is understood more comprehensively when theories which explicitly address institutional change and the role of strategic skilled agents, from New Economic Sociology, are articulated to traditional institutional models of path dependence and isomorphism, respectively from New Institutional Economics and New Organization Institutionalism.

The findings showed evidence that the major changes which took place in the Brazilian electricity sector, concerning its technological choices along the last century were driven by (i) formal and informal constraints (institutions), (ii) internal and external crises and (iii) strategic action of social skilled agents.

The choice for hydroelectric generation in Brazil is not only due abundance of hydric resources and the technological set available at the beginning of the 20th century. This paper has shown that institutional constraints, crises, and social skill drove the configuration of the Brazilian electric matrix toward the dominance of large dams and hydroelectric facilities. Institutional reproduction of the electricity generation pattern was only placed in check when external or internal crises broke out, as respectively the 1929's crash and the national offer crisis of 2002.

The replication of the analytical framework in further studies should incorporate specific social and cultural aspects which influence strategic action in the organizational and individual level, as well as shaping the power balance in the field. Considering context premises, the framework can also be applied to assess institutional change in other economic sectors. Future applications are promising for natural monopolies²⁷ as utility sectors, and other cases with expressive sunk investments associated with assets specificity²⁸. The analytical framework could contribute to elucidate why countries as Canada, Norway or New Zealand, which present different social and political characteristics compared to Brazil, ended up presenting central hydroelectric as the dominant generation option.

Limitations are associated to methodological choices: the qualitative methods are not exhaustive, the respondents were chosen by availability and not randomly,

²⁷ A natural monopolies arise because a single firm can supply a good or service to an entire market at a smaller cost than could two or more firms (MANKIW, 2017).

²⁸ Assets specificity is the difficulty to liquidate a specific asset in case of bad business bias (WILLIAMSON, 1985, 2007).

ontology shapes researchers view and the analytical model is not falsifiable and was not conceived to deliver predictions.

Research results contribute to elucidate the phenomena of institutional constraints over Brazilian electric generation choices, and the study overcomes single-theory explanations for why Brazil adopted hydroelectric since the beginning of the historical trajectory, and why technological changes occurred.

2.7 ACKNOWLEDGMENTS

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001. Also, both authors would like to thank grant 2015/03804-9, São Paulo Research Foundation (FAPESP). Annelise Vendramini Felsberg, Sylmara Lopes Francelino Gonçalves-Dias and, Oswaldo dos Santos Lucon also contributed with valuable institutional insights for modeling theoretical concepts into operational variables. Respondents from in-depth interviews also elucidated the narrative with shreds of evidence that otherwise would not be enlightened, for that the authors show appreciation to José Goldemberg from the Institute of Energy and Environment from the University of São Paulo (IEE-USP), Gabriel Kozen from EPE, and the engineers Luciano Pelegrina, entrepreneur from mc2 solar, and Elio Vicentini, from AES Eletropaulo.

2.8 REFERENCES

ACKERMANN, Thomas; ANDERSSON, Göran; SÖDER, Lennart. Distributed generation: a definition. **Electric power systems research**, v. 57, n. 3, p. 195-204, 2001.

ARAÚJO, Kathleen. The emerging field of energy transitions: Progress, challenges, and opportunities. **Energy Research & Social Science**, v. 1, p. 112-121, 2014.

BACCHIEGGA, Fábio; DA COSTA FERREIRA, Lúcia. Uma análise das aproximações e distanciamentos epistemológicos das noções de campo em P. Bourdieu e de arena em E. Ostrom. **Diálogos**, v. 18, p. 49-66, 2014.

BEN. **Balanco Energético Nacional 2014**. Rio de Janeiro: Empresa de Pesquisa Energética, 2014.

BOURDIEU, Pierre. Questions de sociologie. **Revue Française de Sociologie**, Vol. 22. Paris: Sciences Po University Press, 1980.

BOURDIEU, Pierre. Le champ économique. **Actes de La Recherche En Sciences Sociales**, 119, p. 48-66, 1997.

CESARIS, Luis Enrique Urtubey de. **Reconceitualizando o Institucionalismo Histórico: path dependence, agência e mudança institucional**. 2009. Tese de Doutorado. Universidade de São Paulo.

COASE, Ronald Harry. The Nature of the Firm. **Economics**, v. 4, p. 386-405, 1937.

CRESWELL, John. Qualitative, quantitative, and mixed methods approaches. In: CRESWELL, John (editor). **Research Design**. 2 ed. California, Thousand Oaks: Sage, 2003.

DAVIS, Lance Edwin; NORTH, Douglass C.; SMORODIN, Calla. **Institutional change and American economic growth**. CUP Archive, 1971.

DENZAU, Arthur T.; NORTH, Douglass C. Shared mental models: Ideologies and institutions. **Kyklos**, 47, 3-31, 1994.

DENZIN, Norman Kent. **The Research Act: Symbolic Interaction: A Reader in Social Psychology**. Vol. 1. New York: Routledge, 1978.

DIMAGGIO, Paul J.; POWELL, Walter W. The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. **American sociological review**, p. 147-160, 1983.

ELETROBRÁS. **Relatório Anual e de Sustentabilidade**. Rio de Janeiro, 2015. Disponível em: https://eletrobras.com/pt/SobreaEletrobras/Relatorio_Anual_Sustentabilidade/2015/Relatorio-Anual-e-de-Sustentabilidade-Eletrobras-2015.pdf.

EPE. **Balanco Energético Nacional da Empresa de Pesquisa Energética**. Rio de Janeiro: EPE, 2017.

FEARNSIDE, Philip M. Social impacts of Brazil's Tucuruí dam. **Environmental Management**, v. 24, n. 4, p. 483-495, 1999.

FEARNSIDE, Phillip M. Dams in the Amazon: Belo Monte and Brazil's hydroelectric development of the Xingu River Basin. **Environmental management**, v. 38, n. 1, p. 16-27, 2006.

FLICK, Uwe; VON KARDOFF, Ernst; STEINKE, Ines (Ed.). **A companion to qualitative research**. Sage, 2004.

FLIGSTEIN, Neil. Social skill and the theory of fields. **Sociological theory**, v. 19, n. 2, p. 105-125, 2001.

FLIGSTEIN, Neil; MCADAM, Doug. **A theory of fields**. Oxford University Press, 2012.

GONZALEZ, Carlos Germán Meza; AMADO, Nilton Bispo; SAUER, Ildo Luis. Desenvolvimento Sustentável, Transição Energética Mundial Póscombustíveis Fósseis e o Pensamento Político da Esquerda Latinoamericana. **Anais do II Simpósio Internacional Pensar e Repensar a América Latina**, 2016.

GREENWOOD, Royston; OLIVER, Christine; LAWRENCE, Thomas B., MEYER, R.E. Organizational institutionalism. **The SAGE Handbook of Organizational Institutionalism**. Thousand Oaks: SAGE, 2008.

HOFFMAN, Andrew J. Institutional evolution and change: Environmentalism and the US chemical industry. **Academy of management journal**, v. 42, n. 4, p. 351-371, 1999.

IEA. **Key World Energy Statistics**. Paris: International Energy Agency, 2014.

INCE, David; VREDENBURG, Harrie; LIU, Xiaoyu. Drivers and inhibitors of renewable energy: A qualitative and quantitative study of the Caribbean. **Energy Policy**, v. 98, p. 700-712, 2016.

KRAUSE, Décio; DENZIN, Norman Kent. The research act: A theoretical introduction to sociological methods. **Teaching Sociology**, 17(4), 500, 1989.

KUCHARSKI, Jeffrey B.; UNESAKI, Hironobu. An institutional analysis of the Japanese energy transition. **Environmental Innovation and Societal Transitions**, v. 29, p. 126-143, 2018.

LEITE, Antônio Dias. **A Energia do Brasil**. Rio de Janeiro: Editora Nova Fronteira, 1997.

LEITE, Antônio Dias. **A Energia do Brasil**. 3 ed. Rio de Janeiro: Lexicon, 2014.

MANKIW, N. Gregory. **Principles of economics**. Vol. 53. Mason, OH: South-Western College Publishing Group, 2017.

MEMÓRIA DA ELETRICIDADE. Rio de Janeiro: Memória da Eletricidade, 2015. Disponível em: <http://www.memoriadaeletricidade.com.br/Default.asp?pagina=destaques/linha&menu=368&iEmpresa=Menu#368>. Acesso em: 15 dez 2015.

NEE, Victor. The new institutionalisms in economics and sociology. **The handbook of economic sociology**, v. 2, p. 49-74, 2005.

NEE, Victor. Middle-Range Theories of Institutional Change. **Sociological Forum**, 33(4), p. 845-854, 2018.

NEE, Victor; SWEDBERG, Richard. Economic sociology and new institutional economics. In: **Handbook of new institutional economics**. Springer, Boston, MA, p. 789-818, 2005.

NORTH, Douglass C. **Institutions, Institutional Change and Economic Performance**. Washington, DC: Cambridge University Press, 1990.

NORTH, Douglass C. Institutions and the performance of economies over time. In: **Handbook of new institutional economics**. New York: Springer, p. 21-40, 2008.

OSTROM, Elinor. Reflections on the commons. In: **Governing the Commons**. Cambridge: Cambridge University Press, p. 1-28, 1990.

OSTROM, Elinor. Doing institutional analysis: Digging deeper than markets and hierarchies. In: **Handbook of New Institutional Economics**. 1 ed. Dordrecht: Springer, p. 819-848, 2008.

SAUER, Ildo Luís. A gênese e a permanência da crise do setor elétrico no Brasil. **Revista USP**, n. 104, p. 145-174, 2015.

SAUER, Ildo Luís; ROSA, Luiz Pinguelli; CARVALHO, Joaquim Francisco; TERRY, Leslie Afrânio; PRADO, Luiz Tadêo Siqueira; LOPES, J.E.G. **A Reconstrução do Setor Elétrico Brasileiro**. 1 ed. São Paulo: Paz e Terra, 2003.

SOLOMON, Barry D.; KRISHNA, Karthik. The coming sustainable energy transition: History, strategies, and outlook. **Energy Policy**, v. 39, n. 11, p. 7422-7431, 2011.

WILLIAMSON, Oliver Eaton. **The Economics Institutions of Capitalism**. 1 ed. New York: The Free Press, 1985.

WILLIAMSON, Oliver Eaton. Transaction cost economics: An introduction. **Economics Discussion Paper**, n. 2007-3, 2007.

3 O DESAFIO DAS MUDANÇAS INSTITUCIONAIS NA ECONOMIA ECOLÓGICA: UM *FRAMEWORK* A PARTIR DO IAD DE OSTROM

Pavanelli, J. M. M.; Oliveira, C. E.; Igari, A. T. O Desafio das Mudanças Institucionais na Economia Ecológica: um *framework* a partir do IAD de Ostrom. **Revista Iberoamericana de Economia Ecológica**, v. 35, n. 1, p. 36–55, 2022.

RESUMO

As balizas civilizatórias pautadas pelos avanços no campo da Economia Ecológica demandam profundas mudanças institucionais para manter os sistemas socioecológicos funcionando dentro de seus limites de resiliência ambiental e guiados por justiça intra e intergeracional. As instituições são normas sociais formais (e.g. leis) ou informais (e.g. costumes) que restringem e dão previsibilidade às relações entre os atores sociais. Mudanças institucionais representam assim processos de disputas éticas, científicas, sociais e políticas. O *Institutional Analysis and Development* (IAD) de Ostrom, auxilia no equacionamento desses processos complexos envolvendo instituições, através da análise de como regras, condições físicas e materiais, e atributos da comunidade afetam a estrutura das arenas de ação, os incentivos atuantes sobre os indivíduos e indicam os possíveis e prováveis desfechos resultantes. O IAD analisa profundamente a arena de ação, mas carece de detalhamento e articulação entre as variáveis exógenas para que se possa entender melhor a distribuição de dotações econômicas, sociais e ambientais entre as coalizões ou agentes. O presente ensaio apresenta um *framework* inspirado no IAD de Ostrom que permite aprofundar a compreensão sobre essas condições exógenas. Para ilustrar a aplicabilidade do *framework* proposto, foram utilizados metadados históricos e sínteses institucionais obtidas na análise do setor elétrico brasileiro, realizada por Pavanelli e Igari (2019). As evidências sobre os processos de emergência, avanço, consolidação e recentes reveses da geração hidrelétrica no Brasil contribuem para a compreensão das potencialidades e desafios para as mudanças institucionais necessárias às transformações na relação entre sociedade e ambiente sob a perspectiva da Economia Ecológica.

Palavras-chave: IAD (*Institutional Analysis and Development*); Mudança institucional; Indústria da eletricidade brasileira; Dotações sociais, econômicas e políticas; Arenas de ação.

ABSTRACT

The civilizing guidelines supported by advancements in the Ecological Economics field demand profound institutional changes to maintain the socio-ecological systems working within their environmental limits and guided by intra and intergenerational justice. Institutions are formal (e.g., laws) or informal (e.g., customs) social norms that constrain and conceive predictability to relationships among social actors. Institutional changes then represent processes of ethical, scientific, social, and political disputes. The Institutional Analysis and Development (IAD) framework of Ostrom contributes to addressing these complex problems involving institutions through the analysis of how rules, physical and material conditions, and community attributes affect the structure

of the action arenas, the underlying incentives on individuals and indicate the possible and probable outcomes. The IAD analyzes the arena of action profoundly, however, it lacks detailing and articulation between exogenous variables to better understand the distribution of economic, social, and environmental endowments among coalitions or agents. This essay presents a framework inspired by Ostrom's IAD that allows deepening the comprehension around those exogenous conditions. To illustrate the applicability of the proposed framework, we used historical metadata and institutional syntheses obtained in the analysis of the Brazilian electricity industry, undertaken by Pavanelli and Igari (2019). The evidence regarding the processes of emergence, advancement, consolidation, and the recent setbacks of the hydroelectricity generation in Brazil contribute to the comprehension of the potentialities and challenges for institutional changes necessary for transforming the relationship between society and environment under the perspective of Ecological Economics.

Keywords: IAD (Institutional Analysis and Development); Institutional change; Brazilian electricity industry; Social, economic, and political endowments; Social arenas.

JEL Codes: D02, P48, Q40, Q57.

3.1 INTRODUÇÃO

Os limites ambientais para as atividades humanas, associados à perda de biodiversidade, exaustão de recursos, poluição, entre outros fatores, ganharam destaque com os estudos Malthusianos no final do século XVIII, foram retomados nas discussões no âmbito dos limites para o crescimento econômico no Clube de Roma (*Limits to Growth*) em 1972 e, mais recentemente, sintetizados através da análise do estado de conservação dos ecossistemas pela Avaliação Ecosistêmica do Milênio entre 2001 e 2005 e, por fim, analisados por Rockström et al. (2009) e posteriormente Steffen et al. (2015), que identificaram os limites ambientais seguros para a humanidade, mostrando que em muitos parâmetros estamos próximos, ou mesmo já ultrapassamos os limiares de resiliência dos ecossistemas.

A ultrapassagem dos limites ecosistêmicos pode comprometer diretamente as funções ecosistêmicas associadas e, conseqüentemente, comprometer a provisão de serviços ecosistêmicos, que são fundamentais para sustentar a vida humana, através de processos e fluxos de matéria ou energia gerados pelos ecossistemas naturais (COSTANZA et al., 1997; DAILY, 1997). A pesquisa sobre a governança dos limites de uso e degradação dos elementos bióticos e abióticos (capital natural) que fornecem recursos e serviços à humanidade é extensa, diversa e recorrentemente com conflitos teóricos e metodológicos entre suas contrastantes agendas de investigação.

A Economia Ambiental Neoclássica entende que o uso do capital natural e a consequente degradação ambiental ou geração de poluição é compensado pela geração de bem estar econômico para a humanidade ao longo do tempo, sendo que o objetivo final seria que a somatória dos capitais humano, social, natural e econômico deveria crescer ou, no mínimo, manter-se constante na sociedade. Esta visão implica na possibilidade de plena e ilimitada substituição entre as formas de capital, e tem a valoração econômica do capital natural e dos serviços ecossistêmicos como principal método para incorporação de parâmetros ambientais na tomada de decisão individual, assim como tem os mercados como principais arenas para alocação dos benefícios e custos ambientais.

Por outro lado, a Economia Ecológica representa uma abordagem antagônica quanto à conservação do capital natural, apontando fragilidades nas premissas e nos métodos utilizados pela Economia Ambiental Neoclássica, dada a incomensurabilidade entre os valores substantivos atribuídos ao capital natural e serviços ecossistêmicos e os valores de troca para bens e serviços construídos. A Economia Ecológica busca, a partir das Ciências Naturais, o estabelecimento dos limites máximos de degradação e dos limites mínimos de conservação do capital natural, com isso os mercados estariam limitados aos parâmetros de conservação dos ecossistemas e não o contrário, como previsto pela Economia Ambiental Neoclássica. Ademais, os mercados em concorrência perfeita, sob a perspectiva da Economia Ambiental Neoclássica, também são desprovidos de parâmetros éticos ou morais, e as decisões seriam pautadas em parâmetros exclusivamente econômicos. A Economia Ecológica entende que os mercados, particularmente os globais, são instrumentos de alocação econômica que devem, necessariamente, ser regulados por instituições com intuito de conservação dos ecossistemas, de equidade e justiça na apropriação de benefícios e alocação dos ônus ambientais (MARTÍNEZ-ALIER, 2012).

A governança sobre os serviços ecossistêmicos é sensível à disputa entre as abordagens da Economia Ambiental Neoclássica e da Economia Ecológica, sendo a primeira amplamente majoritária. Para adaptar a alocação do capital natural à estrutura dos mercados, a Economia Ambiental desenvolveu instrumentos econômicos de valoração de bens públicos (de acesso livre e uso não concorrente, como a regulação climática) e comuns (de acesso livre e uso concorrente, como o fornecimento de água doce), reduzindo a multifuncionalidade dos serviços ecossistêmicos a meros atributos de transação econômica.

Por mais inovadoras que sejam iniciativas como Pagamentos por Serviços Ambientais, mercado de emissões, subsídios e taxações ambientais, sob a abordagem da Economia Ambiental Neoclássica, elas representam ajustes incrementais à apropriação do capital natural com ênfase nos ganhos econômicos, que recorrentemente deixam em segundo plano os limites ecossistêmicos e a justiça ambiental. Por outro lado, quando balizados pelos limites de resiliência do capital natural, estes mesmos instrumentos podem representar formas efetivas de proteção ambiental dentro dos limites de resiliência e também meios de alocação justa do ônus e dos benefícios econômicos, tanto para as gerações presentes quanto futuras.

Crises podem potencializar e precipitar mudanças no balanço de forças nos campos sociais, criando um ambiente mais permeável às mudanças institucionais disruptivas (FLIGSTEIN e MCADAM, 2012; PAVANELLI e IGARI, 2019). Contudo, crises ambientais podem ser notadas tardiamente pela sociedade, em um ponto onde a degradação do capital natural já tenha atingido limiares irreversíveis, além de sua capacidade de resiliência (ROCKSTRÖM et al., 2009; FREITAS et al., 2021).

As mudanças institucionais voltadas à conservação de serviços ecossistêmicos passam pelo aumento da percepção da sociedade sobre sua dependência em relação ao ambiente (DAILY, 1997). Assim, as mudanças institucionais na governança de serviços ecossistêmicos vão muito além de uma disputa teórica entre Economia Ambiental Neoclássica e Economia Ecológica, elas dependem do resultado de disputas éticas e de visões civilizatórias na ciência e na sociedade, que contemplam o entendimento e ressignificação das relações entre humanidade e natureza.

Muitos serviços ecossistêmicos podem ser entendidos como bens comuns, representando benefícios, materiais e imateriais compartilhados por comunidades humanas. A governança dos bens comuns, assim como dos serviços ecossistêmicos, é foco de disputas teóricas acirradas desde o início do século XX. O equacionamento mais difundido assume que a livre apropriação de bens comuns por agentes econômicos leva à exaustão desses bens, pois sem controle ou atribuição de custos de acesso e uso, os agentes acabam por perseguir exclusivamente o objetivo de maximização do benefício individual, sem compromisso com parcimônia ou eficiência no seu uso (OLIVEIRA, PAVANELLI E IGARI, 2020).

A livre apropriação de bens comuns favorece agentes com maior capacidade de exploração, com dotações privilegiadas de capital humano, capital social, capital construído e capital financeiro. Estas assimetrias alimentam e aprofundam a injustiça

intrageneracional na alocação do capital natural e dos serviços ecossistêmicos (DEFRIES, FOLEY e ASNER, 2004; MARTÍNEZ-ALIER, 2012).

Ademais, a priorização da apropriação de bens comuns para a geração presente, em detrimento das necessidades e interesses de futuras gerações, fomenta também uma injustiça intergeracional. A alocação de bens comuns seria então uma escolha civilizatória, de âmbito redistributivo e envolvida em interesses e disputas tanto intrageneracionais quanto intergeracionais. O escopo temporal e espacial destas disputas na sociedade colocaria o Estado como arena natural para a alocação dos bens comuns (IGARI, 2021).

Entretanto a efetividade estatal para a alocação e conservação dos comuns é contestada pelo pensamento econômico neoclássico e neoliberal, que entende que tanto a alocação quanto a conservação dos comuns podem ser alcançadas de forma mais eficiente por meio da atribuição de direitos de propriedade privada e da livre transação via mercados, dados os elevados custos estatais para monitoramento e controle (HARDIN, 1968).

O modelo popularizado por Arthur Cecil Pigou (1920), por outro lado, assume que o Estado tem papel central no equacionamento do dilema dos bens comuns. Entretanto, nesse caso os bens não ficariam sob posse ou propriedade estatal, sendo apropriados pelos agentes privados, que ficam sujeitos à taxação pelo uso (ou degradação) dos bens comuns ou têm direito a subsídios por sua conservação. Esse modelo também assume a tecnocracia estatal como suficiente para o monitoramento, valoração econômica e controle sobre o uso e conservação dos bens comuns.

Modelos posteriores assumem progressivamente a redução do papel do Estado na governança dos bens comuns. Ronald Coase (1960) enfatiza a insuficiência do Estado para promover alocação economicamente eficiente de bens comuns, assumindo que caberia a este apenas estabelecer a alocação inicial, garantir os direitos de propriedade e a livre transação dos mercados.

O clássico *"The tragedy of the commons"* de Hardin (1968) representa um marco da contestação do papel do Estado na gestão dos comuns, e advoga pelo protagonismo dos mercados, dada a pretensa incapacidade dos indivíduos em gerir coletivamente bens comuns. A base deste argumento é a lógica econômica neoclássica em que, na ausência de custos de aquisição, um indivíduo racional não teria limites para aumentar permanentemente o uso e apropriação individual dos comuns, mesmo que o benefício incremental seja pequeno e declinante, e tendo

ciência que a exaustão dos comuns prejudica o bem-estar coletivo (OSTROM, 1990).

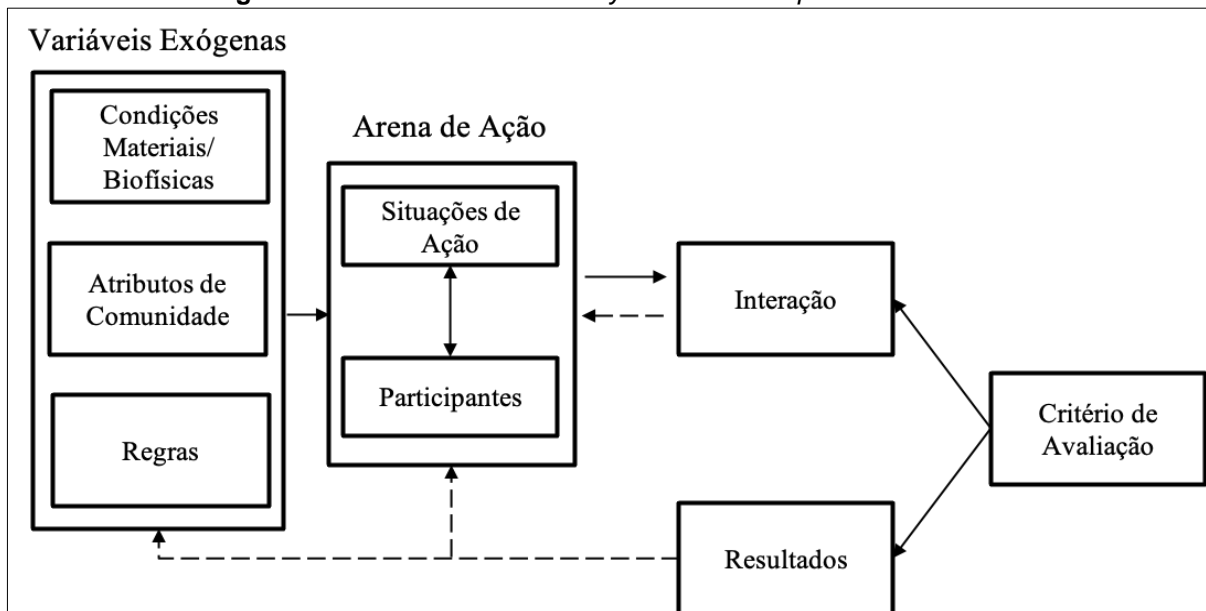
Por outro lado, Elinor Ostrom em seu trabalho “*Governing the commons*” de 1990, equacionou os elementos de exaustão, apropriação e justiça sob uma forma de governança alternativa tanto ao domínio do Estado quanto dos mercados. Ostrom (1990) mostrou que, em escala local, em pequenas e médias comunidades, onde o capital social é consolidado em relações de confiança historicamente construídas, as ações coletivas voltadas à autogestão dos bens comuns mostraram-se mais eficazes para conservação dos serviços ecossistêmicos do que o controle estatal ou privado. Ostrom (1990) reconhece a importância da regulação pelo Estado, contudo defende que a governança também deve ocorrer “de baixo para cima”, estabelecida pelas comunidades e gerida publicamente a partir da perspectiva de controle social pela coletividade.

Nesse sentido, em 2005 Ostrom desenvolveu o modelo IAD (*Institutional Analysis and Development framework*)²⁹. O IAD contribui para o equacionamento de problemas complexos envolvendo instituições, através da análise de como regras, condições físicas e materiais, e atributos da comunidade, aqui entendidos como dotações de capitais sociais, políticos e econômicos, afetam a estrutura das arenas de ação, os incentivos atuantes sobre os indivíduos e indicam os possíveis e prováveis desfechos resultantes.

Ostrom (2005, 2008) entende que as dinâmicas institucionais, em um dado nível hierárquico e momento do tempo, dependem de variáveis externas categorizadas como: a) condições biofísicas, b) atributos de comunidades e c) regras em uso (Figura 1). Estas variáveis influenciam as disputas na situação de ação e as interações entre agentes, cujos resultados são reavaliados constantemente (setas pontilhadas da Figura 1) e realimentam os parâmetros das próprias variáveis externas e da situação da ação.

²⁹ Ostrom (2011) propõe uma hierarquia para a compreensão dos desdobramentos e relações entre as variáveis de um fenômeno. A autora afirma que *frameworks* identificam os principais elementos de um fenômeno e as relações explicativas entre as variáveis, enquanto as teorias são conjuntos de elementos relevantes particulares de um *framework* com objetivo de formulação de premissas. Modelos discriminam premissas precisas sobre um conjunto limitado de variáveis. Neste ensaio o termo *framework* será utilizado para denotar enquadramento teórico de variáveis.

Figura 1 – IAD - *Institutional Analysis and Development framework*



Fonte: Ostrom (2005, 2008).

O IAD caracteriza e organiza o ambiente institucional, articulando aspectos econômicos, sociais e ambientais influenciadores do processo de apropriação dos bens comuns. As condições biofísicas e materiais caracterizam o contexto e as características próprias dos bens comuns em disputa. A rivalidade é uma propriedade intrínseca dos bens comuns, e manifesta-se independentemente das regras sociais estabelecidas para sua apropriação e uso (DALY e FARLEY, 2010).

A estruturação de regras de apropriação dependeria de informação completa, principalmente quanto à disponibilidade local, capacidade de recomposição (no caso de recursos naturais renováveis), e limite biofísico máximo para apropriação dos bens comuns pela comunidade. Os atributos da comunidade, por sua vez, são historicamente construídos e consolidados em traços culturais e valores compartilhados, manifestados no capital social e relações sociais, assim como nas dotações de capital político e econômico.

As instituições se materializam em regras (Figura 1) que balizam as interações sociais entre os atores participantes das arenas de ação. Estas instituições são recursivamente alteradas ou reproduzidas ao longo do tempo de acordo com os resultados das interações na arena de ação (linhas tracejadas da Figura 1). Os resultados se dão de acordo com as preferências e interesses dos atores, e de acordo com critérios de avaliação econômicos (renda gerada, atribuição de custos), sociais (desigualdade nos ganhos ou nos custos, valores culturais e históricos, transformação das relações sociais) e políticos. Assim, os resultados gerados podem realimentar as

situações de ação nas arenas ao longo do tempo até que se consolidem regras de apropriação e uso dos bens comuns legitimadas socialmente.

As instituições são escrutinadas constantemente nas arenas de ação, e novas configurações institucionais têm mais probabilidade de surgir em momentos de crise. As crises ocorrem quando as regras em uso em determinado momento não são suficientes para gerar previsões razoáveis sobre os resultados das ações estratégicas dos agentes participantes da arena (PAVANELLI e IGARI, 2019).

Esta incerteza leva ao acirramento de disputas nas arenas e também gera oportunidades para atores e/ou coalizões sociais desafiantes mudarem as relações de forças nas arenas de ação. Conseqüentemente, o novo arranjo de forças pode fazer surgir novas configurações institucionais no momento seguinte, que atendam melhor os interesses dos agentes que possuam dotações de capital vantajosas na disputa pelo controle das instituições (ACEMOGLU, JOHNSON e ROBINSON, 2005).

Inspirado no IAD, proposto por Ostrom (1990, 2005, 2008), o presente ensaio apresenta adaptações que permitem aprofundar e detalhar as condições exógenas que influenciam a distribuição de poder (dotações) entre agentes e coalizões. Para ilustrar a aplicabilidade do *framework* proposto neste ensaio, suas variáveis são aplicadas à análise da narrativa histórica da indústria de eletricidade brasileira, desvelando os processos de reprodução ou mudança das regras em uso.

3.2 ADAPTAÇÃO DO *FRAMEWORK*: EXPANDINDO E DETALHANDO AS VARIÁVEIS DO IAD

O IAD no formato proposto por Ostrom analisa profundamente a arena de ação, caracterizando sete diferentes tipos de regras e as interações entre os agentes na arena (OSTROM, 2005, 2008), mas carece de articulações entre as variáveis exógenas, de forma que permita-se entender melhor as condições que preconizam a distribuição de dotações entre as coalizões ou atores, para que se possa elucidar a construção histórica que balizou a estruturação dos atributos da comunidade e as relações entre os atores na arena de ação (IGARI et al., 2020).

Diferentemente de Ostrom, que procurou por sistematizar centenas de casos de governança de bens comuns e públicos, este estudo, assim como o de Pavanelli, Oliveira e Igari (2021), adota uma perspectiva menos abrangente, procurando elucidar, através das indicações gerais feitas por Ostrom, as relações entre as

variáveis externas encontradas no caso específico da indústria de eletricidade brasileira. O detalhamento de casos singulares (em desenvolvimento pelos autores em outros trabalhos) resulta no *framework* analítico proposto, que é adaptado ou aprofundado (variando o nível de detalhe de suas variáveis e dotações) de acordo com o impacto das variáveis para cada caso.

A adaptação do IAD (Figura 2) busca expandir o detalhamento das características da comunidade em dotações sociais e econômicas, e as condições biofísicas como capital natural e seus limites (PAVANELLI, OLIVEIRA e IGARI, 2021)³⁰. As regras em uso, por sua vez, passam a ser resultantes das disputas e as arenas são unidades de análise de instâncias concêntricas (níveis de governança) das disputas. As dotações e as regras em uso são intermediadas pela arena de ação e se influenciam mutuamente ao longo do tempo.

Os atributos de comunidades, destrinchados no *framework* ilustrado na Figura 2, resultam em dotações sociais e econômicas, que por sua vez desdobram-se nas seguintes variáveis: a) sociais: i) modelos mentais compartilhados; ii) capital simbólico, iii) capital social; iv) capital humano; v) ideologia; vi) capital político e, b) econômicas: i) capital financeiro; ii) capital tecnológico; iii) capital construído³¹.

A adaptação do *framework* (Figura 2) evidencia e detalha as variáveis externas do IAD, permitindo representar com mais precisão os processos e as articulações entre sociedade, economia e ambiente. Embora Ostrom tenha apresentado com McGinnis o SES (*Socio-Ecological System*) um *framework* institucional hierárquico que articula as variáveis do IAD, o SES também foca nas diferentes regras da arena de ação, não detalhando as variáveis exógenas (dotações econômicas, sociais e políticas, bem como as condições biofísicas historicamente construídas) (MCGINNIS e OSTROM, 2014).

O enquadramento teórico-analítico proposto também representa visualmente os processos de reprodução e mudança institucional ao longo do tempo. A noção de North (1990) de *path dependence*, utilizada também por Ostrom e Basurto (2011),

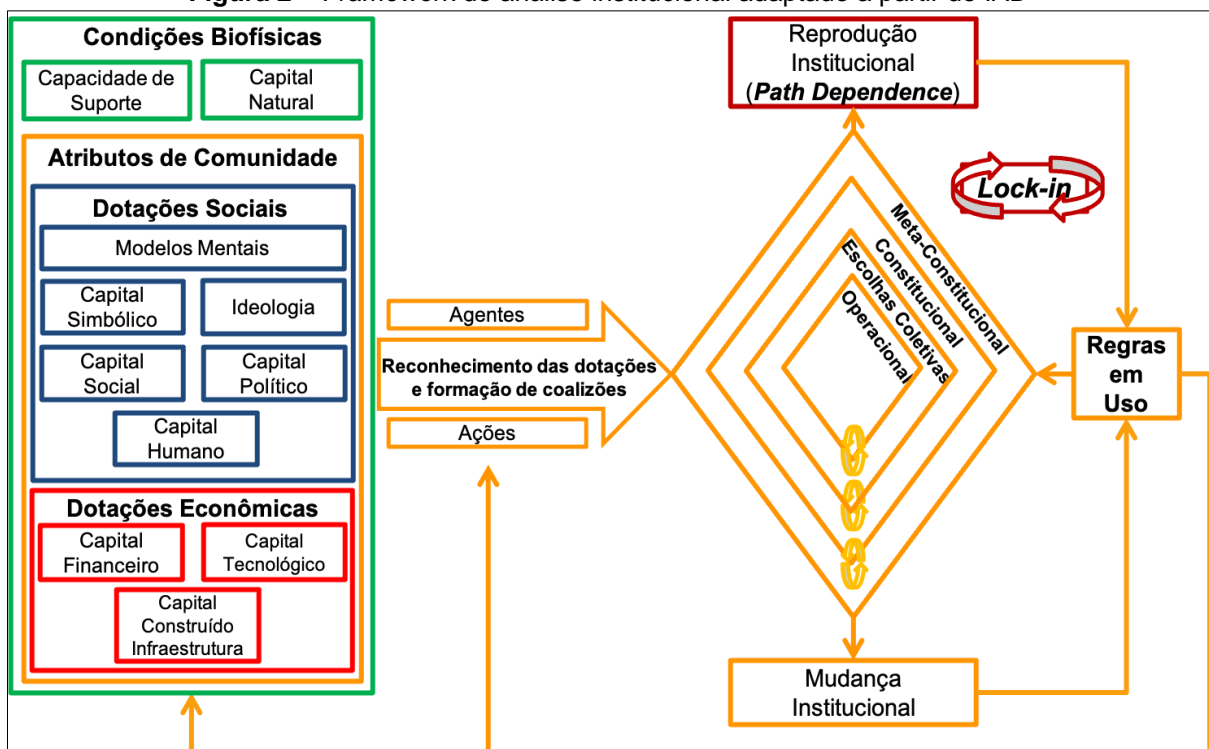
³⁰ Uma versão preliminar do *framework* apresentado na Figura 2 foi apresentado no Seminário Interdisciplinar de Sustentabilidade, realizado pelo Programa de Pós Graduação em Sustentabilidade da Escola de Artes, Ciências e Humanidades da Universidade de São Paulo, com respectiva publicação em anais do evento.

³¹ Há uma diferença entre o *framework* proposto na Figura 2 e o de IAD de Ostrom e o SES que ela elabora em conjunto com McGinnis em 2014, que entendem que o capital construído constitui parte das condições biofísicas. Este ensaio categoriza o capital construído dentro de atributos de comunidade, mais especificamente, conforme apresentado, como parte de dotações econômicas.

indica a reprodução das instituições e experiências diante de agentes que, avessos ao risco, tendem a mimetizar ao longo do tempo soluções disseminadas como bem sucedidas, cristalizando-se em pretensas melhores práticas, restringendo escolhas futuras e dificultando a mudança das regras em uso.

O *framework* tem por premissa que mudanças na distribuição das dotações sociais, econômicas e políticas ou na disponibilidade do capital natural podem estabelecer espaço para novos grupos e coalizões, oferecendo oportunidades de mudanças das regras em uso em um momento futuro.

Figura 2 – *Framework* de análise institucional adaptado a partir do IAD



Fonte: Elaboração do autor, com base em Pavanelli, Oliveira e Igari (2021), Ostrom (2005, 2008), Ostrom e Basurto (2011) e North (1990).

As regras em uso resultantes em um momento do tempo realimentam os estados, tanto dos atributos de comunidade, como da disponibilidade de capital natural. Esta influência recursiva pode tanto reproduzir (sempre que as coalizões dominantes acumularem mais dotações nas disputas nas arenas em seus níveis hierárquicos) quanto mudar (quando as dotações são redistribuídas, por uma crise econômica ou ambiental, por exemplo) as regras em uso em momentos subsequentes.

Para investigar a aplicabilidade do *framework*, o presente estudo utilizou-se de sínteses históricas obtidas na análise da indústria de geração de energia de

eletricidade brasileira de Pavanelli e Igari (2019). A geração de energia elétrica no Brasil pauta-se majoritariamente em grandes usinas hidrelétricas. Apesar dos impactos socioambientais negativos de sua instalação e operação, a hidroeletricidade rompe com a lógica global dominante de utilização de reservas fósseis para geração de energia.

As fontes fósseis representam a apropriação contemporânea da energia solar convertida em biomassa e hidrocarbonetos ao longo de centenas de milhões de anos, um balanço temporal claramente imprudente, que devolve carbono à atmosfera num ritmo muito superior à resiliência dos sistemas socioecológicos atuais. A hidroeletricidade, por outro lado, é muito mais síncrona com relação à conversão e uso de energia.

A energia solar fornece energia para todo o ciclo da água, com a formação de chuvas, acúmulo de energia potencial hídrica (sólida ou líquida) em montanhas e planaltos, que é convertida em energia cinética no movimento dos rios e finalmente das turbinas geradoras. Desta forma, a energia hidrelétrica resulta da apropriação da energia solar e de seus processos de conversão a partir do ciclo hídrico contemporâneo, o que limita a geração e uso de energia elétrica à resiliência e conservação dos ecossistemas presentes.

Uma releitura dos resultados de estudos anteriores dos autores é desenvolvida a seguir, aplicando-se o *framework* proposto na seção 2, no qual os principais conjuntos de variáveis estruturais referem-se às condições biofísicas e aos atributos de comunidade, estes últimos divididos em dotações sociais e econômicas. Através da identificação histórica de evidências empíricas de cada elemento estrutural, vislumbram-se as condições das disputas entre os agentes e é possível compreender os resultados sobre as regras em uso em relação à sua reprodução ou mudança.

3.3 APLICAÇÃO DO *FRAMEWORK* DE ANÁLISE INSTITUCIONAL À NARRATIVA HISTÓRICA DA INDÚSTRIA DE ELETRICIDADE BRASILEIRA

A indústria de eletricidade brasileira iniciou-se ao final do século XIX com o entusiasmo de D. Pedro II e de empreendimentos privados de agentes locais, como Bernardo Mascarenhas e Arthur Thiré no sudeste de Minas Gerais (MEMÓRIA DA ELETRICIDADE, 2015). Tratava-se de concessões municipais para usinas privadas

descentralizadas³² de geração por meio de fontes hídricas e térmicas (movidas a derivados de petróleo). Neste primeiro período, entre 1879 e 1903 (Quadro 1 – Anexo), os agentes que disputam pelos recursos energéticos são majoritariamente locais privados e públicos, sendo os primeiros dotados prioritariamente de capitais econômicos, e os segundos de capital político (PAVANELLI e IGARI, 2019).

A arena constitucional fornece o arcabouço institucional para o estabelecimento das concessões no nível local de escolhas coletivas (Figura 2 – Losangos Concêntricos), que ocorrem em função dos interesses privados nas áreas de maior potencial para geração hidrelétrica. Apesar do uso concorrente dos rios entre a geração de energia e as outras alternativas econômicas, como a transporte, a pesca e o abastecimento humano, animal e agrícola, a escala dos empreendimentos hidrelétricos iniciais não afetava substancialmente a disponibilidade hídrica para as outras atividades e nem a capacidade de suporte ou o limite de resiliência dos rios (Figura 2 – Condições Biofísicas),

O modelo descentralizado de concessão e de geração de energia no período entre 1879 e 1903 dava ampla liberdade à iniciativa privada quanto à escolha de tecnologias (hidráulica ou térmica) e quanto à localização dos empreendimentos. Em situações de intensificação do uso dos recursos naturais, esta abordagem pouco controlada poderia caminhar rapidamente para um cenário de tragédia dos bens comuns quanto à exploração dos recursos hídricos. Além disso, as concessões municipais eram bastante sensíveis ao capital financeiro, social e simbólico (Figura 2 – Atributos da Comunidade) dos empreendedores, que dominavam a arena de ações coletivas, fazendo com as concessões, entendidas aqui como instituições formais (Figura 2 – Regras em Uso) que regulamentam o uso concorrente dos recursos hídricos, atendessem prioritariamente os seus interesses de exploração para uso hidrelétrico.

A partir do século XX, principalmente no período entre 1904 e 1933 (Quadro 1 – Anexo), as multinacionais Light e Amforp se consolidam e concentram os ativos da

³² Em relação à escala, os projetos de geração elétrica podem ser divididos contemporaneamente em centralizados (grandes usinas de geração que transmitem eletricidade para centros de consumo recorrentemente distantes) e distribuídos (aplicações de menor escala, que podem ou não estar conectadas à rede elétrica, e que suprem uma demanda de escala local). Do final do século XIX até início do século XX, a transmissão de eletricidade em grande escala e em grandes distâncias não era tecnologicamente madura e, portanto, todas as aplicações eram descentralizadas, com usinas locais que supriam as demandas municipais.

indústria de eletricidade nacional (LEITE, 2014). Embora a governança dos ativos naquele momento estivesse sob domínio do capital estrangeiro, com a Light operando em muitos centros importantes de consumo, as concessões ainda se mantiveram locais, municipalizadas e com geração descentralizada local até 1934.

Com o aumento de escala da geração e do consumo, associado à concentração do setor em torno das multinacionais, muda a coalizão dominante nas arenas de escolhas coletivas, deixando em segundo plano os empresários locais. A nova coalizão dominante acentua o domínio nas arenas locais e exerce ainda mais influência sobre os municípios e sobre a concessão de uso dos recursos hídricos.

Com isso, observa-se um *lock-in* (Figura 2 – Reprodução Institucional) que favoreceu a persistência dos processos municipais de concessão (Figura 2 – Regras em Uso) que, por sua vez, mantiveram-se como instituições vantajosas também à nova coalizão dominante. O aumento da escala de geração e a implementação de redes regionais de transmissão ainda não foram suficientes para que a indústria de eletricidade brasileira considerasse o capital natural como limitante para suas atividades neste período.

A além da atuação no nível das escolhas coletivas, as multinacionais mobilizaram suas dotações sociais e econômicas também no nível constitucional, resultando na estruturação da cláusula ouro como nova instituição formal para o setor (Figura 2 – Regras em Uso). A cláusula ouro, que entrou em vigor em 1904, estabelecia remuneração fixa em moeda estrangeira para as multinacionais da indústria de eletricidade, poupando-as de flutuações cambiais da moeda local, e garantindo uma vantagem comparativa em relação às empresas nacionais (PINTO JUNIOR et. al, 2007).

A dominância das multinacionais na indústria de eletricidade brasileira foi abalada pela crise econômica de 1929, que fragilizou o seu capital financeiro e evidenciava o risco de insolvência das empresas instaladas no Brasil. Neste contexto de enfraquecimento da coalizão dominante, em 1934 Getúlio Vargas toma o controle desta arena constitucional, derruba a cláusula ouro e inicia um processo de centralização no Governo Federal das funções de planejamento e execução da expansão da indústria de eletricidade brasileira.

O período de 1934 a 1963 (Quadro 1 – Anexo) é caracterizado pela mudança do balanço de forças na arena constitucional. A presidência de Getúlio Vargas é marcada pelo capital simbólico de liderança popular e por posições ideológicas

pautadas na centralidade do Estado no desenvolvimento socioeconômico do país, Estas dotações manifestam-se no capital político necessário para a estruturação de novas instituições formais na arena constitucional (Figura 2 – Mudança Institucional), como a criação do Código de Águas e do CNAEE (Conselho Nacional de Águas e Energia Elétrica), em 1934, passaram a regular o uso dos rios brasileiros e seu potencial hidrelétrico.

Inaugura-se um novo período da indústria de eletricidade brasileira, caracterizado por ocupar os maiores potenciais hídricos do país com grandes usinas de geração e com o poder legal e regulatório centralizado no Governo Federal (GOMES, 2002). Paulatinamente, os ativos da indústria vão sendo incorporados pelo Estado, e este processo é intensificado em 1962, com a criação da Eletrobrás (proposta por Getúlio Vargas em 1954), e em 1964, após o golpe militar (PINTO JUNIOR et. al, 2007). A exploração do potencial hídrico em escala nacional neste período ainda não vislumbra o horizonte de esgotamento da capacidade de suporte para geração de energia hidrelétrica. A governança hídrica é pautada na centralidade do Estado no planejamento e apropriação do capital natural.

O golpe militar de 1964 marcou o início de outra fase na indústria de geração de energia elétrica no Brasil, que perdurou até 1992 (Quadro 1 – Anexo). Um golpe de Estado é uma anomalia subcivilizatória e anti-institucional, que rompe com as premissas mais elementares da vida em sociedade. Trata-se da apropriação violenta do capital político, seguida da sustentação também violenta das demais dotações sociais e econômicas, recorrentemente com ênfase nos elementos ideológicos dos grupos golpistas.

A apropriação violenta das dotações reflete-se no domínio das arenas em todos os seus níveis e controle sobre as instituições, que passam a legitimar, consolidar e fortalecer as novas coalizões dominantes. Este período mostra a centralização do controle dos ativos de geração no Governo Federal, através da Eletrobrás e do Ministério de Minas e Energia (MME). Em meados dos anos 1980, grandes usinas hidrelétricas de geração, como Tucuruí, no Pará, e Itaipu Binacional, no Paraná, consolidaram o modelo hidrelétrico centralizado como maior responsável pela oferta de geração nacional (LEITE, 2014).

Essas imensas usinas representam sinalizações que a indústria de geração de eletricidade reunia capitais tecnológico, construído, financeiro e humano plenamente capazes de conceber empreendimentos e instituições capazes de ultrapassar em

larga margem os limites de resiliência do capital natural. Boa parte destes projetos centralizados foi financiada por organizações internacionais, como o Banco Mundial, que alimentavam com capital financeiro as dotações das coalizões dominantes (PAVANELLI e IGARI, 2019).

Foi também relevante para a o *lock-in* em torno da geração hidrelétrica a formação e consolidação do capital humano formado por engenheiros civis especialistas em barragens e hidroeletricidade, que dominaram historicamente as decisões nas empresas (Figura 2 – Capital Humano) da indústria de eletricidade brasileira (PAVANELLI, 2016; PAVANELLI e IGARI, 2019)

Em 1990, após o período de redemocratização do país, por insolvência das empresas públicas da indústria de eletricidade, fruto do desbalanceamento das tarifas (que não remuneravam adequadamente as empresas de acordo com seus custos de operação) (PAVANELLI e IGARI, 2019), iniciou-se um processo de privatização da indústria, baseado no modelo inglês de separação dos ativos nos setores de geração, transmissão e distribuição. O processo de privatização da indústria de eletricidade, apesar de contar com o alinhamento ideológico das coalizões dominantes, não prosperou como mudança institucional em função da erosão do capital social e político do governo, que culminou com o *impeachment* do presidente Fernando Collor em 1992.

Com o *impeachment*, uma nova coalizão se estrutura, mais robusta, favorável à privatização e inicia-se o período de 1993 a 2002 da indústria de eletricidade (Quadro 1 – Anexo). A privatização, só ocorreu concretamente a partir de 1995, após a equalização das tarifas, e ganhou intensidade a partir de 1997, após a criação da ANEEL (Agência Nacional de Energia Elétrica), autarquia em regime especial criada para regular econômica e tecnicamente a indústria de eletricidade nacional (PINTO JUNIOR et. al, 2007; PAVANELLI, 2019).

Iniciando-se pelo setor de distribuição, a indústria de eletricidade nacional foi sendo assimilada progressivamente pelo capital privado. Sob a perspectiva metaconstitucional, o receituário liberal de redução do Estado, concretizado nas privatizações, demonstra a influência ideológica dominante nesta arena sobre as instituições que balizam a arena constitucional, onde foi regulamentada uma nova governança na indústria, com controle privado por um lado e regulação estatal por parte da ANEEL (Figura 2 – Mudança Institucional).

Em 2000 e 2001 uma série de crises de oferta afetou o suprimento de

eletricidade nos principais centros de consumo do sudeste do país, provocando racionamentos e *blackouts*. Identificam-se na literatura como principais causas das crises de oferta: a crise hídrica no período (LEITE, 2014), representando uma sinalização que os empreendimentos haviam ultrapassado os limites de resiliência hídrica; falhas pontuais em equipamentos (PINTO JUNIOR et. al, 2007); e problemas de infraestrutura de transmissão.

Estes dois últimos fatores relacionam-se à insuficiência do capital construído nos sistemas de geração e transmissão. Há substancial entendimento também que a principal razão da crise foi a falta de planejamento em nível nacional (SAUER et. al, 2003; PINTO JUNIOR et. al, 2007; LEITE, 2014). Na presente análise, os planos também representam instituições resultantes das arenas: constitucionais (e.g. planos decenais do setor); de escolhas coletivas (e.g. leilões para expansão da geração e transmissão de energia); e operacionais (e.g. planejamento estratégico das empresas concessionárias). Assim, o planejamento do setor deveria reunir instituições responsáveis, em conjunto, por dar previsibilidade às relações entre os agentes nos diferentes níveis da indústria, inclusive os consumidores finais.

A mudança institucional que guiou a saída da crise de oferta elétrica do início dos anos 2000 foi responsável pela emergencial implementação e incorporação de fontes térmicas, principalmente alimentadas a gás natural proveniente de gasodutos com a Bolívia. O comitê de crise à época (secretaria vinculada à presidência da república com status ministerial) elaborou o PPT (Programa Prioritário de Termelétricas), uma instituição formal que viabilizou e implementou usinas térmicas em um período de tempo bem curto (PAVANELLI, 2016).

A oferta nacional de eletricidade por fontes térmicas quase dobrou entre 1999 e 2003, saltando de 7.793 MW de potência instalada para 15.140 MW (EPE, 2008). Assim, o final deste período é marcado pelo efeito da mudança institucional nas dotações econômicas da indústria, incorporando no capital tecnológico a geração térmica a gás natural e no capital construído as novas usinas e gasodutos. Estas novas dotações, por sua vez, influenciam o contexto institucional futuro do setor, caracterizando a realimentação positiva representada na Figura 2 pelas setas inferiores, orientadas da direita para a esquerda.

De 2003 em diante, no último período analisado, o Brasil caracteriza-se por um modelo híbrido de governança da indústria de eletricidade, com parte dos ativos privados e parte públicos em todos os segmentos (geração, transmissão e

distribuição), contanto com a ANEEL no papel de órgão regulador e o ONS (Operador Nacional do Sistema) na operação do SIN (Sistema Interligado Nacional).

Neste período, pressões por mitigação das mudanças climáticas começam a fomentar mudanças nas agendas locais e nacionais quanto ao planejamento da expansão da geração de eletricidade, para priorização de fontes mais limpas e renováveis. A Conferência do Clima, instituída em 1992, e seus desdobramentos, como o protocolo de Quioto e a COP 21, pressionaram (e ainda pressionam) os governos locais e nacionais a mitigar suas emissões de gases de efeito estufa.

Um dos impactos destas preocupações com a capacidade de suporte do planeta quanto às mudanças climáticas na agenda brasileira de planejamento energético evidencia-se no PROINFA (Programa de Incentivo às Fontes Alternativas de Energia Elétrica), lançado em 2002. O PROINFA subsidiou tarifas diferenciadas para fontes alternativas de geração, como a eólica e a biomassa. Em 2019, a geração eólica, principalmente originária do nordeste do Brasil, respondeu por 8,6% da oferta elétrica nacional (EPE, 2020), e a cogeração a partir de biomassa de resíduos da cana-de-açúcar, com expressividade no interior paulista, 8,4%.

Em 2012, a ANEEL publicou a RN482, que regulamenta a geração distribuída de aplicações com até 5 MW de potência instalada a partir de fontes renováveis (solar, eólica, pequenas centrais hidrelétricas e biomassa), possibilitando que agentes locais voltem a poder influenciar e participar ativamente da geração elétrica do país, como ocorria no início do século XX. A fonte fotovoltaica através da geração distribuída ainda é tímida no Brasil, e embora tenha apresentado expressivo crescimento anual, ainda representa por volta de 1% da oferta nacional de geração elétrica (EPE, 2020).

A expansão das fontes renováveis indústria de eletricidade depende da estruturação de coalizões suficientemente dotadas de atributos sociais e econômicos, capazes de promover mudanças institucionais nos níveis constitucional, de escolhas coletivas e operacional.

3.4 CONSIDERAÇÕES FINAIS

O *framework* apresentado neste ensaio, inspirado no IAD de Ostrom, buscou entender como se estruturaram as disputas institucionais que originaram reprodução e mudança em cada período. A distribuição de dotações (variáveis estruturais) entre as coalizões ou atores puderam explicar os momentos de mudança do controle da

governança da indústria de geração de energia elétrica brasileira entre o poder público e o privado, assim como as mudanças na fonte primária e tecnologia de geração dominantes para a oferta elétrica.

A crise de 1929, por exemplo, afetou negativamente as dotações econômicas dos entes privados multinacionais, abrindo uma janela de oportunidade para que coalizões com modelos mentais estatistas pudessem assumir protagonismo nas arenas, tornando, paulatinamente, públicos os ativos da indústria de eletricidade nacional. A crise de oferta de 2001 e 2002, ocasionada por uma mudança momentânea no padrão hidrológico evidencia, de fato, uma crise resultante da extrapolação dos limites do capital natural. Esta crise catalisou a adoção de fonte térmica, principalmente a partir de gás natural, na oferta nacional de eletricidade.

Ao categorizar e analisar as evidências históricas a partir das variáveis estruturais apresentadas no *framework* proposto neste ensaio, foi possível identificar a distribuição de dotações entre os principais agentes que disputaram o controle das instituições que balizaram a indústria de eletricidade nacional, contextualizando as escolhas por governança, por tecnologias e fontes de geração.

O *framework* possibilita analisar as relações entre agentes e coalizões ao longo dos níveis de arena e também os efeitos recursivos das mudanças institucionais sobre suas dotações sociais e econômicas, evidenciando efeitos de realimentação positiva. A dinâmica de recursividade reflete também a potência do efeito de reprodução das dotações e instituições ao longo do tempo. As evidências históricas mostram, por outro lado, fenômenos que foram capazes de alterar o balanço de dotações e promover mudanças institucionais no período analisado.

A compreensão das dinâmicas institucionais pelas lentes teóricas escolhidas, principalmente sobre os aspectos que precedem suas mudanças, permitiu observar as interconexões entre sociedade e meio ambiente. As instituições, sob a perspectiva da Economia Ecológica, entendidas como interfaces entre o mundo social e o mundo natural, são determinantes nos processos produtivos de apropriação, distribuição e uso de recursos naturais.

O *framework* apresentou a distribuição de poder entre os agentes (através do mapeamento de suas dotações), e possibilitou a identificação dos interesses dos grupos, recursos e níveis hierárquicos dos momentos de acirramento das disputas. Para a Economia Ecológica, o *framework* pode colaborar como uma ferramenta para aprofundar a compreensão sobre a apropriação historicamente constituída das

dotações (ambientais, sociais e econômicas) que estruturam e ponderam as disputas pelas regras que balizam o uso dos recursos naturais. O framework contribui ainda para o entendimento, em diferentes níveis hierárquicos, do impacto dos interesses de agentes com maiores dotações nas escolhas finais de apropriação, distribuição e uso do capital natural.

3.5 AGRADECIMENTOS

O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior Brasil (CAPES) - Código de Financiamento 001. O primeiro autor gostaria de agradecer à *Fox Fellowship* do *McMillan Center* da Universidade de Yale. Este artigo é um resultado parcial das atividades do Projeto Temático “Governança ambiental na Macrometrópole Paulista, face à variabilidade climática” (processo n. 15/03804-9) financiado pela FAPESP.

3.6 REFERÊNCIAS

ACEMOGLU, Daron; JOHNSON, Simon; ROBINSON, James A. Institutions as a fundamental cause of long-run growth. **Handbook of economic growth**, v. 1, p. 385-472, 2005. . DOI: [https://doi.org/10.1016/S1574-0684\(05\)01006-3](https://doi.org/10.1016/S1574-0684(05)01006-3).

EPE. **Balanco Energético Nacional 2008**. Brasília: Empresa de Pesquisa Energética, 2008. Disponível em: <https://www.gov.br/mme/pt-br/assuntos/secretarias/spe/publicacoes/balanco-energetico-nacional/5-edicoes-anteriores/01-ben-2008-ano-base-2007-pdf/view>.

EPE. **Balanco Energético Nacional 2020 - Relatório Síntese**. Brasília: Empresa de Pesquisa Energética, 2020. Disponível em: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-479/topico-521/Relatório Síntese BEN 2020-ab 2019_Final.pdf.

COASE, Ronald Harry. The problem of social cost. In: GOPALAKRISHNAN, Chennat (Ed.). **Classic Papers in Natural Resource Economics**. Londres: Palgrave Macmillan, 1960. DOI: https://doi.org/10.1057/9780230523210_6.

COSTANZA, Robert; D'ARGE, Ralph; DE GROOT, Rudolf; FARBER, Stephen; GRASSO, Monica; HANNON, Bruce; LIMBURG, Karin; NAEEM, Shahid; O'NEILL, Robert V.; PARUELO, Jose; RASKIN, Robert G.; SUTTON, Paul; VAN DEN BELT, Marjan. The value of the world's ecosystem services and natural capital. **Nature**, Vol. 387: 253-260, 1997. DOI: <https://doi.org/10.1038/387253a0>.

DAILY, Gretchen C. **Nature's Services: Societal Dependence on Natural Ecosystems**. Washington, DC: Island Press, 1997.

DALY, Herman E.; FARLEY, Joshua. **Ecological economics: principles and applications**. 2ª ed. Washington. Vol. 55, 2010.

DEFRIES, Ruth S.; FOLEY, Jonathan A.; ASNER, Gregory P. Land-use choices: Balancing human needs and ecosystem function. **Frontiers in Ecology and the Environment**, v. 2, n. 5, p. 249-257, 2004. DOI: [https://doi.org/10.1890/1540-9295\(2004\)002\[0249:LCBHNA\]2.0.CO;2](https://doi.org/10.1890/1540-9295(2004)002[0249:LCBHNA]2.0.CO;2).

FLIGSTEIN, Neil; MCADAM, Doug. **A theory of fields**. Oxford University Press, 2012.

FREITAS, Carlos Eduardo Dias de; SINISGALLI, Paulo Antônio Almeida; ALMEIDA, Paulo Santos de; LEÃO, Renata de Souza; IGARI, Alexandre Toshiro. O instrumento de outorga e os limites ambientais. **Revibec: Revista Iberoamericana de Economía Ecológica**, Vol. 34: 155-178, 2021. Disponível em: <https://redibec.org/ojs/index.php/revibec/article/view/vol34-1-8>.

GOMES, João Paulo Pombeiro. **O campo de energia elétrica no Brasil-de 1880 a 2002**. 2005. Tese de Doutorado. Faculdade Getúlio Vargas.

HARDIN, Garrett. **The Tragedy of the Commons**. Science Vol. 162: 1243-1248, 1968. DOI: <https://doi.org/10.1126/science.162.3859.1243>.

IGARI, Alexandre Toshiro. Sustentabilidade e instituições: desafios aos pactos civilizatórios. **Nexo Jornal - Políticas Públicas**, v. 28, n. 12, 2021. Disponível em: <https://pp.nexojornal.com.br/opiniaio/2021/Sustentabilidade-e-instituicoes-desafios-aos-pactos-civilizatorios1>. Acesso em: 28 dez 2021.

IGARI, Alexandre Toshiro; PAVANELLI, João Marcos Mott; OLIVEIRA, Camila Espezio de. SINISGALLI, Paulo Antonio de Almeida. Mudanças institucionais e governança de serviços ecossistêmicos. **Diálogos Socioambientais na Macrometrópole Paulista**, Vol. 3: 9-11, 2020. Disponível em: <https://periodicos.ufabc.edu.br/index.php/dialogossocioambientais/article/view/295/267>.

PINTO JUNIOR, Helder Queiroz (Org.); ALMEIDA, Edmar Fagundes; BOMTEMPO, José Vitor; IOOTTY, Mariana; BICALHO, Ronaldo Goulart. Economia da Indústria Elétrica. In: **Economia da energia: fundamentos econômicos, evolução histórica e organização industrial**, 4ª ed. São Paulo: Campus Elsevier, p. 343, 2007.

LEITE, Antônio Dias. **A Energia do Brasil**. 3 ed. Rio de Janeiro: Lexicon, 2014.

MARTÍNEZ-ALIER, Joan. Environmental justice and economic degrowth: an alliance between two movements. **Capitalism Nature Socialism**, v. 23, n. 1, p. 51-73, 2012. DOI: <https://doi.org/10.1080/10455752.2011.648839>.

MCGINNIS, Michael D.; OSTROM, Elinor. Social-ecological system framework: initial changes and continuing challenges. **Ecology and society**, v. 19, n. 2, 2014. DOI: <http://dx.doi.org/10.5751/ES-06387-190230>.

MEMÓRIA DA ELETRICIDADE. Rio de Janeiro: **Memória da Eletricidade**, 2015.

Disponível em:
<http://www.memoriadaeletricidade.com.br/Default.asp?pagina=destaques/linha&menu=368&iEmpresa=Menu#368>. Acesso em: 15 dez 2015.

NORTH, Douglass C. **Institutions, Institutional Change and Economic Performance**. Washington, DC: Cambridge University Press, 1990.

OLIVEIRA, Camila Espezio de; PAVANELLI, João Marcos Mott; IGARI, Alexandre Toshio. Serviços ecossistêmicos e bens comuns: uma breve conceitualização. **Diálogos Socioambientais**, v. 3, n. 07, p. 24-26, 2020. Disponível em: <https://periodicos.ufabc.edu.br/index.php/dialogossocioambientais/article/view/302>.

OSTROM, Elinor. **Governing the commons: The evolution of institutions for collective action**. Cambridge university press, 1990.

OSTROM, Elinor. **Understanding institutional diversity**. 1 ed. Princeton, New Jersey: Princeton University Press, 2005.

OSTROM, Elinor. Doing institutional analysis digging deeper than markets and hierarchies. In: **Handbook of new institutional economics**. Springer, Boston, MA, 2005. p. 819-848.

OSTROM, Elinor. Background on the institutional analysis and development framework. **Policy studies journal**, v. 39, n. 1, p. 7-27, 2011. Disponível em: <https://doi.org/10.1111/j.1541-0072.2010.00394.x>.

OSTROM, Elinor; BASURTO, Xavier. Crafting analytical tools to study institutional change. **Journal of institutional economics**, v. 7, n. 3, p. 317-343, 2011. DOI: <https://doi.org/10.1017/S1744137410000305>.

PAVANELLI, João Marcos Mott. **A integração da geração fotovoltaica distribuída à matriz elétrica brasileira: uma análise sob a ótica institucional**. 2016. Escola de Artes, Ciências e Humanidades - Universidade de São Paulo. Disponível em: <https://teses.usp.br/teses/disponiveis/100/100136/tde-05022017-164641/pt-br.php>.

PAVANELLI, João Marcos Mott; IGARI, Alexandre Toshio. Institutional Reproduction and Change: An Analytical Framework for Brazilian Electricity Generation Choices. **International Journal of Energy Economics and Policy**, Vol. 9: 252-263, 2019. DOI: <https://doi.org/10.32479/ijeeep.8056>.

PAVANELLI, João Marcos Mott. Meso-institutions Ongoing: The Brazilian Case of Thermal Electric Generation. **Anais do Seminário Internacional Territórios da Energia, Mudanças Climáticas e Sustentabilidade da Macrometrópole Paulista - Resumos**, São Paulo: IEE – USP, 2019. Disponível em: <http://www.iee.usp.br/?q=pt-br/noticia/anais-do-seminario-internacional>.

PAVANELLI, João Marcos Mott; OLIVEIRA, Camila Espezio de; IGARI, Alexandre Toshio. Expandindo As Variáveis Externas do IAD de Ostrom: Como Análises Históricas Institucionais Contribuem com Problemas Ambientais Complexos. **Anais Do Seminário Interdisciplinar de Sustentabilidade: Agendas Locais e Globais Da**

Sustentabilidade, 2021. Disponível em:
<https://drive.google.com/file/d/1crfpTFILeVQPr3EGNDdolo59RC2gGkm8/view>.

PIGOU, Arthur. **The economics of welfare**. Londres: Macmillan and co, 1920.

ROCKSTRÖM, Johan; STEFFEN, Will; NOONE, Kevin; PERSSON, Åsa; CHAPIN III, F. Stuart; LAMBIN, Eric F.; LENTON, Timothy M.; SCHEFFER, Marten; FOLKE, Carl; SCHELLNHUBER, Hans Joachim; NYKVIST, Björn; WIT, Cynthia A. de; HUGHES, Terry; VAN DER LEEUW, Sander; RODHE, Henning; SÖRLIN, Sverker; SNYDER, Peter K.; COSTANZA, Robert; SVEDIN, Uno; FALKENMARK, Malin; KARLBERG, Louise; CORELL, Robert W.; FABRY, Victoria J.; HANSEN, James; WALKER, Brian; LIVERMAN, Diana; RICHARDSON, Katherine; CRUTZEN, Paul.; FOLEY, Jonathan A. Safe operating space for humanity. **Nature**, Vol. 461: 472-475, 2009. DOI: <https://doi.org/10.1038/461472a>.

SAUER, Ildo Luís; ROSA, Luiz Pinguelli; CARVALHO, Joaquim Francisco; TERRY, Leslie Afrânio; PRADO, Luiz Tadêo Siqueira; LOPES, J.E.G. **A Reconstrução do Setor Elétrico Brasileiro**. 1 ed. São Paulo: Paz e Terra, 2003.

STEFFEN, Will; Richardson, Katherine; ROCKSTRÖM, Johan; Cornell, Sarah E.; FETZER, Ingo; BENNETT, Elena M.; BIGGS, Reinette; CARPENTER, Stephen R.; VRIES, Wim de; WIT, Cynthia A. de; FOLKE, Carl; GERTEN, Dieter; HEINKE, Jens; MACE, Georgina M.; PERSSON, Linn M.; RAMANATHAN, Veerabhadran; REYERS, Belinda; SÖRLIN, Sverker. Planetary boundaries: Guiding human development on a changing planet. **Science**, Vol. 347, 2015. DOI: <https://doi.org/10.1126/science.1259855>.

ANEXO

As variáveis do *framework* são apresentadas no Quadro 1, acompanhadas da identificação do marco que a representa na narrativa histórica da indústria de eletricidade brasileira. São identificados também os níveis hierárquicos institucionais (arenas) categorizados por Ostrom (2008) (MT = metaconstitucional; CO = constitucional; AC = ações coletivas; OP = operacional). Dentro de cada célula da tabela, entre parênteses, apresenta-se o principal nível hierárquico do marco ou da disputa em questão.

Quadro 1 – Categorização dos eventos históricos de acordo com as variáveis propostas no *framework* de análise institucional (linhas), ao longo dos períodos da indústria de eletricidade brasileira (colunas)

-	1879-1903	1904-1933	1934-1963	1964-1992	1993-2002	2003-2016
CAPITAL NATURAL	Recursos não são considerados fatores limitantes	Recursos não são considerados fatores limitantes	Vislumbra-se o horizonte de esgotamento do potencial hídrico para geração	Potencial hídrico começa a se esgotar, os melhores locais já estão ocupados	Pressões climáticas começam a influenciar agendas de expansão elétrica	Fontes solar e eólica passam a compor recursos primários de geração
CAPACIDADE DE SUPORTE	Reposição de recursos hídricos suficiente para oferta elétrica e outros usos	Reposição de recursos hídricos suficiente para oferta elétrica e outros usos	Reposição de recursos hídricos suficiente para oferta elétrica e outros usos	Reposição de recursos hídricos suficiente para oferta elétrica e outros usos	Crise Hídrica e de oferta elétrica (CO, AC, OP)	Crise Climática (MT, CO, AC, OP)
MODELOS MENTAIS	Liberal (CO)	Liberal (CO)	Estatista (CO)	Estatista (CO)	Liberal (CO)	Liberal CO)
IDEOLOGIA	Privatismo nacional (AC, OP)	Privatismo multinacional (AC, OP)	Nacionalismo (CO, OP)	Nacionalismo (CO, OP)	Privatismo (CO, AC, OP)	Misto (CO, AC, OP)
CAPITAL POLÍTICO	Influência de concessões municipais (AC, OP)	Influência de concessões municipais (AC, OP)	Governo federal centraliza planejamento energético (CO)	Golpe militar (CO)	Redemocratização e Privatismo (CO, AC, OP)	Acordos público-privados (CO, AC, OP)

-	1879-1903	1904-1933	1934-1963	1964-1992	1993-2002	2003-2016
CAPITAL SOCIAL	Redes de contatos entre empresas e governos locais (AC, OP)	Rede de multinacionais e governos locais (AC, OP)	Rede de empresas públicas e governo federal (CO, OP)	Rede de empresas públicas e governo federal (CO, OP)	Rede de empresas públicas e privadas e governo federal (CO, OP)	Rede de empresas públicas e privadas e governo federal, ações coletivas, comunidades locais, e pressões internacionais (MT, CO, AC OP)
CAPITAL SIMBÓLICO	D. Pedro II, Bernardo Mascarenhas, Arthur Thiré (CO, OP)	Light, Amforp (OP)	Getúlio Vargas, CNAEE (CO)	Governo Militar (MME) (CO), Eletrobrás (OP)	ANEEL (AC), comitê de crise (CO)	MME, EPE (CO), ANEEL (AC),
CAPITAL HUMANO	Empreendedores nacionais e multinacionais (OP)	Provido pela Light e pela Amforp (OP)	Desenvolvimento de capital humano nacional para hidrelétricas (CO)	“Barrageiros” (engenheiros especialistas em barragem) (AC, OP)	-	Instaladores Independentes de fontes Fotovoltaicas (OP)
CAPITAL FINANCEIRO	Privado nacional e multinacional (OP)	Privado multinacional (Light e Amforp) (OP) Escassez provocada pela Crise de 1929 (MC), multinacionais perdem solvência (OP)	Estado - Governo Federal (CO)	Estado - Governo Federal (CO) (Eletrobrás - OP) via Banco Mundial (MT)	Privado nacional e multinacional (CO, OP)	Misto (público-privado) (CO, OP)

-	1879-1903	1904-1933	1934-1963	1964-1992	1993-2002	2003-2016
CAPITAL CONSTRUÍDO	Redes Municipais de transmissão (AC, OP)	Redes regionais de transmissão(CO)	Redes regionais de transmissão (CO)	Redes regionais de transmissão (MT, CO)	Redes nacionais de transmissão (MT, CO, AC, OP)	Redes nacionais de transmissão (MT, CO, AC, OP)
CAPITAL TECNOLÓGICO	Hidro e térmica descentralizada	Hidro e térmica (petróleo, carvão) centralizada	Hidro e térmica (petróleo, carvão, nuclear, gás) centralizada	Hidro e térmica (petróleo, carvão, nuclear, gás) centralizada	Hidro e térmica (petróleo, carvão, nuclear, gás) centralizada	Hidro, térmica (petróleo, carvão, nuclear, gás, biomassa), eólica centralizada e fotovoltaica distribuída
EMERGÊNCIA E REPRODUÇÃO	Surgimento da indústria de eletricidade, concessões municipais para agentes privados nacionais e estrangeiros. Modelo descentralizado hidro e térmica (petróleo)	Reprodução do modelo anterior através da Cláusula Ouro, priorizando a remuneração de empresas estrangeiras. Modelo centralizado hídrico e térmico (petróleo)		Manutenção do Estado como centralizador do planejamento e operação da indústria de eletricidade nacional. Modelo majoritariamente centralizado hídrico, com incremento térmico (petróleo, gás, biomassa)		Manutenção de governança privada e pública, e parcerias público privadas. Modelo centralizado, hidrelétrico, térmico (gás, petróleo, nuclear) e eólico e solar distribuída

-	1879-1903	1904-1933	1934-1963	1964-1992	1993-2002	2003-2016
MUDANÇA			<p>Fim da Cláusula Ouro (1934), centralização do planejamento no Governo Federal (a partir de 1954 até 1962).</p> <p>Modelo centralizado hídrico e térmico (petróleo)</p>		<p>Plano de Privatização, abertura do mercado brasileiro de energia de eletricidade no modelo britânico. Modelo centralizado hídrico e térmico (petróleo, gás, nuclear, biomassa)</p>	<p>Inserção de potência instalada eólica centralizada às opções tecnológicas de geração via PROINFA</p>

Fonte: Elaborado pelo autor, com dados obtidos em Pavanelli e Igari (2019).

4 AN INSTITUTIONAL FRAMEWORK FOR ENERGY TRANSITIONS: LESSONS FROM THE NIGERIAN ELECTRICITY INDUSTRY HISTORY

Pavanelli, J. M. M., Sang, Erika V., Oliveira, C. E., Campos, F. R., Lázaro, L. L., Edomah, N., Igari, A. T. An Institutional Framework for Energy Transitions: Lessons from the Nigerian Electricity Industry History. Submitted to **Energy Research and Social Science** on 18 June 2022.

ABSTRACT

Reducing the dominance of fossil-based electricity generation is a crucial strategy to address climate change. However, issues impacting on sustainable energy transitions such as the petroleum industry's sunk costs and other socio-political influences can delay, halt, or even revert decisions in favour of renewable energy sources. Most traditional economic models often fail to consider the social, institutional and historical interrelated and recursive relationships in energy systems decisions and planning. In this paper, we explored the historical electricity dynamics in the Nigerian electricity industry to ascertain how they have impacted on energy infrastructure choices. Using the Multidimensional Institutional Dynamics Analysis (MIDA), we built a historical narrative of the Nigerian electricity industry dynamics covering the: imperial period (1896-1960); early independence period (1961-1970); military regime period (1971-1985); first economic reforms period (1986-1999); and intensive privatization period (2000-2020). This paper proposes a framework that articulates institutional dynamics, applying a multi-level historical approach to explain energy infrastructure and governance choices. It presents the complex cross-scale interactions and the broad set of drivers influencing energy transitions over time. The framework can identify critical aspects for institutional change and the prospects for different electricity infrastructure sources and governance modes.

Keywords: Energy in Africa; Energy history; Institutional Analysis and Development; Institutional Dynamics; Institutional Change.

Declaration of Interests: None.

4.1 INTRODUCTION

Electricity is a modern type of energy and can be converted to multiple other forms (e.g., thermal, mechanical). The electricity share represented around 20% of the world's energy supply in 2018, of which 63,9% was generated by coal, oil, or natural gas (IEA, 2020). To shift this trend and introduce an appropriate amount of renewable energy sources in the electricity mix, an energy transition away from fossil fuels must occur, complying with planetary safe operating boundaries (ROCKSTRÖM et al., 2009; STEFFEN and ROCKSTRÖM, 2015) and multilateral climate agreements (COP 21, 2015). However, energy transitions that reduce fossil fuel emissions are still

incremental and insufficient (GERMÁN, AMADO and SAUER, 2016; LAMPIS et al., 2021; YORK and BELL, 2019a)

The energy transition is usually identified as an expressive shift from fossil fuels to renewables in energy production and/or consumption patterns (EDOMAH, 2019; SMIL, 2017a). Social, economic, political, and environmental drivers are relevant for achieving substantial energy transitions (SOVACOOOL et al., 2020). The energy transitions definition in this study also encompasses incorporating new renewable sources to meet the increasing demand, called energy additions (YORK and BELL, 2019b). Then, renewable additions reduce the relative share of fossil fuel power plants in electricity generation.

Research has shown that new sources can rapidly be added to national or regional electricity offers (e.g., the Brazilian case of the sudden expansion of thermal generation in the early 2000s (PAVANELLI, 2016, 2019; PAVANELLI and IGARI, 2019)) or can be added incrementally and throughout extended periods (e.g., the consolidation of oil's global dominance (SOLOMON and KRISHNA, 2011)).

Sovacool (2017) and Smil (2015, 2016a, 2017a, 2017b) compiled several complex cases of energy transitions, detailing both types of change: rapid and slow-paced. Nevertheless, no consolidated model has been proposed to analyze fast and slow-pace transitions and their likelihood of occurrence. This difficulty might be related to the local cultural diversity and biophysical heterogeneity among the different energy transition cases.

Technological advancements and economic feasibility explain only part of the choices for the source (fossil vs. renewable) and governance modes (centralized vs. decentralized, and public vs. private) in electricity industries (PAVANELLI and IGARI, 2019). Institutions (rules and norms) play a relevant role in structuring the interface between social and ecological systems (FOLKE, 2006; MCGINNIS and OSTROM, 2014; PAAVOLA, 2006). They can foster or hinder some choices for energy sources and governance instead of others. Formal and informal institutions are guidelines for social relations, making their outcomes predictable for agents. The institutional settings result from disputes between individuals and groups in social arenas. In those disputes, dominant coalitions set institutions suitable for safeguarding their interests. Therefore, understanding institutional change processes in electricity industries is a promising pathway for investigating the historical evidence and developing a proper context for present and future energy transitions.

Institutional emergence, reproduction, and change are identified in this research as essential for understanding how sources of generation and modes of governance were chosen and consolidated throughout time in different institutional hierarchical levels (PAVANELLI and IGARI, 2019). Each hierarchical level accounts for one or more groups or coalitions with preferences for source, technology, and/or governance option (OSTROM, 1990a; 1990b; OSTROM, 1999; OSTROM, 2008a; 2008b; OSTROM et al., 1999a; POLSK and OSTROM, 1999). Edomah and others (EDOMAH, BAZILIAN and SOVACOOOL, 2020) pointed out that conciliating public policy arrangements to citizen-claimed preferences can lead to a more sustained and legitimized energy transition, evidencing those multilevel institutional dynamics are pivotal for shifting energy patterns.

This study proposes a multilevel (operational, collective choice, constitutional and meta-constitutional) and multidimensional (environmental, social, and economic) institutional framework based on Ostrom's (1990a, 2008b) and North's (1990, 2008) theoretical foundations to analyze historical evidence and to categorize the main drivers for institutional reproduction or change. Institutional outcomes are the choices for generation sources and governance in the Nigerian electricity industry. The present study unveils the history of the Nigerian electricity industry according to institutional theoretical lenses to understand its emergence, reproduction, and change mechanisms. Results contribute to understanding how and why the agents' (or coalitions') preferences for governance and generation sources might have been reproduced or changed along with Nigerian history.

Nigeria is the most populated country in Africa, with 206 million inhabitants in 2020 (WORLD BANK, 2020). The country struggles to advance in the energy transition to renewable sources and pursues goals regarding improving its network security and reliability, as declared by the State Policy (The National Renewable Energy and Efficiency Policy - NREEEP). According to Emodi (2016), some of the main problems in the Nigerian electricity industry are technical research and human capital shortcomings, the lack of substantive investments, and the recurrent instability of the electricity infrastructure. The country presented a representative change in the preferences for generation sources and governance structure in the electricity industry after 1960 and the independence from Great Britain. Also, Nigeria is expected to increase its population (WORLD BANK, 2020) and, consequently, its electricity demand (IEA, 2020).

On the other hand, Nigeria is endowed with fossil primary energy resources such as oil and gas reserves and renewables, with substantial hydrological, solar, and wind potential. From colonial to military, political shifts disrupted the former balance among economic agents and fostered the long-term choices for primary sources and governance of the electricity industry. Therefore, the energy transitions in Nigeria are less constrained by the availability or abundance of sources and take place in a historical context of substantial political, social, and economic changes, which presents a suitable case to understand the aspects behind changes in choices for the generation source and the governance in the national electricity industry.

In the next section, we present the institutional theoretical foundations, emphasizing the ideas and implications of Ostrom and North's contributions and section 3 presents the methodology. The main findings are presented in section 4, highlighting the institutional framework, and the historical evidence for a period of 124 years. Finally, we present the policy implications and conclusions and identify future research directions in section 5.

4.2 GRAPPLING A THEORETICAL FOUNDATION FOR ENERGY TRANSITIONS AND INSTITUTIONAL CHANGE

Mainstream economic-centered institutional approaches attribute the reproduction and change of the institutions to an equilibrium toward quasi-optimal organizational configurations that are aimed at minimizing transaction costs (OSTROM et al., 1979; DENZAU and NORTH, 1994; GREIF and MOKYR, 2017; DAVIS and NORTH, 1971; OSTROM, 1993, 2000). However, concurrent social-centered approaches have highlighted the importance of social preferences and attributes as drivers or constraints in the processes of institutional evolution (DENZAU and NORTH, 1994; GREIF and MOKYR, 2017; OSTROM, 2008b). Furthermore, new institutions in emerging fields arise from consolidating agents' preferences, materializing the first institutions that guide social interactions in a new economic sector (PAVANELLI and IGARI, 2019). This initial institutional set usually emerges from previous institutionalized neighbor fields (GRUNDMANN and EHLERS, 2016; SHAH and NILES, 2016).

This early institutional transposition is recurrently driven by social capital (COLEMAN, JAMES, 1988; OSTROM, 1993, 2000a, 2009a) accumulated by the

dominant coalition in the emergent field. Social capital can be manifested in many forms, such as legitimacy (OSTROM, 2008b), reputation (COLEMAN, JAMES, 1988), community acknowledgment (BOURDIEU, 1989), reciprocity, sense of belonging (BODIN, 2017), and social cohesion (GRITSENKO, 2018). Legitimacy and social cohesion can be understood as community shared social capital, which provides non-rival and non-excludable public benefits, such as reduction of free-riding, malfeasance, and lower costs for monitoring and enforcing social compromises.

On the other hand, reputation, community acknowledgment, and political representativeness are manifested as social endowments, which benefit a limited group of privileged individual or collective agents. Therefore, social endowments legitimize the enforcement of institutions even when they are perverse to some groups, reinforcing dominant coalitions and their institutional advantages in the arena. Institutional advantages encompass power distribution between agents such as trade benefits and facilitated access or use of a particular set of natural, technological, constructed, or financial resources.

Path dependence, in turn, explains institutional reproduction in the field or arena and refers to the tendency of agents to reproduce (mimic) past institutional choices even when their efficiency or outcomes are sub-optimal. It considers that mimetic behavior emerges when a norm or strategy is identified as suitable to avoid risk and uncertainty (NORTH, 1990; OSTROM, 1990a, 2008b; a; OSTROM and BASURTO, 2011). The path dependence mechanism traps other institutional options by locking agents' preferences and reproducing the institutional choices. So, dominant agents or coalitions in the action arena may not change their institutional preferences even when a more efficient institutional option emerges.

Changes in biophysical conditions (such as the availability of natural capital or its exhaustion) or community attributes (e.g., the social, political, and economic endowments held by agents or coalitions) might reconfigure power distribution and resettle coalitions (OSTROM, 1990; POLSK and OSTROM, 1999; BAUWENS, GOTCHEV and HOLSTENKAMP, 2016; KELLY and GEYER, 2018). A crisis, an episode when institutions can no longer deliver predictability for social relations and actions, can also affect the power distribution between coalitions and foster institutional change (PAVANELLI and IGARI, 2019). Those crises can be endogenous when they happen inside the economic sector or social field under analysis (e.g., when a natural monopoly goes bankrupt) or exogenous when it occurs outside the economic sector or

social field (e.g., the 1929's crash which impacted the world's investments in all economic sectors). Internal and external crises can redistribute social, political, and economic endowments and modify the ecosystem carrying capacity, reconfiguring, or stirring the disputes for power to control institutional choices.

Many scholars have explored each institutional process (emergence, reproduction, and change) separately (NORTH, 1990; KELLY and GEYER, 2018; MÄRKER, VENGHAUS and HAKE, 2018; LAMMERS and HOPPE, 2018; HOLSTENKAMP, 2019). Apart from theories proposed by Acemoglu and others (LAMMERS and HOPPE, 2018) and DellaPosta et al. (KELLY and GEYER, 2018), historical recursiveness is rarely understood as an endogenous phenomenon. This research incorporates historical effects in institutional reproduction and change since persistence and incorporation in culture are recursive processes that foster institutional lock-ins and hinder change. The historical evidence compiles more than one hundred years of Nigerian electricity history.

For the analysis of energy transitions, we deployed an adaptation of Ostrom's IAD framework (OSTROM, 1990a, 2008a; 2008b). The IAD was chosen due to its capacity to analyze multiple hierarchical levels, considering biophysical conditions and community attributes to explain institutional choices. Energy transitions encompass multiple governance hierarchical levels and articulate local, regional, national and global preferences (EDOMAH, BAZILIAN and SOVACOOOL, 2020), making Ostrom's IAD a suitable starting point for anchoring the theoretical foundations of the proposed framework.

4.2.1 Fundamentals of Ostrom's IAD Framework

Ostrom (1990a, 2008a; 2008b) was primarily concerned with problems regarding the commons. However, the orthodox approaches for governing the commons dilemmas were addressed by economists, who defined commons as those goods and services characterized by rivalness – the physical feature that impede their simultaneous use by more than one agent – and by non-excludability – the absence of formal or informal institutions which define their rights for private appropriation (LAMMERS and HELDEWEG, 2019). Like Ronald Coase (MILCHRAM et al., 2019; LAMMERS and HOPPE, 2019), early institutional economists understood that simply assigning property rights to commons would make the markets appropriate to allocate

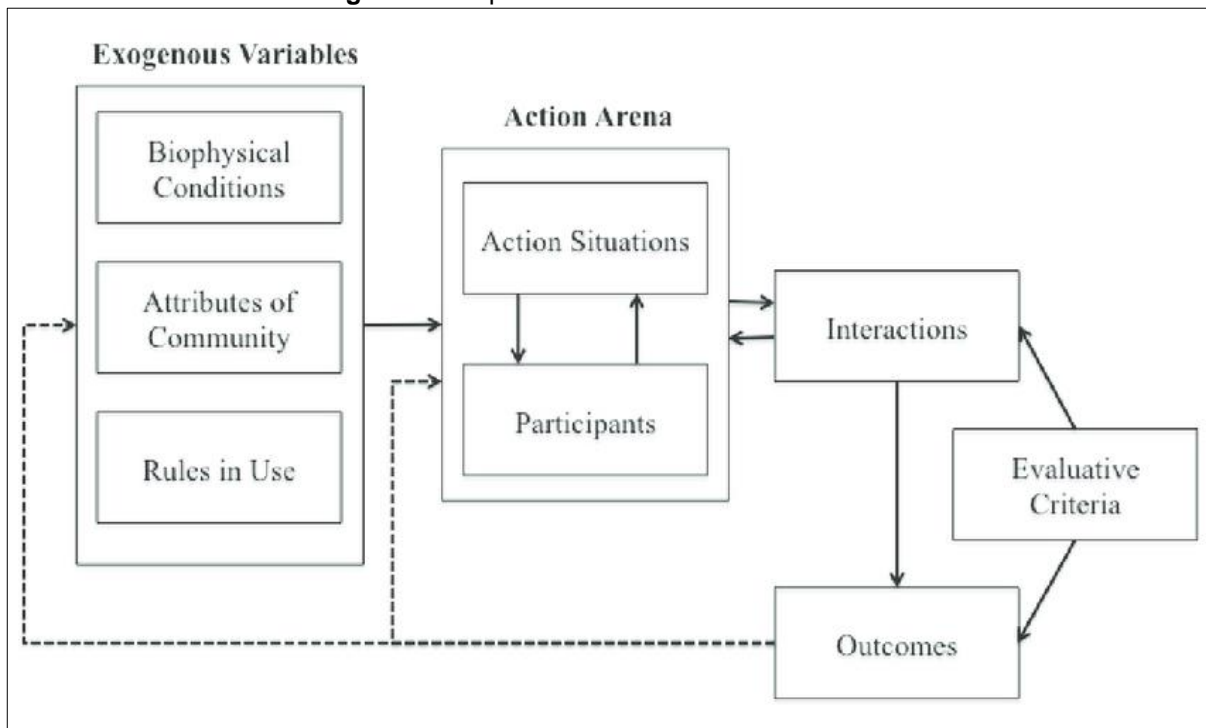
them and prevent inefficient use. As Pigou (SPIJKERBOER, 2019) others understood that, instead of markets, the State would be responsible for delivering the appropriate economic incentives for private management of the commons through institutions such as taxes and subsidies. On the other hand, Ecological Economists (PAAVOLA, 2006) understand that the State's role regarding commons governance is far beyond assigning property rights or enacting taxes or subsidies as guidelines for private management. The state might steward social welfare and environmental sustainability. The scope of their institutions for managing commons, such as the establishment of protected areas and policies for air, water, soil, and natural resources conservation, might be oriented simultaneously by social civilizing bottom lines (e.g., poverty alleviation, access to food, water, energy, healthcare, education) and by safe and sustainable environmental standards (e.g., climate change, air pollution, availability of fresh water, forests, and biodiversity).

Amidst this context of a theoretical dispute regarding the role of the State, markets, and the scope of institutions in the governance of the commons, Elinor Ostrom (2008a; 2008b) proposed an alternative approach by considering locally settled institutional arrangements as a promising pathway for addressing the commons dilemma. The author was concerned with the legitimacy of institutional choices (i.e., the rules-in-use), so she incorporated the diverse social and economic interests of distinct groups to analyze the preferable institutional configuration rather than departing from the market-driven premise that explains the choice for institutions as an outcome of a mere economic-utility stand-alone interest, such as Pareto's optimality. By understanding how collective action is structured and influences institutional contexts, the author explained many cases (OSTROM, 1990a, 2008b) where local communities could manage resources, crafting and maintaining rules-in-use capable of sustaining the long-term availability of the commons.

Ostrom concluded that neither market nor State contributions to governance could explain an institutional outcome's suitability alone. In the emblematic cases of farmers' irrigation collective governance in California and Southeast Asia, the diversity of the local arrangements and the compliance with community-enforced rules (social capital-driven) were identified as a more parsimonious explanation for institutional and governance outcomes (BRONDIZIO, OSTROM and YOUNG, 2009; OSTROM, 2000a, 2008b, 2002, 2009a; 2009b; Ostrom et al., 1999b). Ostrom (1990a, 2008a, 2008b, 2009b) with others (OSTROM and BASURTO, 2011; OSTROM and COX, 2010;

POLSK and OSTROM, 1999) accumulated evidence to propose a framework (Figure 1) to explain institutional dynamics for commons' appropriation, distribution, and usage, as a synthesis of decades of empirical analysis (e.g., fishery in Maine (OSTROM, 1999), irrigation in California (OSTROM, 2008), and southeast Asia (WOLSINK, 2020), and many forests conservation cases (OLADIPO et al., 2018)).

The IAD framework stresses the social interactions in action arenas (Figure 1 – Central Elements). We highlight the conflictive relationships (that were not the focus of Ostrom's original proposition) of participants (agents and coalitions) engaging in action situations (e.g., disputes for material resources, social positions in the community, governance rules) according to what is at stake and what is taken as granted. Governance rules and social positions in the community are usually taken for granted in ordinary actions arenas to resolve disputes regarding appropriation of benefits or allocation of liabilities. Those governance rules are institutions (both formal and informal) that conceive predictability to the outcomes of the action arenas (Figure 1 – Elements on the Right Side). We understand that the critical evaluative criteria of the outcomes (Figure 1) are usually in compliance with the interests of the dominant coalition in the action arena, regardless of whether the outcome is fair, equitable, or democratic. The positive feedback of the outcomes in action arenas and towards exogenous variables reinforces the social and economic endowments of the dominant coalitions. Therefore, the positive feedback hinders institutional changes that could produce different outcomes. This feedback-driven lock-in phenomenon represents fundamental evidence of institutional reproduction in action arenas.

Figure 1 – Representation of the IAD framework

Source: Ostrom (2008b).

On the other hand, the IAD framework relies on changes in their exogenous variables (Figure 1 – Elements on the Left Side) to explain how and why the outcomes of the action arenas could change. Externally-driven changes in biophysical conditions (e.g., soil productivity, water availability, climate suitability, biomass production), in attributes of the community (e.g., economic inequality, social ties, community cohesion, reciprocity, reputation), or rules-in-use (e.g., property rights, trade, governance, social control, monitoring, and sanction) would produce a novel balance of social and economic endowments among the agents in the action arena. Then, new dominant coalitions can rise and promote institutional change toward alternative outcomes and feedback (setting a new path-dependent trajectory). This social arena's approach is analogous to the notion of fields (LAMMERS and HOPPE, 2019) and institutional fields (MÄRKER, VENGHAUS and HAKE, 2018), and refers to the social instance where symbolic disputes for appropriation and accumulation of diverse types of capital occur, in which outcomes are usually hard to predict. Action arenas may be materialized as a congress, an assembly, a local cooperative, a deliberating or consultative council, and many other organized social instances focused on crafting formal rules.

Therefore, our view of Ostrom's IAD framework differs from the more frequent collaboration-oriented, collective action-driven, and context-centered analysis, as we

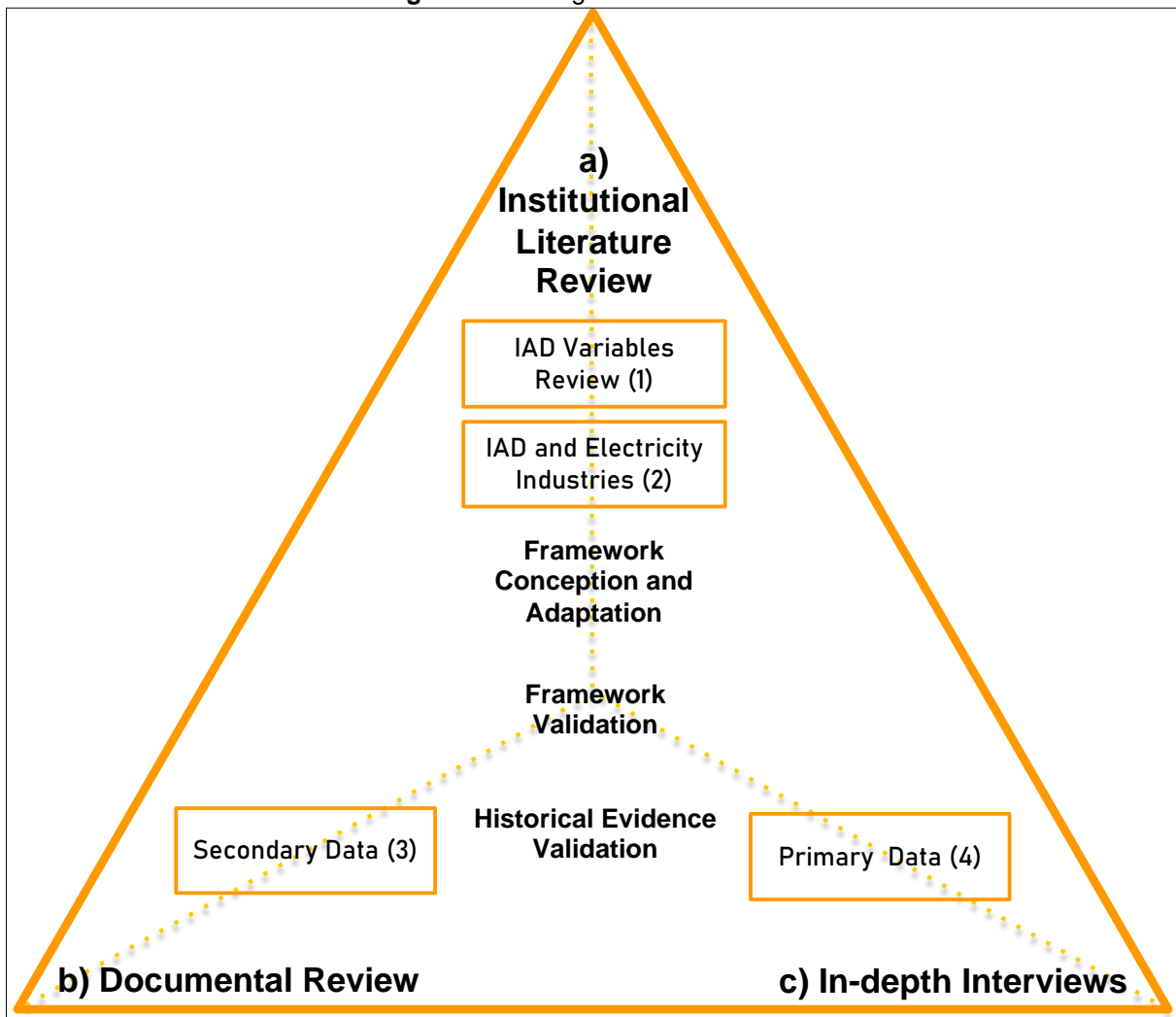
emphasize dispute-oriented and endowment appropriation-driven approaches in a long-term and multidimensional scope. The multidimensional scope will be appropriately detailed in the presentation of the analytical framework (results section). The IAD was initially designed to analyze how local communities set institutional preferences for governing the commons (e.g., irrigation systems, fishing sites, forest resources). In those contexts, exogenous variables were taken for granted, and the analyses usually addressed how novel rules for collective use of the commons emerged from collaboration-oriented actions arenas. Social capital plays a pivotal role in the effectiveness of those collective actions.

In contrast, to the comparative transversal research approach of the dominant IAD studies, our proposal emphasizes longitudinal and historical investigation of institutional changes. Then, the exogenous variables, which usually represent relatively fixed context parameters to the action arenas in comparative transversal approaches, are seen as dynamic and explicative of long-term institutional change in the historical longitudinal analysis. Institutional choices for electricity generation involve long-term processes encompassing numerous agents throughout hierarchical levels of governance.

4.3 MATERIALS AND METHODS

This research is supported by a triangulation of methods (CRESWELL, 2003, 2009) which comprises three main steps: i) A literature review of Ostrom's institutional contributions to New Institutional Economics and Ostrom's IAD (Institutional Analysis and Development) studies, followed by studies applying/adapting the IAD to electricity industries in order to develop an analytical framework; ii) a document review, using qualitative and quantitative data of Nigeria's electricity history and; iii) in-depth interviews with specialists to validate the results from the historical narrative retrieved from the document review. An illustration representing the methodology is presented in Figure 2. The orange boxes inside the triangle of Figure 2 represent each part of the triangulation process.

Figure 2 – Triangulation of Methods



Source: Developed by the authors based on Creswell (2003).

The triangulation of methods increases the robustness of the findings from the qualitative approach (CRESWELL, 2003). For example, in-depth interviews provided information to confirm, complement, or even challenge (as a way of validating) the historical evidence retrieved from the document review. At the same time, theoretical triangulation in the literature review supported the selection of variables that integrate the institutional framework we proposed in this paper, taking as the main point of departure the studies that applied or adapted Ostrom's IAD framework.

We detailed in the next subsections the operationalization of each part of the triangulation. While the theoretical research indicated the concepts and definitions for institutional variables capable of explaining reproduction and change in formal and informal rules. The documental review was supported by the historical narrative obtained during the in-depth interviews to increase robustness of the findings and to a certain the proper timeframes of the various periods.

4.3.1 Institutional Analysis and Development (IAD) framework and its adaptation in electricity industry analysis

The choice for Ostrom's IAD is due to the framework's emphasis on “rules-in-use” as outcomes of disputes between agents and coalitions in the multilevel action arenas. Action arenas are instances where agents dispute resources and institutional control. The disputes are modulated by environmental, social, and economic endowments historically appropriated by agents and coalitions. The first literature review (orange box #1 in Figure 2) was non-exhaustive and captured Ostrom's main concepts and critical variables that we adapted, detailed, and deployed in this paper (BRONDIZIO, OSTROM and YOUNG, 2009; MCGINNIS and OSTROM, 2014; OSTROM, 1986, 1993, 1999, 2000b, 2002, 2003, 2008, 2009a, 2009b, 2010, 2011; OSTROM et al., 1999a; OSTROM and BASURTO, 2011; OSTROM and COX, 2010; POLSK and OSTROM, 1999; POTEETE and OSTROM, 2004). This immersion in her ideas aimed to clarify the origins and epistemological limits of the elements from the original IAD framework and ensure that the framework proposed here does not conflict with the author's core ideas.

The second literature review (orange box #2 in Figure 2) was systematic. It aimed to identify studies that applied/adapted Ostrom's IAD framework or specific concepts and variables to analyze electricity industries and sectorial cases. We departed from keywords, searched in two different scientific databases (Scopus and Web of Science), which restricted the inclusion criteria as follows: [("IAD") or ("Institutional Analysis and Development")] and [("Electric Sector") or ("Electricity Sector") or ("Electrical Sector") or ("Utility") or ("Utilities") or ("Electricity")]. Documents/papers were excluded if they did not present at least one citation or variable of the seminal Ostrom's IAD framework (OSTROM, 1990a, 1990b; OSTROM, 1999; OSTROM, 2008a, 2008b; OSTROM, 2011; OSTROM et al., 1999a; OSTROM and BASURTO, 2011; POLSK and OSTROM, 1999).

This final selection resulted in 21 papers (ASQUER, 2011; BAUWENS, GOTCHEV and HOLSTENKAMP, 2016; CHERP, JEWELL and GOLDTHAU, 2011; GRITSENKO, 2018; GRUNDMANN and EHLERS, 2016; HELDEWEG, 2017a, 2017b; HOLSTENKAMP, 2019; KELLY and GEYER, 2018; LAMMERS and HELDEWEG, 2019; LAMMERS and HOPPE, 2018, 2019; LAMMERS and VASENEV, 2017; MÄRKER, VENGHAUS and HAKE, 2018; MELVILLE et al., 2018; MILCHRAM et al.,

2019; SHAH and NILES, 2016; SPIJKERBOER et al., 2019; VERHOOG, GHORBANI and DIJKEMA, 2016; VAN DER WAAL, DAS and VAN DER SCHOOR, 2020; WOLSINK, 2020), which supported the adaptation of Ostrom's IAD framework proposed in this study. The selected documents were fully read to identify:

- i) Whether Ostrom's IAD was applied literally or adapted, and
- ii) How the IAD was adapted to analyze constitutional arenas (policy-making level), addressing agents and coalitions with heterogeneous interests and endowments.

4.3.2 Document Review

The review searched for documents (orange box #3 in Figure 2) that could evidence the historical change in the economic, technical, and institutional contexts. Documents included scientific papers, books, and information on official websites of Nigerian electricity sector players, such as regulatory agencies, ministries and public or private companies. The keywords (inclusion criteria) searched during the document review on Scopus, Google Scholar, and Web of Science were organized in the following logical string: [("Nigerian electric* sector") and ("institution*") and ("history")], where "*" indicates any complement of the term.

The documents selected according to the inclusion criteria were papers, book chapters, official documents, and other studies that presented facts, tables, contents, past statistics, or any elements that contributed to retrieving the history of the Nigerian electric sector. The result was a timeline with hundreds of facts organized according to the variables of the institutional framework as presented in this research, represented by orange box #3 of Figure 2. During the document review, documents regarding installed electricity generation capacity presented conflicting data. Most of the installed capacity was not fully operational due to inadequate financing, lack of personnel, gas supply, and maintenance issues (OLADIPO et al., 2018). We estimate that only one-third of the total installed capacity is deployed to generate electricity in Nigeria (ADVISORY POWER TEAM, OFFICE OF THE VICE PRESIDENT AND POWER AFRICA, 2015; OWEBOR et al., 2021). However, historical data showed only the total installed capacity (in MW) rather than the power deployed to supply electricity (in MWh). This lack of accurate data regarding the electricity supply can overestimate the

generation in older, underused, or underfinanced facilities.

Moreover, there was a lack of electricity generation information for prolonged periods in the Nigerian records. As the intent of this study was not to assess exhaustively (year by year) the evolution of the electricity generation sources in Nigeria, instead, we stressed some moments of change (e.g., where an option/source's quantity becomes visible, with more than 10% of the total share, and/or dominant) (SMIL, 2016b, 2017a, 2017b). Then, we resorted to interpolations throughout the gaps from one register to the next. Independently of what may have happened between the available records, it was possible to identify the main changes in the participation of different sources in the Nigerian electricity industry history and their respective dominance in each period.

4.3.3 In-depth Interviews

In-depth interviews with specialists supplied the primary data for the institutional analysis (orange box #4 in Figure 2). That contributed to confronting the historical facts of the narrative from the document reviews or deepening the knowledge of the participants' current renewables (and other sources) expectations. The inclusion criteria were determined by the agents' experience represented by at least two years of acting in a decision-making position involving an organization in the Nigerian electricity industry.

The participants were chosen from a list consisting of contacts from some of the co-authors who were in Nigeria. We invited about twelve potential participants from the list through e-mail and/or telephone. Only three respondents agreed to participate (all males):

- i) A foreign private entrepreneur focused on commercial activities of photovoltaic equipment and systems, with nine years of experience, from which four years in Nigeria (identified as A1);
- ii) A manager of an energy distribution private company with 20 years of experience (identified as A2) and;
- iii) A Nigerian senior attorney with more than 35 years of experience who worked for the Senior Legal Support of the Director General of the Nigerian Presidency's Bureau of Public Enterprises, dealing with electricity sector

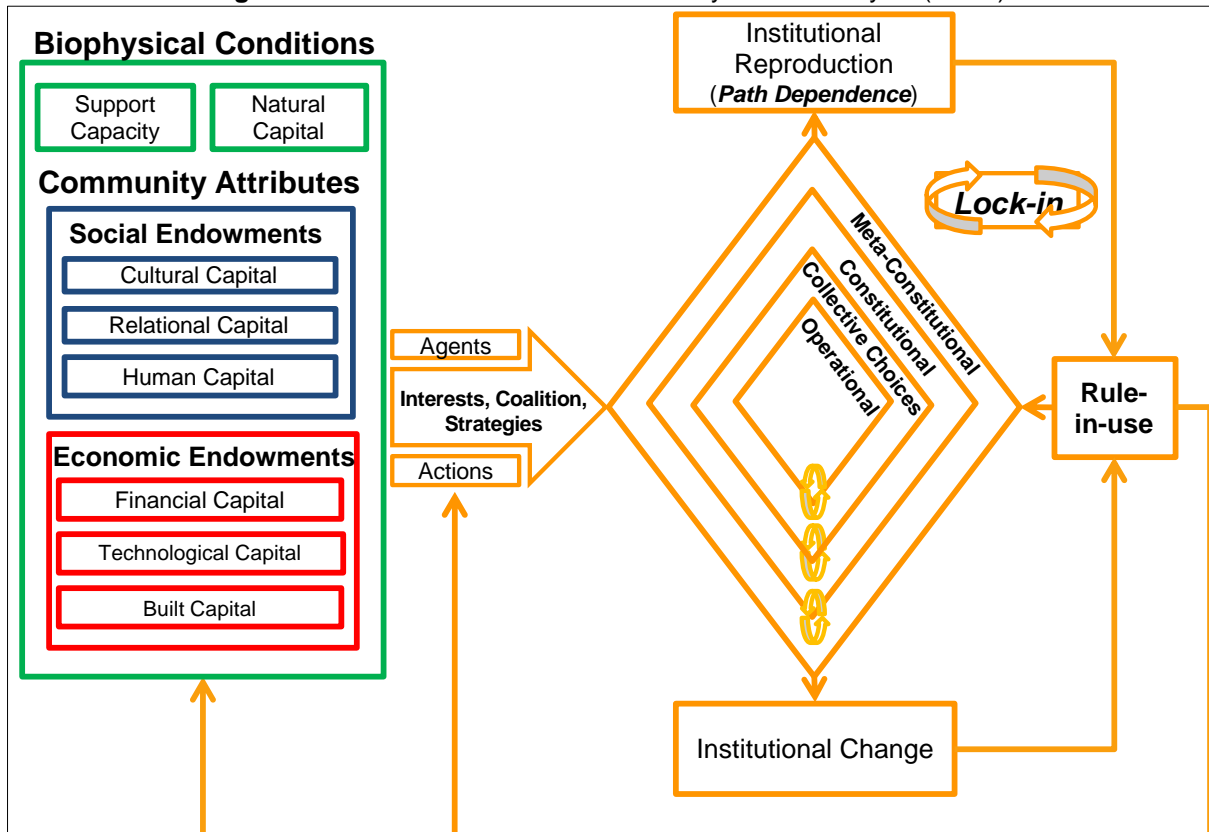
matters (2003-2007), as a former legal advisor/counsel of the Nigerian Electricity Regulatory Committee (NERC) and as committee chair in a private oil and gas production and exploration company for seven years (identified as A3).

Participants identified as A2 and A3 elucidated some historical facts - such as the privatization processes, the unbundling of the industry, and validated the division of the periods chosen to drive the narrative. Participant A1 was relevant to illustrate the difficulties of expanding renewables, especially photovoltaic distributed generation.

4.4 PRESENTING THE MIDA: MULTIDIMENSIONAL INSTITUTIONAL DYNAMICS ANALYSIS

We propose an analytical framework with broad scope variables representing the main influences on agents' past and current choices in the Nigerian electricity industry. The institutional reproduction and change processes are described and explained by the Multidimensional Institutional Dynamics Analysis framework – MIDA, illustrated in Figure 3.

Figure 3 – Multidimensional Institutional Dynamics Analysis (MIDA)



Source: Elaborated by the authors (2022), based on Ostrom (1990, 2005, 2008) and North (1990, 2008).

The structural part of the MIDA, derived from Ostrom (OSTROM, 2008a), presents the biophysical conditions (green boxes) and the community attributes (blue and red boxes in Figure 3) as drivers to explain the power distribution between agents. The functional part of the MIDA assumes that agents have three main choices to deploy their actions: a) regarding compliance, they can comply or confront the current institutional *status quo*; b) regarding coalitions in arenas, agents can choose if (and with whom) they form coalitions; and c) regarding strategies and behavior, they can choose their preferable strategies and behaviors. The center diamond of the MIDA is based on the notion of action arenas from Ostrom (2008a) and represents the hierarchical levels of disputes: meta-constitutional, constitutional, collective choice, and operational. The Conference of the Parties (COP), for example, can be seen as a meta-constitutional (macro) level of the climate change disputes, and a photovoltaic condominium can be classified as an operational level (micro) in the institutional hierarchy.

The biophysical conditions are represented by the green boxes in Figure 3 and present two variables, the natural capital availability and its support capacity (the

maximum amount of resource available to be used, or the maximum environmental capacity to bear pollution deployment, safeguarding critical ecological tipping points). The community attributes, historically crafted, set the anthropical domain represented by the social (blue boxes in Figure 3) and economic (red boxes) endowments. Those endowments deliver the status of the power distribution between agents. In this study, we assume that the community attributes, represented by the social and economic endowments, are manifested through the following variables of the framework:

- Cultural capital: aggregated preferences, values, and symbols accumulated over time that influences agents' interests and general preferences. In that sense, it affects the dispute tacitly by guiding values embedded in agents' choices (judging them as "good" or "bad," "adequate" or "inadequate"). We can identify cultural capital in ideological preferences, explicitly stated in missions of political parties and organizations or implicitly incorporated in social actions, practices, and customs.
- Relational capital: hierarchical position occupied (with its prerogatives) and the social ties available for an agent. It represents the component of social capital that agents and coalitions can appropriate and cumulate for their interests. It can be empirically observed in formal and informal privileged positions in organizations, communities, and state bureaucracy.
- Human capital: the conjoint of the available skills, cognitive, theoretical, and other human competencies that favor the agents in pursuing their interests. We identify it by, for example, the amount of knowledge available to an agent or coalition to perform a given action in each place and time.
- Financial capital: the assets (e.g., cash, savings, funding, credit) available to agents and coalitions to perform economic activities such as production, consumption investment, and trade.
- Technological capital: the technically viable technology and private-owned knowledge in each moment and region. It differs from human capital in the extent that it is possible to assign property rights over knowledge, and it can be traded or exchanged apart from the flux of expert agents endowed with the skills.
- Built capital: the available infrastructure. We identify built capital by the long-term material assets available to perform an economic activity.

The communities' attributes (social and economic endowments) and the biophysical conditions set the parameters for power disputes between agents who can choose: a) their goals; b) their coalitions; and c) their strategies (OSTROM, 2008a, 2008b). From the multiple forms for appropriating the resources under dispute, those experiences more suitable for the interests of the dominant coalitions are usually institutionalized as underlying rules-in-use (rightest box in Figure 3). The enforcement of such institutions even improves dominant coalitions' social and economic endowments (bottom arrows in Figure 3). That rules-in-use are reproduced along time as a path-dependent institutional trajectory (NORTH, 1990) (upper box of Figure 3), which closes positive feedback of institutional lock-in.

Institutions may change whenever one or more variables on the left side of Figure 3 suffer some substantial shift. These shifts can stir the disputes and resettle the power balance and coalition arrangements in the action arenas. Disturbs in action arena order can be triggered, for example, by a newly elected government with different political ideologies, and economic crisis such as the 1970s' oil shock or the 1929 financial crash, or by a natural disaster that impacts the local availability of natural resources or built capital. The following section presents the Nigerian electricity industry historical narrative, analyzed according to the variables of the MIDA framework, built on the triangulation of the theoretical approach and the empirical evidence obtained in the document review and in-depth interviews with specialists.

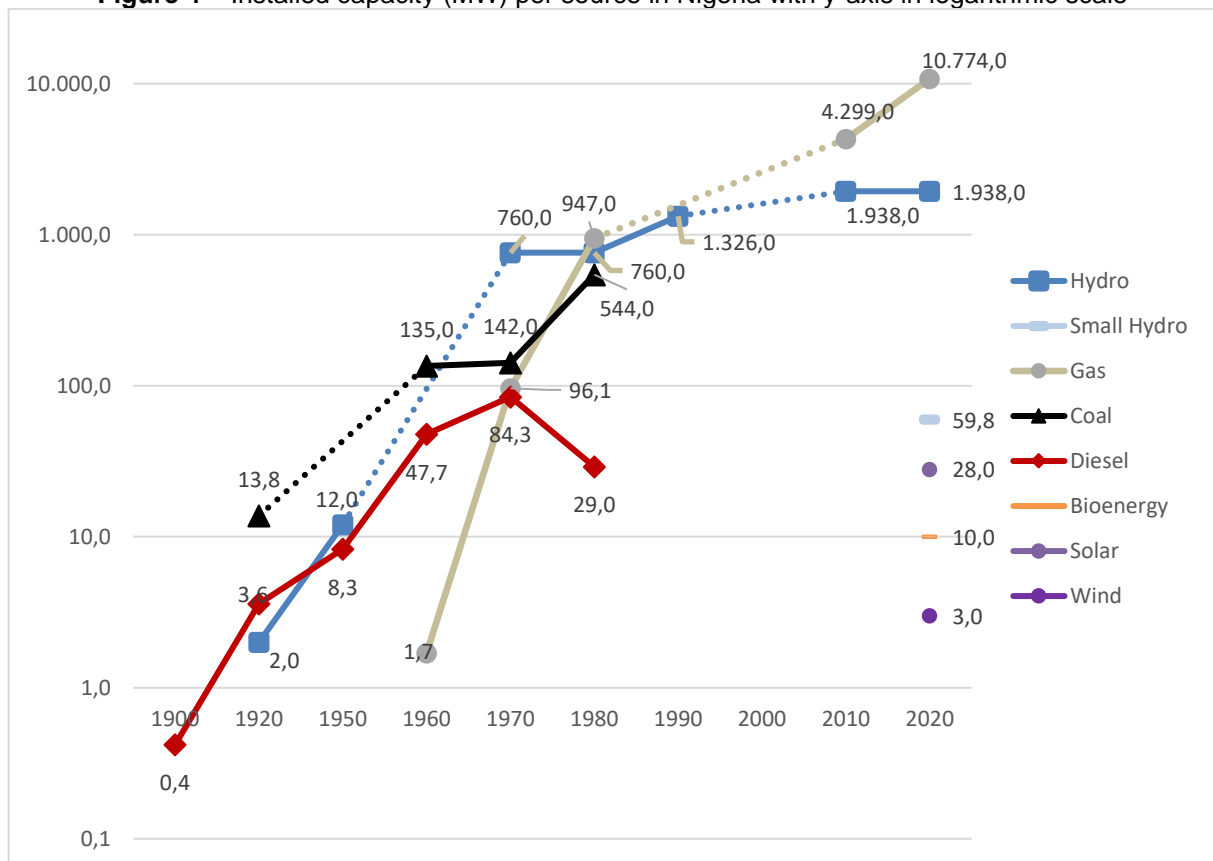
4.5 USING THE MIDA TO BUILD THE NIGERIAN ELECTRICITY INDUSTRY'S NARRATIVE

The following subsections present the Nigerian electricity industry's history in five main periods. In each period, the evidences were categorized according to the variables of the MIDA framework to explain the main changes in source and technology for generation (from coal to hydro and later from hydro to gas) and in governance structure (from British Empire to local military elites, and finally to private capital dominance). Choices for electricity source and governance represented the rules-in-use (the institutional outcome) in each historical context. The changes were tipping points in those rules that required more attention.

We suggest that changes in institutional outcomes (rules-in-use) were driven by previous shifts in social and/or economic endowments and/or biophysical conditions.

Therefore, each period presents an expressive institutional change in which a challenger coalition has cumulated enough endowments to propose (and struggle for) a new source of generation and/or some novel mode of governance for the Nigerian electricity industry. The main changes in installed capacity per primary source in Nigeria are synthesized in Figure 4, which shows the moments when dominant sources were replaced or threatened in Nigeria.

Figure 4 – Installed capacity (MW) per source in Nigeria with y-axis in logarithmic scale



Dotted lines indicate that intermediate data was missing, and the gap was interpolated.

Source: Elaborated by the authors (2022), based on AKPEN, 2017; ALIYU, RAMLI and SALEH, 2013; EDOMAH, 2021; EMODI, 2016; GIZ, 2015; IRENA, 2020; OLADIPO et al., 2018; OSENI, 2011.

During the decade of 1960-1970, we noted transitions from coal (black triangles) and diesel (red diamonds) to hydroelectricity (blue squares). This period is marked by the independence of Nigeria. Further, Figure 4 shows the change from hydro to gas-fueled thermoelectricity (gray circles) from 1970 to 1980, following Nigeria's inclusion in OPEC (Organization of the Petroleum Exporting Countries), and finally, a consolidation of gas-fueled installed capacity domain after 2005, and the intensification of liberal economic reform.

4.5.1 The Imperial Period (1896-1960)

Nigeria's electricity history began at the end of the 19th century with thermal experiences guided by the British Metropolis's interests in exploiting coal and other natural resources (AYAMOLOWO et al., 2019). The colonizers were responsible for deploying the human, economic and technical capital necessary to structure an electricity industry in Nigeria. Oil basins (natural capital) were discovered at the beginning of the 20th century but have not shown economic viability, mainly because oil prices were meager. On the other hand, the metropole was interested in exploring and exporting coal and other natural resources, partly due to the proximity of those natural stocks to the ocean ports. The lack of metropole's interest in oil and the focus on coal exploitation (LADAN, 2014) guided the preference for thermal coal generation during this period.

Those initial thermal experiences with coal-fueled power plants were also deployed for public lighting, government buildings, and hospital services. The metropole endowed the regulated state monopoly (PWD – Public Work Department) (AKPEN, 2017) with financial, relational, human, and technological types of capital. PWD also deployed the infrastructure necessary to exploit the local natural capital according to British interests.

During this initial period, the Nigerian electricity industry aggregated the generation, transmission, and distribution under the control of PWD (AKPEN, 2017). By 1922, as described by Edomah and others (EDOMAH, FOULDS and JONES, 2016), NESCO (Nigerian Electricity Supply Corporation) incorporated PWD and became responsible for "developing electrical energy supply (generation) infrastructure" and for regulatory functions. NESCO maintained the Metropolis' interests, and it was created to consolidate and centralize the efforts of electricity generation for natural capital exploitation and export.

By 1956, Shell D'Arcy had discovered oil reserves of suitable commercial quality and large quantity at Oloibiri, near the shore (72km west of Port Harcourt) at the beginning of the 20th century (STEYN, 2009). However, at that time, Shell's technical and financial capitals were insufficient to trigger the exploitation of the oil reserves (natural capital). Even with the impetus for changing the trains' engines in the middle of the 1950s, the metropole remained more interested in coal exploitation. It kept the domain in the arena due to its larger endowments of relational, human, and cultural

capital compared to the incipient local elites and Shell.

Until 1960, the metropole accumulated enough social and economic endowments to prevent Nigeria's local elites' or other international agents from influencing the outcomes of the action arenas. Furthermore, as illustrated in Figure 4, coal was Nigeria's dominant fuel source for electricity generation during the imperial period. The main agents and interests identified in the narrative until 1960 are placed in Table 1, which also shows their endowments, the contextual biophysical condition, the resultant rules-in-use, and the organization responsible for crafting them.

Table 1 – Agents and interests, biophysical conditions, economic and social endowments, rules-in-use and the organizations responsible for crafting them: The Imperial Period (1896 - 1960)

THE IMPERIAL PERIOD (1896 - 1960)				
AGENT: INTEREST	BIOPHYSICAL CONDITIONS	ECONOMIC ENDOWMENTS	SOCIAL ENDOWMENTS	RULES-IN-USE / REGULATORY BODY
Metropolis: extraction and exporting of natural capital, mainly coal	Coal reserves nearby the shore fomented the resource's exploitation and exportation	Financial, Technological, Built	Human, Relational and Cultural	Decentralized coal power plants, under regulation and assets ownership first centered at PWD and later at NESCO
Shell D'Arcy: finding oil in suitable quality and quantity		Financial, Technological	Human	

Source: Elaborated by the authors (2022).

4.5.2 The Early Independence Period (1961-1970)

The independence from the Metropole was followed by a civil war that settled a military government, which centralized the infrastructure of the electricity industry under state monopolies (EDOMAH, 2018). The industry lost human capital once British planners and managers returned to Britain, and the emerging military elites decided to shift the electricity generation source. Therefore, in 1962, the Federal Government established the Niger Dam Authority (NDA) to run hydroelectric power plants and transmission lines (AKPEN, 2017; AYAMOLOWO et al., 2019). Those changes in the institutional scenario resulted in the Kainji Dam Hydroelectric, with 720 MW of installed capacity in the Niger River in central Nigeria.

The availability of oil reserves, discovered in 1955, has not been sufficient to prevent the shift towards hydroelectricity, at least in the early moment. Although diesel-

fueled power plants showed an increase in installed capacity during this period (Figure 4), the Kainji Dam and the creation of the NDA represented substantive drivers (built capital and rules-in-use, respectively) for hydro dominance by the end of the 1960s (Figure 4). Oil was again underused (considering the availability of the resource) for electricity generation in Nigeria.

The civil war in this period may have aggravated the lack of financial resources to expand the electricity industry. Like most developing countries, Nigeria relied on the World Bank and the IMF (International Monetary Fund) to provide investments and loans for expanding the generation capacity, including constructing the Kenji Dam. Those international financial organizations have a liberal view of the projects and pressured the government (constitutional level) to comply, not only with debt payments but also with the regulatory arrangement for the projects. This liberal pressure - originated since the Washington Consensus - from those meta-constitutional agents in the Nigerian electricity industry pressured to unbundle the industry into three sectors (generation, transmission, and distribution) to foment privatizations (from the Federal Government) (A2). However, privatizations were significantly initiated only after the 1990s'.

The documental review undertaken in this study did not find environmental pressures that constrained electricity generation technologies (neither hydrological potential nor fossil fuels reserves) and governance choices in the industry during this period. The main agents and their respective interests identified in the historical narrative until 1970 are shown in Table 2. Table 2 also presents their endowments and the contextual biophysical conditions, and the resultant organizations/agents that held the prerogative for crafting rules-in-use.

Table 2 – Agents and interests, biophysical conditions, economic and social endowments, rules-in-use and the organizations responsible for crafting them: The Early Independence Period (1961 - 1970)

THE EARLY INDEPENDENCE PERIOD (1961 - 1970)				
AGENT: INTEREST	BIOPHYSICAL CONDITIONS	ECONOMIC ENDOWMENT S	SOCIAL ENDOWMENT S	RULES-IN-USE / REGULATORY BODY
Military Elites: centralizing electricity under state monopolies	No biophysical constraints or limitations influenced the action arenas	Built	Relational, Cultural	Centralized hydro power plants (rule-in-use) under regulation and ownership of NDA (regulatory organization)

World Bank and IMF: fostering investments for decoupling and privatizing electricity companies		Financial	None identified for Nigeria's case	
--	--	-----------	------------------------------------	--

Source: Elaborated by the authors (2022).

4.5.3 The Military Regime Period (1971 - 1985)

In 1971 Nigeria became a member of OPEC (Organization of the Petroleum Exporting Countries) (LADAN, 2014) (A2), which can influence the meta-constitutional level of the global arena. OPEC is understood here as a robust international coalition around the interests of the leading multinational oil producers, which owned enough technology, infrastructure, human, relational, and natural capital to control global oil prices and the return on capital for companies and investors (OPEC, 2018). The OPEC membership endowed Nigeria with the power of a geopolitical network capable of controlling international prices. The country boosted local oil and natural gas production, and the abundance of natural capital fostered the construction of infrastructure for gas, mainly gas pipelines and gas-fueled electricity power plants. Also, a substantial external impact, the general increase in international oil prices (during the first oil shock in 1973), benefited the economic viability of oil production. Therefore, the growth of Nigerian oil competitiveness in the global market would be a primary cause for natural gas internal abundance, and consequently for the dominance of gas-fueled electricity supply in Nigeria since the 1980s' (Figure 4).

In 1979, the ECN (Energy Commission of Nigeria) became responsible for coordinating and general surveillance of the energy resources in Nigeria. In 1977, NEPA (National Electricity Power Authority) and NNPC (Nigerian National Petroleum Corporation) were created as regulatory agencies for the electricity, oil, and gas sectors. Besides its regulatory power, NEPA was also the owner of almost all electricity industry assets until the 1990's liberal reforms (A2, A3). The joint creation of NNPC and NEPA suggests that oil exploitation and electricity were planned under common interests in this period.

By 1985, the electricity industry was still a state monopoly; however, instead of the British Metropolis or NDA, it was regulated and owned by NEPA. Military elites in the government maintained the electricity industry's expansion by accelerating

industrialization and fossil fuels exploitation, with less care for social development (AKPEN, 2017), financed by the World Bank and with OPEC's safeguard. The military elites centralized their interests around oil and gas exploitation and had shown enough social and economic endowments to dominate the rule crafting. NEPA and NNPC increased the installed capacity for gas-fueled power plants by 1980, as illustrated in Figure 4. The main agents and interests identified in the narrative between 1971 and 1985 are in Table 3, showing the general biophysical condition and distribution of endowments in the columns and the resultant rules-in-use and agents responsible for them at the end of the period.

Table 3 – Agents and interests, biophysical conditions, economic and social endowments, rules-in-use and the organizations responsible for crafting them: The Military Regime Period (1971 - 1985)

THE MILITARY REGIME PERIOD (1971 - 1985)				
AGENT: INTEREST	BIOPHYSICAL CONDITIONS	ECONOMIC ENDOWMENTS	SOCIAL ENDOWMENTS	RULES-IN-USE / REGULATORY BODY
OPEC (coalition): controlling oil global market	Natural gas abundance fostered gas- fueled power plants preferences	Financial, Technological	Cultural, Relational	Centralized hydro and natural gas power plants coordinated by ECN and executed and regulated by NEPA
World Bank and IMF: fostering investments and privatizations		Financial, Technological	Cultural	
Military Elites: accelerating industrialization		Built	Cultural, Human	

Source: Elaborated by the authors (2022).

4.5.4 The First Economic Reform Period (1986 - 1999)

By 1986, following a global trend of liberalization in electricity industries (PINTO JUNIOR et al., 2007), the Nigerian Federal Government shifted its preferences towards privatization, keeping with the State the planning and regulatory prerogatives. The electricity industry was unbundled into the generation, transmission, and distribution sectors. This unbundling pathway has roots in the liberal directives of the World Bank [96] for industries and sectors (A2, A3), imposed as constraints on the financed countries. Those meta-constitutional constraints induced a similar liberalization process in England, Brazil, South Africa, Chile, and other countries (VICTOR and HELLER, 2007). Electricity industry regulation and asset ownership, which until that

moment were centered at NEPA, began to be privatized. These liberal interests were materialized in Nigeria as the SAP (Structural Adjustment Program), which sponsored and coordinated the commercialization and privatization of public utilities.

Institutions at the constitutional level during this period were constrained by drivers at the meta-constitutional level, such as the OPEC agreements and the World Bank directives for investments. Although the meta-constitutional pressures, NEPA remained, during this period, the primary holder of electricity assets in the country and responsible for the regulation of most of the industry, not fully materializing the privatizations at the operational level (A2). The lack of cultural and relational capital from multinationals and national investors may have reduced the traction of the SAP during this period. Also, the interviews point to a lack of maintenance in the electricity network's infrastructure and the Federal Government's constant subsidies on tariffs for final consumers as barriers to private agents' investments (A1, A2, A3). According to the privatization program (SAP), natural gas-fueled power plants were preferred for electricity generation. We pointed out some reasons, such as the abundant oil reserves (A2), OPEC membership, and lower prices for gas generation compared to other sources, including hydroelectricity.

In 1988, the NGC (Nigerian Gas Company) was created to develop policies for the transmission, distribution, marketing, and pricing of natural gas (NORTH, 2008). By 1990, the Federal Government issued a decree offering fiscal incentives to investors in gas projects. In 1995, the Oil and Gas Pipeline Regulations were implemented to provide pipeline design, construction, inspection, testing, environmental protection, operation, and maintenance (LADAN, 2014). Those are materializations, at the constitutional level, of gas preferences to supply electricity.

Although the environmental pressures from events such as Rio 92 and subsequent international environmental pledges, no agent in Nigeria showed evidences of gathering enough endowments to sufficiently influence the institutional disputes. There is a lack of coalitions with enough power to propose and enforce sustainability constraints. The Federal Ministry of Environment (FME – an agent in the constitutional arena) was created in 1999 to protect the natural environment against pollution, and degradation, and conserve natural resources. Although with the assistance of the UNDP (United Nations Development Program) to implement renewables through the Renewable Energy Master Plan (REMP), aiming for 10% of the total energy consumption by 2025 (AYAMOLOWO et al., 2019), we were not able

to find FMEs' influence on the electricity preferences for source or governance in Nigeria.

By the end of this period, as observed in Figure 4, natural gas continues to expand as the country's dominant source of electricity generation. At the same time, NGC and the SAP are organizations with institutional prerogatives and interest in natural gas expansion and privatizations, respectively. The main agents and interests identified in the narrative between 1985 and 1999 are in Table 4, which also shows the general biophysical condition and distribution of endowments in the subsequent columns. The final organizations holding institutional prerogatives are shown in the last column with the rules-in-use.

Table 4 – Agents and interests, biophysical conditions, economic and social endowments, final rules-in-use, and the organizations responsible for crafting them: The First Reform Period (1986 - 1999)

THE FIRST REFORM PERIOD (1986 - 1999)				
AGENT: INTEREST	BIOPHYSICAL CONDITIONS	ECONOMIC ENDOWMENTS	SOCIAL ENDOWMENTS	RULES-IN-USE / REGULATORY BODY
OPEC (coalition): controlling oil global market	Early international concerns about climate change. No evidence of those concerns impacting the action arenas as agents or coalitions' actions	Financial, Technological	Cultural Relational	Centralized natural gas power plants (with hydro as an important complement), regulated by NEPA and NGC under the guidelines of SAP (privatization program)
Private Agents: seeking attractive opportunities		Financial	Human	
World Bank and IMF: liberalizing sectors and industries		Financial, Technological	Cultural, Relational	
Federal Government: liberalizing sectors and industries		Built	Relational, Cultural	

Source: Elaborated by the authors (2022).

4.5.5 The Intensification of the Privatization Programs (2000 - 2020)

The intensification of the privatization reforms in Nigeria occurred from 2000 onwards. Both private agents and the World Bank influenced electricity industry expansion. The political elites began to express concern with the environmental pressures from international multilateral agreements such as the COPs (Conference of the Parties) on the UN Climate Change Convention (meta-constitutional arena).

Along with the FME, created in 1999, we identified the emergence of two entities responsible for climate change issues: the Special Unit Climate Change (SUCC) and the Special Unit on Renewable Energy (SURE) (EMODI, 2016). We observed in this period concerns about climate change and the exhaustion of reserves regarding electricity expansion strategies. However, natural gas-fueled electricity generation remained expanding, as shown in Figure 4.

An electricity generation crisis in 1999/2000 moved the Federal Government towards an aggressive infrastructure plan to rehabilitate the hydro and thermal installed capacity, which was implemented between 1999 and 2004 (OKOLOBAH and ISMAIL, 2014). In 2001 the National Electric Power Policy (NEPP) was created and became responsible for executing reforms. In 2004, the National Integrated Power Project (NIPP) was conceived to boost electricity generation capacity by expanding gas power plants. Finally, in 2005 a series of structural reforms were undertaken by the Federal Government, enacted as The Reform Act (Electric Power Sector Reform Act - EPSRA), which transferred the control and operations of the industry from the public to the private holders [34]. Those private holders were acknowledged as Independent Power Producers, who would be able to sell electricity to NBET (Nigerian Bulk Electricity Trading) (AGBOOLA, 2011).

Also, in 2005 the Nigerian Electricity Regulatory Commission (NERC) was created as the regulatory body, with the responsibility of regulating new private agents in the electricity industry according to Federal Government directives. Complementarily, the Power Holding Company of Nigeria (PHCN) began to operate, responsible for the privatization contracts of eleven distribution companies. This reform ended with the current configuration of the Nigerian electricity industry, with 18 independent companies distributed between public and private agents (AYAMOLOWO et al., 2019; OKOLOBAH and ISMAIL, 2014): a) One transmission company (TCN – Transmission Company of Nigeria – Transcos – State-owned company); b) Six generations companies (Gencos – Generation Companies – public and private agents) and; c) Eleven distribution companies (Discos – Distribution Companies – public and private agents). Gencos and Discos are public companies and independent producers (private agents). They are responsible for generating and distributing electricity (billing the final consumers). TCN is responsible for transmitting electricity (connecting Gencos and Discos) and maintaining the efficiency of the electricity transmission grid.

However, in those reforms, in 2015, only around 31% of the total installed

capacity was used to generate electricity in Nigeria (GIZ, 2015). Currently, Nigeria relies on natural gas for most of its electricity generation and private capital for investment in the electricity industry. The industry is divided into generation, transmission, and distribution subsectors, with organizations under various regulatory directives. Concerning the liberal arguments for privatizing the electricity industry to increase efficiency, the privatization in Nigeria did not relieve Federal Government expenditures (A2, A3), which are still responsible for many incentives and financial aid to maintain the tariffs stable. All the respondents (A1, A2, A3) stressed the substantial Federal Government expenditures in the electricity industry. The main agents and interests identified in the historical narrative between 2000 and 2020 are shown in Table 5, along with their endowment's distribution, the general biophysical condition, and the organizations responsible for elaborating and enforcing the rules-in-use.

Table 5 – Agents and interests, biophysical conditions, economic and social endowments, final rules-in-use, and the organizations responsible for crafting them: The Intensification Of The Privatization Programs (2000 - 2020)

THE INTENSIFICATION OF THE PRIVATIZATION PROGRAMS (2000 - 2020)				
AGENT: INTEREST	BIOPHYSICAL CONDITIONS	ECONOMIC ENDOWMENTS	SOCIAL ENDOWMENTS	RULES-IN-USE / REGULATORY BODY
OPEC (coalition): controlling oil global market	Global climate change concerns, but resources in Nigeria are still abundant	Financial, Technological	Cultural, Relational	Most of supply generated by centralized natural gas power plants with liberal views under many bodies of governance: NEPP; NIPP; PHCN; NERC; NBET.
Private Agents: seeking attractive opportunities (generators and distributors)		Financial	Relational, Human	
World Bank and IMF: liberalizing of sectors and industries		Financial	Relational	
Federal Government: liberalizing of sectors and industries		Built	Cultural	
TCN: improving the grid efficacy		Built	Relational, Human	
Gencos: generating price competitive electricity (State owned, independent power producers)		Financial, Built	Relational, Human	

Discos: billing final consumers, revenue collection		Financial, Built	Relational, Human	
-		None	None	
International Agents: Increasing environmental pressures		None	Cultural	

Source: Elaborated by the authors (2022).

Despite the focus of this study to understand Nigeria in a national approach, the MIDA also identified substantive meta-constitutional influences. International agents' interests impacted the country's choices, constraining the constitutional level and influencing national policies for electricity generation. Nigeria has 5.475,2 billion m³ of standard crude oil and natural gas reserves (OPEC, 2018). This abundant fossil reserve indicates that the shortage of natural resources would not drive energy transitions in the country in the short term. Despite multilateral environmental agreements, such as the advancements of UN Climate Change COP21 in 2015 (a voluntary meta-constitutional commitment in which Nigeria pledged to zero-emission by 2060), this study indicates the effectiveness of the environmental pledges will depend on substantial capital relocation toward pro-renewables coalitions at energy action arenas. The country shows weak environmental institutions, and at present, constitutional agents (e.g., FME) fail to endow coalitions with enough social and economic capital for defending renewables interests, suggesting an expansion of fossil-fueled electricity generation in the near and even far future.

The MIDA framework contributed to an institutional change comprehension regarding the historical narrative, identifying the leading agents and their interests in each period of the Nigerian electricity industry. Also, it showed the distribution of endowments among agents with different interests (e.g., the Metropolis, military rulers, private organizations, regulatory bodies, and international organizations) to better understand their roles and impacts on the historical contexts in Nigeria's electricity industry. The historical dependence on oil and the current institutional environment in Nigeria stress substantial challenges for changing the fossil-fueled dominance. Our findings suggest that those difficulties may also lay in the lack of agents and coalitions with sufficient endowments to break the fossil's lock-in and advance toward renewable energy sources, evidencing a current institutional resistance to energy transitions.

4.6 CONCLUSION

This paper presented the endowments of pivotal agents who influenced the choices of source, technology, and governance for each period of the Nigerian electricity industry's history. We identified that Nigeria had two significant transitions in electricity generation sources (from coal to hydro and from hydro to gas) and two significant shifts in political governance (British empire to the national military regime, and later from state-owned to privatizations, and hybrid governance). The MIDA framework presented a novel toolbox for institutional analysis: encompassing biophysical and social variables and how those variables interact to consolidate the rules-in-use (for electricity technology, source, and governance). The current choices for the Nigerian electricity industry have resulted from historical disputes between agents endowed with enough capital to dispute and form confronting coalitions in action arenas. For most of history, no expressive agents have gathered enough economic and social capital to dispute with the Federal Government for the domain in action arenas at the constitutional level. Still, meta-constitutional agents, such as OPEC and the World Bank, are constrained expressively at the constitutional level.

Although the explanatory capacity of the MIDA, we acknowledge some methodological limitations, such as not being able to identify and categorize evidence of intra groups disputes. During the history of electricity in Nigeria, military regimes had divergent branches with different interests and strategies, which were not observed when we analyzed only the official documents (the results of those confrontations). However, this methodological blind spot of the analysis can be overcome by addressing the microenvironment and mapping the individuals or branches of the same group as different agents with different interests. For an agent to be considered "different", they should present conflicting interests and/or strategies compared to other agents in the dispute. Therefore intra, group disputes would represent micro-level nested action arenas.

The MIDA framework was fruitful in identifying the Institutional preferences for electricity generation sources and governance modes in Nigeria, relying on social, economic, and biophysical conditions as variables. Throughout Nigerian history, institutional choices were recursively replicated and confronted by distinct groups and interests, which resulted in the current dominance of natural gas as electricity's primary generation source and the hybrid form of governance in the national electricity industry.

This study indicated that if the trajectory keeps running its course, without any crisis affecting social arenas of the electricity industry and sectors, natural gas might continue to grow and represent the dominant source for Nigerian electricity generation expansion.

Policymakers may benefit from the MIDA by understanding and clarifying the power disputes and biophysical conditions which influence electricity industries' institutions. More broadly, the approach may deliver assessments of the chances for success or failure of various sources and governance options in each local perspective. Further studies in Nigeria applying the MIDA framework might adopt a more specific view of a limited period, deepening and detailing the analysis of the agents' endowments distribution and disputes at a particular moment. The MIDA can also elucidate other social processes of institutional crafting, reproduction, and change. We understand that natural monopolies that supply public services and conflicts involving entangled social, economic, and environmental variables can benefit from the framework's contextual diagnosis and analysis approach.

4.7 REFERENCES

ACEMOGLU, Daron; JOHNSON, Simon; ROBINSON, James A. Institutions as a fundamental cause of long-run growth. **Handbook of economic growth**, v. 1, p. 385-472, 2005.

ADVISORY POWER TEAM, OFFICE OF THE VICE PRESIDENT, FEDERAL GOVERNMENT OF NIGERIA; POWER AFRICA. **Nigeria Power Baseline Report**. [s.l: s.n.]. Disponível em: <https://mypower.ng/wp-content/uploads/2018/01/Baseline-Report.pdf>.

AGBOOLA, O. Phillips. Independent power producer (IPP) participation: Solution to Nigeria power generation problem. In: **Proceedings of the World Congress on Engineering, Anais**. London, England: 2011.

AKPEN, Philip et al. Electricity Regulatory Institutions in Nigeria: From Colonial to Post-Colonial Periods. **Historical Yearbook**, v. 14, n. XIV, p. 37-56, 2017.

ALIYU, Abubakar Sadiq; RAMLI, Ahmad Termizi; SALEH, Muneer Aziz. Nigeria electricity crisis: Power generation capacity expansion and environmental ramifications. **Energy**, v. 61, p. 354-367, 2013.

AOKI, Masahiko. Endogenizing institutions and institutional changes. **Journal of institutional economics**, v. 3, n. 1, p. 1-31, 2007.

ASQUER, Alberto. Liberalization and regulatory reform of network industries: A

comparative analysis of Italian public utilities. **Utilities Policy**, v. 19, n. 3, p. 172-184, 2011.

AYAMOLOWO, Oladimeji Joseph et al. Nigeria Electricity Power Supply System: The Past, Present and the Future. **IEEE PES/IAS PowerAfrica Conference: Power Economics and Energy Innovation in Africa, PowerAfrica 2019**, p. 64–69, 2019.

BAUWENS, Thomas; GOTCHEV, Boris; HOLSTENKAMP, Lars. What drives the development of community energy in Europe? the case of wind power cooperatives. **Energy Research and Social Science**, v. 13, p. 136–147, 2016.

BODIN, Örjan. Collaborative environmental governance: Achieving collective action in social-ecological systems. **Science (New York, N.Y.)**, v. 357, n. 6352, ago. 2017.

BOURDIEU, Pierre. The social space and the genesis of groups. **Social Science Information**, v. 24, n. 2, p. 195–220, 1985.

BOURDIEU, Pierre. **O poder simbólico**. Lisboa: Difel, 1989.

BRONDIZIO, Eduardo S.; OSTROM, Elinor; YOUNG, Oran R. Connectivity and the governance of multilevel social-ecological systems: The role of social capital. **Annual Review of Environment and Resources**, v. 34, p. 253–278, 2009.

CHERP, Aleh; JEWELL, Jessica; GOLDTHAU, Andreas. Governing Global Energy: Systems, Transitions, Complexity. **Global Policy**, v. 2, n. 1, p. 75-88, 2011.

COLEMAN, James S. Social Capital in the Creation of Human Capital. **The American Journal of Sociology**, v. 94, n. 1988, p. 95-S120, 1988.

COP 21. **Paris Climate Change Conference-November 2015, COP 21 UNFCCC**. Conference of the Parties (COP). **Anais...**, 2015.

CRESWELL, John W. **Qualitative, quantitative, and mixed methods approaches**. 2^o ed. California: Thousand Oaks, 2003.

CRESWELL, John W. **Research Design: Qualitative, Quantitative and Mixed Approaches (3rd Edition)**. [s.l.: s.n.].

DAVIS, Lance Edwin; NORTH, Douglass C.; SMORODIN, Calla. **Institutional change and American economic growth**. CUP Archive, 1971.

DELLAPOSTA, Daniel; NEE, Victor; OPPER, Sonja. Endogenous dynamics of institutional change. **Rationality and Society**, v. 29, n. 1, p. 5–48, 2017.

DENZAU, Arthur T.; NORTH, Douglass C. Shared Mental Models - Ideologies and Institutions. **KYKLOS - International Review for Social Sciences**, v. 47, n. 1, p. 3–31, 1994.

DIMAGGIO, Paul J.; POWELL, Walter W. The iron cage revisited: Isomorphism and

collective rationality in organizational fields. **American Sociological Review**, v. 48, n. 2, p. 147–160, 1983.

EDOMAH, Norbert. Historical drivers of energy infrastructure change in Nigeria (1800–2015). **Energy Management for Sustainable Development**, p. 24-44, 2018.

EDOMAH, Norbert. Governing sustainable industrial energy use : Energy transitions in Nigeria ' s manufacturing sector. **Journal of Cleaner Production**, v. 210, p. 620–629, 2019.

EDOMAH, Norbert. The governance of energy transition: lessons from the Nigerian electricity sector. **Energy, Sustainability and Society**, v. 11, n. 1, p. 40, 2021.

EDOMAH, Norbert; BAZILIAN, Morgan; SOVACOOOL, Benjamin K. Sociotechnical typologies for national energy transitions. **Environmental Research Letters**, v. 15, n. 11, p. 1–7, 2020.

EDOMAH, Norbert; FOULDS, Chris; JONES, Aled. The role of policy makers and institutions in the energy sector: the case of energy infrastructure governance in Nigeria. **Sustainability**, v. 8, n. 8, p. 829, 2016.

EMODI, Nnaemeka Vincent. **Frontiers in African Business Research Energy Policies for Sustainable Development Strategies: The Case of Nigeria**. 1 ed. Springer, 2016.

FARLEY, Joshua. Conservation through the economics lens. **Environmental Management**, v. 45, n. 1, p. 26–38, 2010.

FLIGSTEIN, Neil. Fields, Power and Social Skill. **Sociology The Journal Of The British Sociological Association**, 1998.

FOLKE, Carl. Resilience: The emergence of a perspective for social-ecological systems analyses. **Global Environmental Change**, v. 16, n. 3, p. 253–267, 2006.

GONZALEZ, Carlos German Meza; AMADO, Nilton Bispo; SAUER, Ildo Luis. Desenvolvimento sustentável, transição energética mundial pós-combustíveis fósseis e o pensamento político da esquerda latino-americana. **Brazilian Journal of Development**, v. 5, n. 11, p. 23334-23355, 2019.

GIZ. **Nigerian Energy Support Programme (NESP)**. [s.l: s.n.].

GREIF, Avner; MOKYR, Joel. Cognitive rules, institutions, and economic growth: Douglass North and beyond. **Journal of Institutional Economics**, v. 13, n. 1, p. 25–52, 2017.

GRITSENKO, Daria. Explaining choices in energy infrastructure development as a network of adjacent action situations: The case of LNG in the Baltic Sea region. **Energy Policy**, v. 112, n. October 2017, p. 74–83, 2018.

GRUNDMANN, Philipp; EHLERS, Melf-Hinrich. Determinants of courses of action in bioenergy villages responding to changes in renewable heat utilization policy. **Utilities**

Policy, v. 41, p. 183–192, 2016.

HELDEWEG, Michiel A. Normative alignment, institutional resilience and shifts in legal governance of the energy transition. **Sustainability (Switzerland)**, v. 9, n. 7, p. 1273, 2017a.

HELDEWEG, Michiel A. Legal regimes for experimenting with cleaner production – Especially in sustainable energy. **Journal of Cleaner Production**, v. 169, p. 48-60, 2017b.

HOLSTENKAMP, Lars. What do we know about cooperative sustainable electrification in the global South? A synthesis of the literature and refined social-ecological systems framework. **Renewable and Sustainable Energy Reviews**, v. 109, n. April 2018, p. 307–320, 2019.

IEA. **Countries & Regions - IEA**. Disponível em: <https://www.iea.org/countries>. Acesso em: 26 mar 2020.

IRENA. **Energy Profile**. INTERNATIONAL RENEWABLE ENERGY AGENCY. [s.l.: s.n.]. Disponível em: https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Nigeria_Africa_RE_SP.pdf.

JOSHI, Neeraj N.; OSTROM, Elinor; SHIVAKOTI, Ganesh; LAM, Wai Fung. Institutional Opportunities and Constraints in the Performance of Farmer-Managed Irrigation Systems in Nepal. **Asia-Pacific Journal of Rural Development**, v. 10, n. 2, p. 67–92, 1 dez. 2000.

KELLY, Patrick John; GEYER, Hermanus Stephanus. The regulatory governance of retail electricity tariff setting in South Africa. **Regional Science Policy and Practice**, v. 10, n. 3, p. 203–220, 2018.

LADAN, Muhammed Tawfiq. Overview of Recent Development in Energy Resources Law in Nigeria. **SSRN Electronic Journal**, n. 3, p. 26, 2014.

LAMMERS, Imke; HELDEWEG, Michiel A. An empirico-legal analytical and design model for local microgrids: Applying the ‘iltiad’ model, combining the iad-framework with institutional legal theory. **International Journal of the Commons**, v. 13, n. 1, p. 479–506, 2019.

LAMMERS, Imke; HOPPE, Thomas. Analysing the institutional setting of local renewable energy planning and implementation in the EU: A systematic literature review. **Sustainability (Switzerland)**, v. 10, n. 9, 2018.

LAMMERS, Imke; HOPPE, Thomas. Watt rules? Assessing decision-making practices on smart energy systems in Dutch city districts. **Energy Research and Social Science**, v. 47, n. October 2018, p. 233–246, 2019.

LAMMERS, Imke; VASENEV, Alexandr. Grid resilience governance of the future: Analyzing the role of associations in experimental smart grid projects in the

Netherlands. **Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST**, v. 203, n. January 2018, p. 142–148, 2017.

LAMPIS, Andrea; PAVANELLI, João Marcos Mott; GUERRERO, Ana Lía del Valle; BERMANN, Célio. Possibilidades e Limites da transição energética: uma análise à luz da Ciência Pós-Normal. **Estudos Avançados**, v. 35, n. 103, p. 1–18, 2021.

MÄRKER, Carolin; VENGHAUS, Sandra; HAKE, Jürgen-Friedrich. Integrated governance for the food–energy–water nexus – The scope of action for institutional change. **Renewable and Sustainable Energy Reviews**, v. 97, n. April, p. 290–300, 2018.

MCGINNIS, Michael D.; OSTROM, Elinor. Social-ecological system framework: Initial changes and continuing challenges. **Ecology and Society**, v. 19, n. 2, 2014.

MELVILLE, Emilia; BURNINGHAM, Kate; CHRISTIE, Ian; SMALLWOOD, Ben. Equality in local energy commons. A UK case study of community and municipal energy. **Rassegna Italiana Di Sociologia**, v. 59, n. 2, p. 315-342, 2018.

Milchram, Christine; MÄRKER, Carolin; SCHLÖR, Holger; KÜNNEKE, Rolf; VAN DE KAA, Geerten. Understanding the role of values in institutional change: The case of the energy transition. **Energy, Sustainability and Society**, v. 9, n. 1, 2019.

MORAN, Emilio F.; OSTROM, Elinor. **Ecosistemas Florestais: Interação Homem-Ambiente**. 1. ed. São Paulo: Edusp, 2009.

NORTH, Douglass C. **Institutions, Institutional Change and Economic Performance**. 1ª ed. Washington: Cambridge University Press, 1990.

NORTH, Douglass C. Institutions and the Performance of Economies Over Time. *In: Handbook of New Institutional Economics*. [s.l: s.n.]. p. 21-40.

OKOLOBAH, Victor; ISMAIL, Zuhaimy. On the issues, challenges and prospects of electrical power sector in Nigeria. **International Journal of Economy, Management and Social Sciences**, v. 2, n. 6, p. 410-418, 2014.

OLADIPO, Kayode; FELIX, Agbetuyi A.; BANGO, Owolabi; CHUKWUEMEKA, Obiakor; OLAWALE, Fagbuaro. Power sector reform in Nigeria: challenges and solutions. *In: IOP Conference Series: Materials Science and Engineering*. IOP Publishing, p. 012037, 2018.

OPEC. **Organization of the Petroleum Exporting Countries (OPEC) Organization of the Petroleum Exporting Countries**. Vienna, Austria: [s.n.]. Disponível em: https://www.opec.org/opec_web/flipbook/ASB2017/ASB2017/assets/common/downloads/ASB2017_13062017.pdf.

OSENI, Musiliu O. An analysis of the power sector performance in Nigeria. **Renewable and Sustainable Energy Reviews**, v. 15, n. 9, p. 4765–4774, 2011.

OSTROM, Elinor. An Agenda for the Study of Institutions. **Public Choice**, v. 48, n. 1, p. 3–25, 1986.

OSTROM, Elinor. Governing the Commons. *In: **Governing the Commons - The Evolution of institutions for collective action***. 1. ed. Cambridge, UK: Cambridge University Press, p. 280, 1990a.

OSTROM, Elinor. Reflections on the commons. **Governing the Commons**, p. 1-28, 1990b.

OSTROM, Elinor. **Constituting social capital and collective action**. Workshop in Political Theory and Policy Analysis. **Anais...** Bloomington, Indiana: Indiana University, 1993.

OSTROM, Elinor. Coping with tragedies of the commons. **Annual Review of Political Science**, v. 2, n. 1968, p. 493–535, 1999.

OSTROM, Elinor. Revisiting the commons: Local lessons, global challenges. **Science**, v. 284, n. 5412, p. 278–282, 1999a.

OSTROM, Elinor. Revisiting the commons: Local lessons, global challenges. **Science**, v. 284, n. 5412, p. 278–282, 1999b.

OSTROM, Elinor. Social Capital: A Fad or a Fundamental Concept? **Social Capital: A Multifaceted Perspective**, p. 172–214, 2000a.

OSTROM, Elinor. Collective action and the evolution of social norms. **Journal of Economic Perspectives**, v. 14, n. 4, p. 137–158, 2000b.

OSTROM, Elinor. Reformulating the Commons. **Ambiente & Sociedade**, v. 2002, n. 2, p. 208–213, 2002.

OSTROM, Elinor. How Types of Goods and Property Rights Jointly Affect Collective Action. **Journal of Theoretical Politics**, v. 15, p. 239–270, 2003.

OSTROM, Elinor. Doing Institutional Analysis: Digging Deeper than Markets and Hierarchies. *In: **Handbook of New Institutional Economics***. 1^o ed. [s.l.] Springer, p. 819-848, 2008a.

OSTROM, Elinor. **Understanding Institutional Diversity**. 1. ed. Princeton, New Jersey: Princeton University Press, 2008b.

OSTROM, Elinor. Institutions and the Environment. **Economic Affairs**, v. 28, n. 3, p. 24–31, 1 set. 2008.

OSTROM, Elinor. What is social capital? *In: OSTROM, E.; AHN, T. K. (Eds.). **Foundations of Social Capital***. [s.l.] Edward Elgar Pub; Abridged edition, p. 17-38, 2009a.

OSTROM, Elinor. **A general framework for analyzing sustainability of social-**

ecological systems *Science*, 2009b.

OSTROM, Elinor. Beyond markets and states: Polycentric governance of complex economic systems. **American Economic Review**, v. 100, n. June, p. 641–672, 2010.

OSTROM, Elinor. Background on the Institutional Analysis and Development Framework. **Policy Studies Journal**, v. 39, n. 1, p. 7–27, 2011.

OSTROM, Elinor; BASURTO, Xavier. Crafting analytical tools to study institutional change. **Journal of Institutional Economics**, v. 7, n. 3, p. 317–343, 2011.

OSTROM, Elinor; COX, Michael. Moving beyond panaceas: A multi-tiered diagnostic approach for social-ecological analysis. **Environmental Conservation**, v. 37, n. 4, p. 451–463, 2010.

OWEBOR, K., DIEMUODEKE, Ogheneruona E.; BRIGGS, Tobinson A.; IMRAN, Muhammad. Power Situation and renewable energy potentials in Nigeria – A case for integrated multi-generation technology. **Renewable Energy**, v. 177, p. 773–796, 2021.

PAAVOLA, Jouni. Institutions and environmental governance : A reconceptualization. **Ecological Economics**, v. 63, p. 93–103, 2006.

PAVANELLI, João Marcos Mott. **A integração da geração fotovoltaica distribuída à matriz elétrica brasileira: uma análise sob a ótica institucional**. Universidade de São Paulo, 2016.

PAVANELLI, João Marcos Mott. **Meso-institutions ongoing: the brazilian case of thermal electric generation**. Seminário Internacional Territórios da Energia, Mudança Climática e Sustentabilidade da Macrometrópole Paulista. **Anais... IEE-USP**, 2019.

PAVANELLI, João Marcos Mott; IGARI, Alexandre Toshiro. Institutional Reproduction and Change : An Analytical Framework for Brazilian Electricity Generation Choices. **International Journal of Energy Economics and Policy**, v. 9, n. 5, p. 252–263, 2019.

PETIT-BOIX, Anna; APUL, Defne. From cascade to bottom-up ecosystem services model: How does social cohesion emerge from urban agriculture? **Sustainability (Switzerland)**, v. 10, n. 4, 2018.

POLSKI, Margaret M.; OSTROM, Elinor. **An Institutional Framework for Policy Analysis and Design**. Workshop in Political Theory and Policy Analysis. **Anais... Indiana University**, 1999.

POTEETE, Amy R.; OSTROM, Elinor. Heterogeneity, Group Size and Collective Action: The Role of Institutions in Forest Management. **Development and Change**, v. 35, n. 3, p. 435-461, 2004.

PINTO JUNIOR, Helder Queiroz et al. Economia da Indústria Elétrica. In: **Economia da Energia**. 4 ed. São Paulo: Campus Elsevier, p. 343, 2007.

ROCKSTRÖM, Johan; STEFFEN, Will; NOONE, Kevin; PERSSON, Åsa; CHAPIN III,

F. Stuart; LAMBIN, Eric F.; LENTON, Timothy M.; SCHEFFER, Marten; FOLKE, Carl; SCHELLNHUBER, Hans Joachim; NYKVIST, Björn; WIT, Cynthia A. de; HUGHES, Terry; VAN DER LEEUW, Sander; RODHE, Henning; SÖRLIN, Sverker; SNYDER, Peter K.; COSTANZA, Robert; SVEDIN, Uno; FALKENMARK, Malin; KARLBERG, Louise; CORELL, Robert W.; FABRY, Victoria J.; HANSEN, James; WALKER, Brian; LIVERMAN, Diana; RICHARDSON, Katherine; CRUTZEN, Paul.; FOLEY, Jonathan A. Safe operating space for humanity. **Nature**, Vol. 461: 472-475, 2009. DOI: <https://doi.org/10.1038/461472a>.

SHAH, Kalim U.; NILES, Keron. Energy policy in the Caribbean green economy context and the Institutional Analysis and Design (IAD) framework as a proposed tool for its development. **Energy Policy**, v. 98, p. 768-777, 2016.

SMIL, Vaclav. Energy transitions, renewables and rational energy use: A reality check. **Organisation for Economic Cooperation and Development**. The OECD Observer, n. 304, p. 36, 2015.

SMIL, Vaclav. Examining energy transitions: A dozen insights based on performance. **Energy Research and Social Science**, 2016a.

SMIL, Vaclav. Examining energy transitions: A dozen insights based on performance. **Energy Research and Social Science**, 2016b.

SMIL, Vaclav. **Energy Transitions: Global and National Perspectives**. 2. ed. Santa Barbara, California: ABC-CLIO, LLC, 2017a.

SMIL, Vaclav. **Energy and civilization: A history**. Cambridge, MA: MIT Press, 2017b.

SOLOMON, Barry D.; KRISHNA, Karthik. The coming sustainable energy transition: History, strategies, and outlook. **Energy Policy**, v. 39, n. 11, p. 7422-7431, 2011.

SOVACOOOL, Benjamin K. The History and Politics of Energy Transitions: Comparing Contested Views and Finding Common Ground. *In*: ARENT, D. *et al.* (Eds.). . **The Political Economy of Clean Energy Transitions**. 1. ed. New York: Oxford University Press, p. 594, 2017.

SOVACOOOL, Benjamin K.; AXSEN, Jonn; SORRELL, Steve. Energy Research & Social Science Promoting novelty , rigor, and style in energy social science: Towards codes of practice for appropriate methods and research design. **Energy Research & Social Science**, v. 45, n. July 2018, p. 12-42, 2020.

SPIJKERBOER, Rozanne C.; ZUIDEMA, Christian; BUSSCHER, Tim; Arts, J. Institutional harmonization for spatial integration of renewable energy: Developing an analytical approach. **Journal of Cleaner Production**, v. 209, p. 1593–1603, 2019.

STEFFEN, Will; ROCKSTRÖM, Johan. Planetary boundaries: Guiding human development on a changing planet. **Science**, 2015.

STEYN, Phia. Oil exploration in colonial Nigeria, c. 1903-58. **Journal of Imperial and Commonwealth History**, v. 37, n. 2, p. 249-274, 2009.

VERHOOG, Reinier; GHORBANI, Amineh; DIJKEMA, Gerard P. J. Modelling socio-ecological systems with MAIA: A biogas infrastructure simulation. **Environmental Modelling and Software**, v. 81, p. 72–85, 2016.

VICTOR, David G.; HELLER, Thomas C. (Ed.). **The Political Economy of Power Sector Reform: The Experiences of Five Major Developing Countries**. 1 ed. Cambridge, UK: Cambridge University Press, 2007.

VAN DER WAAL, Esther C.; DAS, Alexandra M.; VAN DER SCHOOR, Tineke. Participatory experimentation with energy law: Digging in a 'regulatory sandbox' for local energy initiatives in the Netherlands. **Energies**, v. 13, n. 2, p. 1–21, 2020.

WILLIAMSON, Oliver E. **The Economics Institutions of Capitalism**. 1 ed. New York: The Free Press, 1985.

WILLIAMSON, Oliver E. Transaction Cost Economics : An Introduction. **Economics discussion papers**, v. 3, p. 33, 2007.

WOLSINK, Maarten. Distributed energy systems as common goods: Socio-political acceptance of renewables in intelligent microgrids. **Renewable and Sustainable Energy Reviews**, v. 127, n. August 2019, p. 109841, 2020.

WORLD BANK. **Nigeria Data**. Disponível em: <https://data.worldbank.org/country/nigeria?view=chart>. Acesso em: 21 abr 2021.

YORK, Richard; BELL, Shannon Elizabeth. Energy transitions or additions? Why a transition from fossil fuels requires more than the growth of renewable energy. **Energy Research and Social Science**, v. 51, n. January, p. 40-43, 2019.

5 CONCLUSÃO

A presente tese, na forma de compilado de artigos, apresentou três diferentes estruturas conceituais para compor narrativas históricas das indústrias elétricas nacionais de Brasil e Nigéria. Foram identificados os elementos circunscritos aos casos de mudanças institucionais que preconizaram transições energéticas, aqui identificadas na história através de guinadas nas escolhas por fontes na composição da oferta elétrica e/ou por modelos de governança (e.g. público, privado, híbrido, ação coletiva local etc.). Foi possível apresentar três *frameworks* capazes de articular conceitos institucionalistas, mesmo que provenientes de diferentes tradições teóricas, para identificar e explicar a reprodução e mudança das instituições de indústrias elétricas de dois países.

No capítulo 2, através de uma estrutura conceitual com influência funcionalista, com origens na Nova Sociologia Econômica, as explicações de mudanças institucionais são guiadas pelas crises internas e externas (momentos de instabilidade institucional, em que agentes têm pouca ou nenhuma capacidade preditiva atribuída a suas estratégias) e pela habilidade social (capacidades cognitivas, interpessoais e relacionais) de agentes em posições chave (dotados/as de prerrogativas). No caso brasileiro, tratado no capítulo 2, os agentes hábeis funcionaram como uma espécie de catalisador de mudanças diante de crises, estabilizando-as de modo a impor ou influenciar fortemente as escolhas institucionais resultantes.

Apesar dos conflitos epistemológicos e ontológicos inerentes à articulação de conceitos provenientes de diferentes escolas teóricas (NEI, NSE e NOI), o *framework* do capítulo 2 foi capaz de explicar cada mudança de fonte ou governança para os mais de cem anos da indústria elétrica brasileira, identificando elementos de emergência, reprodução e mudança para cada um dos cinco períodos analisados.

Já os capítulos 3 e 4 procuraram detalhar melhor as crises, com foco na Nova Economia Institucional (NEI), identificando variáveis (e suas inter-relações) presentes nos mundos biofísicos e sociais. Inspirando-se em Elinor Ostrom, os capítulos apresentaram estruturas conceituais capazes de explicar os principais elementos biofísicos, sociais e econômicos que preconizaram as mudanças por fonte e tecnologia de geração elétrica e modelo de governança das indústrias elétricas de Brasil (capítulo 3) e Nigéria (capítulo 4), casos oportunamente escolhidos por apresentarem mudanças institucionais em suas trajetórias históricas e que

apresentam assimilação de fontes térmicas em detrimento de fonte hidrelétrica, sendo no caso brasileiro uma adição energética e no caso nigeriano, uma transição energética. Ambos são influenciados pelo modelo de desverticalização e pelas imposições dos agentes de níveis metaconstitucionais e apresentam casos de fontes fósseis assumindo espaço das renováveis, um caminho contrário ao desejado para mitigar os efeitos climáticos das emissões provenientes da geração de eletricidade.

Os capítulos 3 e 4 trabalharam com uma única escola de pensamento, a NEI, amenizando assim eventuais conflitos epistemológicos e ontológicos inerentes a qualquer articulação de conceitos de escolas distintas em um único *framework* explicativo. North (1990) e Ostrom (2005), inclusive, departem de definições institucionalistas bastante sinérgicas e ambos entendem o papel histórico dos confrontos entre agentes como explicação para as mudanças incrementais ao longo do tempo.

Logo, o refinamento do *framework* entre os capítulos 2 e 3, que deu subsídio teórico-conceitual aos capítulos 3 e 4, mitiga a necessidade de buscar conceitos em escolas teóricas distintas para explicar as dinâmicas institucionais. Sendo assim, foi oportuno focar em Elinor Ostrom e seu IAD, detalhando as crises e as entendendo como alterações nas dotações sociais, econômicas e/ou ambientais e/ou a distribuição dessas dotações entre os grupos que disputam pelo controle institucional.

De todo modo, as estruturas conceituais propostas nos capítulos 1, 2, e 3 carregam a compreensão de que as disputas pelo domínio e/ou maior influência nas escolhas institucionais foram estruturadas por elementos externos à arena de ação, mas não alheios às decisões tomadas nessas arenas. Dessa forma, aprofundou-se a recursividade histórica das escolhas finais nos elementos biofísicos, sociais e econômicos, bem como nos (des)interesses de diferentes agentes, procurando incorporar a história como um elemento endógeno aos *frameworks*.

As mudanças institucionais observadas através das estruturas conceituais apresentadas puderam ser entendidas, para os casos de Brasil e Nigéria, através da ilustração dos elementos biofísicos e sociais que se fizeram presentes em instantes que antecederam tais mudanças. Crises que afetam as condições biofísicas (e.g. crise hídrica, escassez de recurso não renovável) e as dotações de capitais social e econômico entre agentes (e.g. mudanças de governo, golpes militares, crise de 29, crise do petróleo) precederam acirramento de disputas e novos modelos institucionais, afetando a composição da oferta elétrica por fonte e/ou no modelo de governança da

indústria nacional de Brasil e Nigéria.

Os *frameworks* apresentados nos manuscritos desta tese possibilitaram, através de narrativas históricas e trajetórias de evolução de potência instalada por fonte, o estabelecimento de relações entre as disputas entre agentes, estruturadas por condições biofísicas e dotações sociais e econômicas, e as resultantes institucionais (em termos de fonte de geração e modelo de governança) em cada período apresentado.

Embora a abordagem desta tese seja longitudinal, os *frameworks* apresentados possibilitam uma análise latitudinal sobre a dinâmica institucional e seus distintos níveis hierárquicos. A abordagem multinível do MIDA (Capítulo 3), por exemplo, considera tanto os impactos resultantes de níveis superiores metaconstitucionais (como as COPs), como experiências de níveis operacionais (como a disputa pelos direitos de propriedade e deveres de contribuição de uma cooperativa de geração fotovoltaica), oportunizando sua aplicação para um caso e um período de tempo específico após a identificação dos elementos constituintes das disputas ao longo da história (tais quais apresentados nos capítulos 2 e 3 para a Nigéria e o Brasil, respectivamente).

As estruturas conceituais apresentadas nesta tese podem também colaborar com diagnósticos institucionais sobre contextos distintos e que guiam proposições regulatórias mais alinhadas hierarquicamente (mais legítimas localmente e plausíveis globalmente), dessa forma mais assertivas, perpassando a consideração da distribuição de poder e as condições históricas e pontuais do capital natural.

Tal proposta de diagnóstico e formulação das instituições vai além das meras condições geográficas e econômicas para explicar as diferenças na composição de oferta elétrica por fontes de indústrias elétricas nacionais. O diagnóstico pode contribuir para a identificação de condições e contextos mais ou menos aptos para o desenvolvimento de fontes alternativas (de fluxo) para geração elétrica.

Esta tese e os manuscritos que a compõem apresentaram alguns limites para a compreensão das resultantes institucionais históricas. Um limite relevante concerne a uma prática recorrente em relações entre entes públicos e privados: a corrupção. Os acordos não oficiais, que podem representar interesses nem sempre explicitados em arenas de ação oficiais, não são passíveis de observação, sendo assim, criam barreiras metodológicas para a identificação dos agentes e seus interesses. Este limite é imposto nos casos de qualquer negociação não oficial ou não explicitada nas

análises documentais, mas que possa ter afetado diretamente as resultantes institucionais. Isso é válido para as estruturas conceituais institucionalistas dos três manuscritos apresentados.

Outro limite é decorrente ao recorte escolhido para a pesquisa, que propicia uma visão de longo prazo dos eventos, mas generaliza elementos que podem apresentar maiores especificidades para períodos específicos do tempo, o que pode ocasionar eventual superestimação de sua relevância para a construção histórica. Estudos futuros, detalhados no próximo parágrafo, podem colaborar para a elucidação mais aprofundada de momentos específicos, decompondo ou adaptando as variáveis selecionadas nos *frameworks* que compõem esta tese de doutoramento.

Por fim, estudos futuros podem se utilizar das estruturas conceituais apresentadas, de modo a adaptá-las, escolhendo a abordagem e conjunto de variáveis presentes nos diferentes casos estudados, aprofundando a compreensão dos elementos biofísicos, sociais e econômicos que, através de dotações em agentes e grupos, estruturam as disputas de poder pelo controle institucional.

Outra aplicação oportuna, para além de novos casos longitudinais de outros países e regiões, trata do aprofundamento de momentos específicos de mudança institucional nas trajetórias brasileira e nigeriana, com uma abordagem focada em um recorte histórico, considerando como pontos de partida e momentos de mudança os resultados das abordagens longitudinais apresentadas nos três manuscritos apresentados nos capítulos 2, 3, e 4.

REFERÊNCIAS DA INTRODUÇÃO E DA CONCLUSÃO

ACEMOGLU, Daron; JOHNSON, Simon; ROBINSON, James A. Institutions as a fundamental cause of long-run growth. **Handbook of economic growth**, v. 1, p. 385-472, 2005. . DOI: [https://doi.org/10.1016/S1574-0684\(05\)01006-3](https://doi.org/10.1016/S1574-0684(05)01006-3).

AYAMOLOWO, Oladimeji Joseph et al. Nigeria Electricity Power Supply System: The Past, Present and the Future. **IEEE PES/IAS PowerAfrica Conference: Power Economics and Energy Innovation in Africa**. PowerAfrica 2019, p. 64–69, 2019.

BOURDIEU, Pierre. **Outline of a theory of practice**. Cambridge University Press, 1977.

COLEMAN, JAMES S. Social Capital in the Creation of Human Capital. **The American Journal of Sociology**, v. 94, n. 1988, p. 95-S120, 1988.

DELLAPOSTA, Daniel; NEE, Victor; OPPER, Sonja. Endogenous dynamics of institutional change. **Rationality and Society**, v. 29, n. 1, p. 5–48, 2017.

DENZAU, Arthur T.; NORTH, Douglass C. Shared Mental Models - Ideologies and Institutions. **KYKLOS - International Review for Social Sciences**, v. 47, n. 1, p. 3–31, 1994.

DIMAGGIO, Paul J.; POWELL, Walter W. The iron cage revisited: Isomorphism and collective rationality in organizational fields. **American Sociological Review**, v. 48, n. 2, p. 147–160, 1983.

EDOMAH, Norbert. On the path to sustainability: Key issues on Nigeria’s sustainable energy development. **Energy Reports**, v. 2, p. 28-34, 2016.

EDOMAH, Norbert. Historical Drivers of Energy Infrastructure Change in Nigeria (1800 – 2015). In: GOKTEN, Soner; KUCUKKOCAOGLU, Guray (Ed.). **Energy Management for Sustainable Development**. 1 ed. London, UK: IntechOpen, 2018.

EDOMAH, Norbert. Governing sustainable industrial energy use: Energy transitions in Nigeria’s manufacturing sector. *Journal of Cleaner Production*, v. 210, p. 620–629, 2019.

EDOMAH, Norbert; FOULDS, Chris; JONES, Aled. Policy making and energy infrastructure change: A Nigerian case study of energy governance in the electricity sector. *Energy Policy*, v. 102, n. July 2016, p. 476-485, 2017.

FLIGSTEIN, Neil. Social Skill and the Theory of Fields. **Sociological theory**, v. 19, n. 2, p. 105-125, 2001.

FLIGSTEIN, Neil; MCADAM, Doug. *A Theory of Fields*. New York: Oxford University Press, 2012.

GONZALEZ, Carlos Germán Meza; AMADO, Nilton Bispo; SAUER, Ildo Luis. *Desenvolvimento Sustentável, Transição Energética Mundial Póscombustíveis*

Fósseis e o Pensamento Político da Esquerda Latinoamericana. **Anais do II Simpósio Internacional Pensar e Repensar a América Latina**, 2016.

GIBSON, Clark C.; WILLIAMS, John T.; OSTROM, Elinor. Local enforcement and better forests. **World development**, v. 33, n. 2, p. 273-284, 2005.

GOLDEMBERG, José; LUCON, Oswaldo. Energia, Meio Ambiente e Desenvolvimento. 3 ed. São Paulo: Edusp, 2012.

GREIF, Avner; MOKYR, Joel. Cognitive rules, institutions, and economic growth: Douglass North and beyond. **Journal of Institutional Economics**, v. 13, n. 1, p. 25-52, 2017.

IPCC. Summary for Policymakers. In: **Climate Change 2022: Mitigation of Climate Change**. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (Eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 2022. DOI: 10.1017/9781009157926.001.

LEITE, Antônio Dias. **A energia do Brasil**. 3 ed. Rio de Janeiro: Lexicon, 2014.

LOONEY, Robert E. **Handbook of Transitions to Energy and Climate Security**. 1 ed. New York: Routledge, 2016.

LOVINS, Amory B. **Reinventing fire: bold business solutions for the new energy era**. Choice Reviews Online, 2012.

MEMÓRIA DA ELETRICIDADE. **Memória da Eletricidade**. Disponível em: <http://www.memoriadaeletricidade.com.br/Default.asp?pagina=destaques/linha&menu=368&iEmpresa=Menu#368>. Acesso em: 14 dez 2015.

NEE, Victor. The new institutionalisms in economics and sociology. **The handbook of economic sociology**, v. 2, p. 49-74, 2005.

NEWELL, Peter J.; GEELS, Frank W.; SOVACOOOL, Benjamin K. Navigating tensions between rapid and just low-carbon transitions. **Environmental Research Letters**, v. 17, n. 4, p. 041006, 2022.

NORTH, Douglass C. **Institutions, Institutional Change and Economic Performance**. 1 ed. Washington: Cambridge University Press, 1990.

NORTH, Douglass C. Institutions and the Performance of Economies over time. In: **Handbook of New Institutional Economics**. Springer, p. 22-31, 2008.

OSTROM, Elinor. **Understanding Institutional Diversity**. 1 ed. Princeton, New Jersey: Princeton University Press, 2008a.

OSTROM, Elinor. Doing Institutional Analysis: Digging Deeper than Markets and

Hierarchies. In: **Handbook of New Institutional Economics**. 1 ed. Springer, p. 819-848, 2008b.

OSTROM, Elinor. Background on the Institutional Analysis and Development Framework. **Policy Studies Journal**, v. 39, n. 1, p. 7-27, 2011.

PINTO JUNIOR, Helder Queiroz et al. Economia da Indústria Elétrica. In: **Economia da Energia**. 4 ed. São Paulo: Campus Elsevier, p. 343, 2007.

RICARDO, David. From The Principles of Political Economy and Taxation. 2001. Ed. Kitchner: Batoche Books, 1821.

SAUER, Ildo Luís; ROSA, Luiz Pinguelli; CARVALHO, Joaquim Francisco; TERRY, Leslie Afrânio; PRADO, Luiz Tadêo Siqueira; LOPES, J.E.G. **A Reconstrução do Setor Elétrico Brasileiro**. 1 ed. São Paulo: Paz e Terra, 2003.

SCHNEIDER, Eric D.; JARZYNSKI, Christopher. **Into the Cool: Energy Flow, Thermodynamics, and Life**. Physics Today, 2006.

SMIL, Vaclav. Energy transitions, renewables and rational energy use: A reality check. **Organisation for Economic Cooperation and Development**. The OECD Observer, n. 304, p. 36, 2015.

SMIL, Vaclav. Examining energy transitions: A dozen insights based on performance. *Energy Research and Social Science*, 2016.

SMIL, Vaclav. *Energy and civilization: A history*. Cambridge, MA: MIT Press, 2017a.

SMIL, Vaclav. *Energy Transitions: Global and National Perspectives*. 2. ed. Santa Barbara, California: Praeger, 2017b.

SOLOMON, Barry D.; KRISHNA, Karthik. The coming sustainable energy transition: History, strategies, and outlook. **Energy Policy**, v. 39, n. 11, p. 7422–7431, 2011.

SOVACOOOL, Benjamin K. The History and Politics of Energy Transitions: Comparing Contested Views and Finding Common Ground. In: ARNDT, Channing et al. (Eds.). **The Political Economy of Clean Energy Transitions**. 1 ed. New York: Oxford University Press, p. 594, 2017.

VICTOR, David G.; HELLER, Thomas C. **The Political Economy of Power Sector Reform: The Experiences of Five Major Developing Countries**. 1 ed. Cambridge, UK: Cambridge University Press, 2007.

WILLIAMSON, Oliver E. **The Economics Institutions of Capitalism**. 1 ed. New York: The Free Press, 1985.

WILLIAMSON, Oliver E. The new institutional economics: Taking stock, looking ahead. **Journal of Economic Literature**, v. 38, n. 3, p. 595–613, 2000.

YERGIN, Daniel. **O petróleo: Uma história mundial de conquistas, poder e**

dinheiro. 7 ed. Rio de Janeiro/São Paulo: Paz e Terra, 2020.

YORK, Richard; BELL, Shannon Elizabeth. Energy transitions or additions?: Why a transition from fossil fuels requires more than the growth of renewable energy. **Energy Research & Social Science**, v. 51, p. 40-43, 2019.

APÊNDICE A – Roteiro Semiestruturado utilizado para condução das entrevistas que subsidiaram resultados dos capítulos 2 e 3.

Para aumentar a compreensão acerca da formação histórica da matriz elétrica brasileira, e com o intuito de encontrar os principais entraves para a utilização plena da fonte fotovoltaica como complemento à rede elétrica brasileira, peço que o Senhor (a) responda, com a sua opinião e de maneira livre e abrangente, as questões propostas abaixo.

1. Na opinião do senhor (a), porque o Brasil optou pela geração centralizada hidrelétrica como principal fonte desde os primórdios do setor elétrico?

1. O senhor (a) acredita que a geração centralizada deve se manter como predominante para as próximas décadas? E até o final do século XXI?
2. Porque o senhor acredita nisso?

2. Quais são os aspectos normativos, técnicos e econômicos, que influenciam positiva ou negativamente a consolidação da geração distribuída no Brasil?

1. O senhor (a) conhece o marco que estabeleceu a padronização de frequência de transmissão para energia elétrica no Brasil?
2. O senhor (a) conhece lei Elizeu Rezende de 1993?
3. O senhor (a) conhece a Resolução Normativa nº 482 de 2012 da ANEEL 2012 (revista pela Resolução Normativa nº 687 de 2015) que regulamenta o ambiente para geração distribuída no Brasil?
4. Na visão do senhor (a), quanto a Resolução Normativa da ANEEL nº 482 de 2012 (revista pela Resolução Normativa nº 687 de 2015) foi ou será impactante para o setor elétrico brasileiro e para a fonte fotovoltaica de geração distribuída?
5. Em sua opinião, tal resolução pode apontar para um crescimento das fontes distribuídas em geral? E especificamente para a fonte solar fotovoltaica?
6. Ao longo da trajetória histórica do setor elétrico quais foram as principais fontes de receita para investimentos para cada período?
 1. Tal estrutura de investimento influenciou a viabilização da geração distribuída no Brasil?

3. Na opinião do senhor (a) o que deve acontecer com fonte fotovoltaica de geração distribuída no Brasil no curto (até 2020) médio (até 2030) e longo prazo (até 2050)?

1. O senhor (a) acredita que a fonte fotovoltaica, se decolar no Brasil, será via grandes fazendas de geração centralizada ou por modelos de geração distribuída? Porque o senhor acha isso?
2. Na opinião do (a) senhor (a), como os leilões devem influenciar a inserção da fonte fotovoltaica no Brasil? Porque o senhor pensa desta forma?

4. A geração distribuída é mais ou menos interessante para a distribuidora de energia elétrica (para concessionárias que comercializam energia elétrica no mercado cativo)?

1. Os prováveis custos de transação envolvidos (contratos, medição, controle de cada instalação), na opinião do (a) senhor (a), superam ou não os ganhos em poder de barganha que a concessionária passa a ter?
2. Quais são os principais custos de transação e quais são os poderes de barganha que se ganham?
3. Se ele dizer que o mercado ainda é pequeno, perguntar: e se crescer muito?

Quais são as possíveis respostas? E como reagir a estas respostas?

APÊNDICE B – Roteiro Semiestruturado utilizado para condução das entrevistas que subsidiaram resultados do capítulo 4

Semi-structured script for conducting the in-depth interviews

Prescript (questions to warm up, pick some):

1. Why did you choose to work in the Nigerian electric sector, or how did you become part of it?
2. How long have you been working on electricity-related business or public regulation?
3. What do you most like working in the Nigerian electric sector?
4. What are the main challenges you would describe the electric sector faces in Nigeria?
5. What would you change if you held absolute power in the Nigerian electric sector?
6. What would you say it works or was an example of good experience or policy for the electric sector in Nigeria?
7. Do you think privatizations helped solve some problems in the Nigerian electric sector, or do you think it aggravated the situation?
8. Do you believe that Nigeria would be able to supply 100% of its renewable energy?
9. Which source would you describe as the most promising to supply the electricity demand growth in Nigeria?
10. In your opinion, why do Nigerians use diesel generators instead of PV?

Script: (the core information needed from the interviews)

1. In your opinion, which energetic resources were available throughout Nigeria's history that was suited for electricity generation?
1. For each period of Nigeria, which source was available, and which ones were used to generate electricity?
2. Tell us, with your own words and experience, which were the main historical facts that impacted the offer configuration in the Nigerian electric sector.
 - a. (policies, economic experiences, technology aspects, etc.)
3. Which were the significant impacts that the Federal Government had and still have on the Nigerian Electricity Industry?
4. Does the shift from hydro to oil have anything to do with the independence process? (or was it merely for economic reasons)
 - a. Why did Nigeria transition from oil to natural gas during the '80s and '90s?

Who holds most of the political power in the Nigerian electric sector?