Jornal of Legal Sciences
Pensar
e-ISSN: 2317-2150
Universidade de Fortaleza

https://doi.org/10.5020/2317-2150.2026.15797

Economic analysis of regulatory law and the use of Megapack in brazil as a way to replace thermoelectric plants [1]

Análise econômica do direito regulatório e o uso da Megapack no Brasil como forma de substituição das termelétricas

Análisis Económico del Derecho Regulatorio y el Uso de la Megapack en Brasil como Forma de Sustitución de las Termoeléctricas

Clara Kelliany Rodrigues de Brito * https://orcid.org/0000-0001-5845-5380, Universidade de Marília, Marília, São Paulo, Brasil
Sebastião Felipe Lucena Pessoa** https://orcid.org/0009-0005-1305-8169, Universidade de Marília, Marília, São Paulo, Brasil
Jonathan Barros Vita *** https://orcid.org/0000-0002-2988-4992, Universidade de Marília, Marília, São Paulo, Brasil

Editorial

Histórico do Artigo
Recebido: 17/02/2025
Aceito: 22/07/2025

Editores-chefes
Katherinne de Macêdo Maciel Mihaliuc
Universidade de Fortaleza, Fortaleza, Ceará, Brasil
katherinne@unifor.br

Sidney Soares Filho
Universidade de Fortaleza, Fortaleza, Ceará, Brasil
sidney@unifor.br

Editor Responsável
Sidney Soares Filho
Universidade de Fortaleza, Fortaleza, Ceará, Brasil
sidney@unifor.br

Autores
Clara Kelliany Rodrigues de Brito, clarardebritoadv@gmail.com
Contribuição: Conceptualization, Methodology, Writing – Original Draft, Writing - Review & Editing.

Sebastião Felipe Lucena Pessoa
felipeepessoa@yahoo.com
Contribuição: Investigation, Writing – Original Draft, Writing - Review & Editing.

Jonathan Barros Vita
jbvita@gmail.com
Contribuição: Supervision, Writing - Review & Editing.

Como citar:
BRITO, Clara Kelliany Rodrigues de; PESSOA, Sebastião Felipe Lucena; VITA, Jonathan Barros. Análise econômica do direito regulatório e o uso da Megapack no Brasil como forma de substituição das termelétricas. **Pensar – Revista de Ciências Jurídicas**, Fortaleza, v. 31, e15955, 2026. DOI: https://doi.org/10.5020/2317-2150.2026.15797

Declaração de disponibilidade de dados

A Pensar – Revista de Ciências Jurídicas adota práticas de Ciência Aberta e disponibiliza, junto à presente publicação, a Declaração de Disponibilidade de Dados (Formulário Pensar Data) preenchida e assinada pelos autores, a qual contém informações sobre a natureza do artigo e a eventual existência de dados complementares. O documento pode ser consultado como arquivo suplementar neste site.

Abstract

This study economically analyzes the regulatory law related to the use of Megapacks as substitutes for thermal power plants in the Brazilian energy sector. The main objective is to evaluate the possible economic impacts of the implementation of Megapacks as an alternative to thermal power plants, from the perspective of regulatory law. To this end, the specific objectives sought to evaluate the current regulatory structure of the energy sector in Brazil, the economic performance of thermal power plants in comparison to Megapacks, as well as to identify the main legal and regulatory challenges for the adoption of these batteries on a large scale in the country. In this sense, the analysis considered the operation and maintenance costs, efficiency and environmental impacts of both thermal power plants and Megapacks. In addition, the regulations governing the operation and integration of these energy sources in the Brazilian energy system were explored. As a general objective, the study aimed to support the formulation of public policies that would encourage the transition to cleaner, more efficient and sustainable energy sources. For the research, the deductive method was used, with a qualitative approach to the indexed documents and bibliographic materials. Finally, it was concluded that it is necessary to explore the diversification of the Brazilian energy matrix and promote a more resilient and environmentally responsible energy storage system, given the high costs and instabilities generated by thermoelectric plants, therefore proposing the adoption of the Megapacks system as an alternative.

Keywords: *economic analysis; storage; regulatory law; Megapacks; energy sector.*

Resumo

Este estudo analisa economicamente o direito regulatório relacionado ao uso de Megapacks como substitutos das termelétricas no setor de energia brasileiro. O objetivo principal é avaliar os possíveis impactos econômicos da implementação dos Megapacks como alternativa às termelétricas, sob a perspectiva do direito regulatório. Para isso, os objetivos específicos buscaram avaliar a atual estrutura regulatória do setor de energia no Brasil, o desempenho econômico das termelétricas em comparação aos Megapacks, bem como, identificar os principais desafios legais e regulatórios para a adoção dessas baterias em larga escala no país. Nesse sentido, a análise considerou os custos de operação e manutenção, a eficiência e os impactos ambientais tanto das termelétricas quanto dos Megapacks. Além disso, exploraram-se as normas que regem a operação e integração dessas fontes de energia no sistema energético brasileiro. Como objetivo geral, o estudo primou em fundamentar a formulação de políticas públicas que incentivassem a transição para fontes de energia mais limpas, eficientes e sustentáveis. Para a pesquisa, utilizou-se o método dedutivo, com abordagem qualitativa dos documentos e materiais bibliográficos indexados. Conclui-se que é necessário explorar a diversificação da matriz energética brasileira e promover um sistema de armazenamento energético mais resiliente e ambientalmente responsável, tendo em vista os altos custos e instabilidades geradas pelas termelétricas, propondo-se, portanto, a adoção do sistema Megapacks como alternativa.

Palavras-chave: *análise econômica; armazenamento; direito regulatório; Megapacks; setor energético.*

[1] Artigo traduzido a partir de Inteligência Artificial.

* Doutora e Mestra em Direito pela Universidade de Marília (UNIMAR/SP), na área de concentração Empreendimentos Econômicos, Desenvolvimento e Mudança Social. É especialista em Direito Público com Magistério Superior (UNISEB) e em Direito Civil e Empresarial (IBMEC/SP). Graduou-se em Direito pela Faculdade do Maranhão. Exerce o cargo de Professora Adjunta da Universidade Estadual do Maranhão (UEMA) e atua como Docente do Programa de Pós-Graduação Stricto Sensu em Direito (Mestrado e Doutorado) da Universidade de Marília (UNIMAR). Também é Coordenadora e Professora em cursos de Pós-Graduação Lato Sensu da SVT Faculdade, tendo lecionado em diversos programas ofertados em parceria com a Escola Superior de Advocacia (ESA).

** Doutorando em Direito Constitucional pelo Instituto Brasileiro de Ensino, Desenvolvimento e Pesquisa (IDP). Mestre em Direito pela Universidade de Marília (Unimar-SP). Especialista em Direito Público e em Gestão, Governança e Setor Público pela Pontifícia Universidade Católica do Rio Grande do Sul (PUC-RS). Bacharel em Direito pela Faculdade Estácio de Teresina (Bolsista integral Prouni). Advogado e Chefe de Gabinete do Prefeito do município de Tuntum-MA.

*** Advogado, Consultor Jurídico e Contador. Especialista em Direito Tributário pelo Instituto Brasileiro de Estudos Tributários (IBET/SP), Mestre e Doutor em Direito pela Pontifícia Universidade Católica de São Paulo (PUC/SP) e Mestre em Segundo Nível em Direito Tributário da Empresa pela Universidade Comercial Luigi Bocconi, Milão/Itália. Estágio de pós doutorado como Senior visiting research fellow na WU (Wirtschaftsuniversität Wien), Viena/Áustria. Coordenador e professor titular do Mestrado e Doutorado em Direito da UNIMAR. Editor da Revista Argumentum, Qualis B1 (ojs.unimar.br). Professor de diversos cursos de pós-graduação no Brasil e exterior. Diretor da ABDF/IFA Brasil. Conselheiro do Conselho Municipal de Tributos de São Paulo. Ex-Conselheiro do CARF, Conselho Administrativo de Recursos Fiscais.

Resumen

Este estudio realiza un análisis económico del derecho regulatorio relacionado con el uso de Megapacks como sustitutos de las plantas termoeléctricas en el sector energético brasileño. El objetivo principal es evaluar los posibles impactos económicos derivados de la implementación de los Megapacks como alternativa a las termoeléctricas, desde la perspectiva del derecho regulatorio. Para ello, los objetivos específicos se orientaron a evaluar la estructura regulatoria vigente del sector energético en Brasil, el desempeño económico de las termoeléctricas en comparación con los Megapacks, así como identificar los principales desafíos jurídicos y regulatorios para la adopción de estas baterías a gran escala en el país. En este sentido, el análisis consideró los costos de operación y mantenimiento, la eficiencia y los impactos ambientales tanto de las termoeléctricas como de los Megapacks. Además, se examinaron las normativas que regulan la operación e integración de estas fuentes de energía en el sistema energético brasileño. Como objetivo general, el estudio buscó fundamentar la formulación de políticas públicas que fomenten la transición hacia fuentes de energía más limpias, eficientes y sostenibles. Para la investigación, se empleó el método deductivo, con un enfoque cualitativo aplicado a documentos y materiales bibliográficos indexados. Se concluye que es necesario avanzar en la diversificación de la matriz energética brasileña y promover un sistema de almacenamiento energético más resiliente y ambientalmente responsable, considerando los elevados costos y las inestabilidades generadas por las termoeléctricas, proponiéndose, por lo tanto, la adopción del sistema de Megapacks como alternativa.

Palabras clave: *análisis económico; almacenamiento; derecho regulatorio; Megapacks; sector energético.*

1 Introduction

The energy sector constitutes an essential element for the economic, industrial, and social development of any nation, being responsible for enabling the operation of large-scale strategic activities. In Brazil, this relevance is accompanied by persistent challenges regarding the maintenance of a secure, efficient, and environmentally sustainable energy supply. Due to the growing demand for alternative energy sources, combined with the need to reduce greenhouse gas emissions, there has been an increasing search for innovative solutions that combine economic feasibility, legal certainty, and environmental rationality. Among these innovations, energy storage systems, such as Megapacks, have been gaining attention in specialized literature and in the energy planning of developed countries.

In light of this scenario, the central scope of this study is to compare Megapack systems with traditional thermoelectric power plants, based on the analysis of their respective operating costs, maintenance requirements, and environmental impact. The research is situated within the field of Economic Analysis of Regulatory Law, with the purpose of assessing the legal and economic effects resulting from the adoption of new energy technologies within the Brazilian regulatory framework.

The guiding question of this investigation is as follows: What are the economic and regulatory impacts of implementing Megapack storage systems in the Brazilian energy sector compared to the traditional thermoelectric model? Based on this question, the specific objectives are to: (i) examine the current regulations in the Brazilian electricity sector, with emphasis on the legal norms governing thermoelectric plants and energy storage systems; (ii) conduct a comparative analysis between both models in terms of operational costs, energy efficiency, and environmental externalities; and (iii) identify the main regulatory challenges and barriers to the implementation of Megapacks, proposing normative guidelines to encourage their adoption.

The justification for this research lies in the urgent need to diversify the national energy matrix, along with the importance of promoting a stable and technologically updated regulatory environment capable of fostering investments in clean technologies. Moreover, this investigation contributes to deepening the legal debate on the energy transition and the role of the State in promoting sustainable innovations, articulating the existing regulatory instruments with the principles of economic efficiency and distributive justice.

To achieve the proposed objectives, the adopted approach is qualitative in nature, based on the deductive method, through document and bibliographic analysis. Legal instruments such as Federal Decree No. 11,120/2022, which addresses foreign trade operations involving lithium minerals and their derivatives; Federal Law No. 14,300/2022, which establishes the legal framework for distributed micro and mini-generation; and Bill No. 1,224/2022, which regulates energy storage within the scope of the National Interconnected System (SIN), were examined. The analysis of these instruments is articulated with the principles of Economic Analysis of Law (EAL), in order to critically understand the legal incentives and disincentives for adopting innovative technologies in the national energy sector.

2 Economic Analysis of Law

The application of economic analysis to law allows for the examination of legal norms through the lens of the incentives they produce, considering them as mechanisms capable of influencing individual behavior. This perspective makes it possible to anticipate collective choices based on the observation of individual patterns (Farnsworth, 2012).

Economic Analysis of Law (EAL) is characterized by breaking with the notion of law as an autonomous discipline disconnected from social dynamics (Esposito, 2015). It is founded on the premise that legal norms are shaped by economic and social factors, which justifies the incorporation of methods from other social sciences into legal analysis (Sunstein, 2013).

Although there are methodological differences between economic and legal approaches, overcoming them is essential to achieve a more comprehensive understanding of legal problems. Despite divergences in language and instruments, law and economics offer distinct yet complementary perspectives on common issues (Mahoney, 2017). Considering them as irreconcilable fields limits analytical capacity. A purely economic interpretation of legal norms proves incomplete, just as the application of law that disregards the effectiveness of its practical effects is also insufficient (Jones; O'Connor; Stake, 2011). Therefore, it becomes necessary to recognize the limits, areas of operation, and utility of each field for society.

In this regard, it is evident that, although distinct, legal and economic sciences are interconnected. In a globalized scenario, it is difficult to conceive of a legal act that does not have repercussions in the economic sphere. Likewise, legislation is sensitive to economic variations and pressures.

While economics is dedicated to the study of human choices and their consequences, law aims to regulate these choices based on values and social principles specific to each historical and cultural context. The interrelation between these two areas of knowledge underpins the proposal of an interdisciplinary approach as a method for interpreting the legal phenomenon. In this context, Economic Analysis of Law consists of the use of concepts and instruments from economics to understand, evaluate, and improve the legal system:

> [...] um método de interpretação do fenômeno jurídico no qual são utilizadas as metodologias criadas na ciência social econômica, especialmente com a incorporação dos elementos valor, utilidade e eficiência. Esse método está baseado em dois enfoques: na análise positiva do Direito, relativo aos efeitos econômicos que ocorrem com um determinado enquadramento jurídico, e na análise normativa do Direito, que determina qual enquadramento jurídico deve ser criado a fim de se atingir a maior eficiência econômica (Morettini; Gonçalves, 2014, p. 56)[2].

Thus, law and economics form "an indivisible whole, like two sides of the same coin, making it difficult to determine to what extent the law shapes the economy or, conversely, the economy influences the law" (Nusdeo, 2021). Although the need for a joint study of these two fields is evident, this approximation is not without risks.

The unrestricted adoption of economic precepts to the detriment of legal norms can be as harmful as ignoring the relevance of economics to legal science. As Mackaay and Rousseau (2015, p. 7) point out, "recognizing the danger of relying on social science does not mean renouncing its use."

Among the challenges of the interdisciplinary approach, the tendency to reduce justice to the concept of efficiency stands out. Such a conception is unacceptable, as it limits law to a purely instrumental logic, disregarding values that are essential to society.

Justice cannot be simplified to economic efficiency. Public policies, rules, and decisions that are efficient from an economic standpoint may still be considered unjust based on legal or social criteria. This tension between justice and efficiency is central to the debate on Economic Analysis of Law. Posner (2010, p. 84), one of the leading exponents of the field, acknowledges the relevance of this connection but also warns of the challenges and limitations inherent to the integration of both disciplines.

Among the main risks of this integration is the possibility that the pursuit of efficiency compromises principles of equity and distributive justice. A public policy that maximizes overall economic welfare may, at the same time, deepen inequalities between social groups, thus violating fundamental principles of social justice (Farber; Hemel, 2020).

---

[2] "[...] a method of interpreting the legal phenomenon in which methodologies developed within the economic social sciences are applied, especially through the incorporation of the elements of value, utility, and efficiency. This method is based on two approaches: the positive analysis of Law, related to the economic effects that arise from a given legal framework, and the normative analysis of Law, which determines what legal framework should be created in order to achieve greater economic efficiency (Morettini; Gonçalves, 2014, p. 56, *free translation*)."

Furthermore, there is a risk that the complexity of law may be reduced to simplistic economic calculations, ignoring intrinsic values such as human dignity and fundamental rights. Judicial decisions based exclusively on economic criteria may disregard moral and ethical aspects, resulting in legally valid but socially unacceptable solutions (Leff, 2021).

> Para muitos estudantes de filosofia moral, Direito e Economia parecem coisas incompatíveis. Mas não são. A teoria dos direitos de propriedade é um importante ramo da teoria microeconômica moderna. Tanto para a ciência jurídica quanto para a Economia, um direito de propriedade é um direito de excluir todas as outras pessoas do uso de algum recurso escasso. Um direito dessa espécie é absoluto dentro de seu domínio (detalhe importante ao qual voltarei em breve), no sentido de que aquele que careça de um determinado bem sobre o qual pessoa tenha direito de propriedade não poderá tirar esse direito dela recorrendo ao bem-estar da sociedade. Estabelecer os direitos de propriedade como absolutos, mas condicionados aos custos de transação e subordinados à meta da maximização da riqueza, significa conferir-lhes um *status* inferior ao que muitos 'teóricos dos direitos' lhes conferem. Embora os direitos de propriedade, do ponto de vista econômico, sejam absolutos e incluam tanto a pessoa humana quanto os bens não humanos (eu tenho, dentro de limites amplos, o direito absoluto de decidir para quem trabalhar ou com quem me casar), não são transcendentes nem têm em si mesmos seu próprio fim; e geralmente operam apenas em cenários de baixos custos de transação. Não obstante, o termo se lhe aplica em um sentido perfeitamente legítimo, a menos que se considere que a ideia de direitos exclua aqueles que, embora absolutos, sejam instrumento de alguma finalidade externa à proteção dos direitos como tais (Posner, 2010, p. 84)[3].

In light of the above, it is important to recognize that, under certain circumstances, the incorporation of economic efficiency principles into the field of justice is necessary for the improvement of the legal system. Such principles involve concepts such as the maximization of social welfare, cost minimization, and the efficient allocation of scarce resources, frequently employed to guide legal decisions and public policies (Cooter; Ulen, 2012). For instance, in civil liability cases, courts may apply the concept of economic efficiency by determining that the party who can prevent damage at the lowest cost should be responsible for doing so. However, the exclusive use of these economic concepts in the pursuit of justice may be inadequate and ineffective within the legal sphere, as it disregards essential aspects such as equity, human dignity, and fundamental rights.

Moreover, it is inappropriate to assume that the joint analysis of law and economics provides definitive answers to the complex legal dilemmas that have been debated by scholars and practitioners for centuries. The greatest challenge, therefore, lies in finding an appropriate balance between law and economics, that is, between justice and efficiency. Achieving this balance requires a careful application of economic principles, without neglecting the intrinsic values of the legal system.

Practical examples of this balance can be observed in judicial decisions where, when applying cost-benefit analysis, courts consider not only the economic impacts of a decision but also ensure the preservation of individuals' fundamental rights. One example is environmental regulation, where courts often weigh the need for environmental protection against the economic costs imposed on companies, seeking a solution that is both efficient and fair (Kazmi *et al*., 2021).

It is within this context that Economic Analysis of Law is proposed as an alternative, promoting the use of economic methods to assess the adequacy of legal norms and decisions.

> A análise econômica do direito é mais ambiciosa. Parte da premissa de que os instrumentos de análise que podem ser utilizados para compreender o "direito econômico" são, igualmente, aplicáveis a outros ramos do direito. Propõe, então, a partir da concepção do ser humano e de suas relações com os

[3] "For many students of moral philosophy, Law and Economics may seem incompatible. But they are not. Property rights theory is an important branch of modern microeconomic theory. For both legal science and Economics, a property right is the right to exclude all other individuals from the use of a scarce resource. Such a right is absolute within its domain (an important detail to which I shall return shortly), in the sense that anyone lacking a certain good over which another person holds a property right cannot deprive that person of the right by appealing to society's welfare. Establishing property rights as absolute, but conditioned by transaction costs and subordinated to the goal of wealth maximization, means granting them a lower status than what many "rights theorists" attribute to them. Although property rights, from an economic perspective, are absolute and encompass both human persons and non-human goods (within broad limits, I have the absolute right to decide for whom I work or whom I marry), they are neither transcendent nor self-justifying; they generally operate only in low transaction cost scenarios. Nevertheless, the term applies to them in a perfectly legitimate sense, unless one assumes that the idea of rights excludes those which, although absolute, serve as instruments for purposes external to the protection of rights themselves (Posner, 2010, p. 84, free translation) ".

> outros a releitura do direito. Procura atualizar a "economia do direito". [...] A análise econômica do direito retoma a razão de ser das instituições jurídicas (Mackaay; Rousseau, 2015, p. 7)[4].

The Economic Analysis of Law demonstrates not only the feasibility but, above all, the necessity of establishing systematic dialogue between the legal and economic fields. In the Brazilian context, jurists such as Eros Roberto Grau and Arnoldo Wald have contributed to the maturation of this approach by advocating the integration of economic science methods as tools to enhance legal interpretation and application (Grau, 2024). The primary role of scholars dedicated to this perspective is precisely to demystify the use of economic analytical tools, demonstrating that such instruments, far from posing a threat to the legal order, can provide a more objective and consequentialist reading of the effects of legal norms.

Nevertheless, resistance to the Economic Analysis of Law is understandable, insofar as the legal system is structured around plural and subjective values, often incompatible with the quantitative metrics typical of economics. The complexity of the Brazilian legal system, marked by a multiplicity of sources, principles, and interpretations, raises legitimate questions regarding the adequacy of normative evaluation based on efficiency indicators and cost-benefit analyses (Ferraz Junior, 2018).

However, it is possible to envision that economic methods, when employed in a subsidiary and complementary manner, have the potential to enrich legal discourse by offering new categories of analysis focused on effectiveness, distributive justice, and the rationalization of public policies. Far from suppressing the intrinsic values of law, economic analysis can, on the contrary, contribute to their realization by structuring decisions that simultaneously promote justice and social welfare.

The consolidation of this perspective finds its foundations in classical authors. Adam Smith, considered the founder of modern economics, had already expressed concern about the effects of legislation on markets in his seminal work The Wealth of Nations, where he criticized excessive state intervention and introduced the concept of an "invisible hand" as a spontaneous regulator of economic interactions. Jeremy Bentham, in turn, introduced utilitarianism as a normative criterion for evaluating legal norms, arguing that the central objective of legislation should be the maximization of collective happiness. In An Introduction to the Principles of Morals and Legislation, he proposes that pain and pleasure as an essential function stimuli to human conduct, thus providing a rational basis for the formulation and interpretation of legal norms (Araújo, 2006).

Similarly, Gary Becker expands the scope of economic rationality by applying it to fields traditionally unrelated to markets, such as criminology and social relations. In Crime and Punishment: An Economic Approach, he argues that criminal behavior can be understood as a rational choice based on an equation between the potential illicit gain and the risk of punishment, considering the probability of detection and the severity of the penalty (Jesus *et al.*, 2023). Although such an approach faces ethical objections, particularly regarding the proposal to toughen sanctions as a more effective form of deterrence, its contribution to the instrumental understanding of criminal law from the perspective of efficiency is undeniable.

The theoretical framework of the Economic Analysis of Law is consolidated with Ronald Coase. In The Problem of Social Cost, the author presents what became known as the Coase Theorem, according to which, under conditions of low transaction costs, resource allocation will be efficient regardless of the initial distribution of property rights (Coase, 1960). This premise inaugurates a new way of thinking about the structure and effects of legal norms, guiding the legislator and legal practitioners towards an economic rationality that considers the social costs involved in legal interactions.

The consolidation of Economic Analysis of Law dates back to the late 19th century, when the first efforts to articulate theoretical connections between the legal and economic sciences emerged. During this period, legislation concerning property rights highlighted the need for an interdisciplinary approach capable of addressing the legal and economic effects of patrimonial relations. This movement gained strength at the University of Chicago from the 1930s onwards, where Economic Analysis of Law found fertile ground for academic institutionalization, gathering a significant number of adherents.

---

[4] The Economic Analysis of Law is more ambitious. It starts from the premise that the analytical tools used to understand "economic law" are equally applicable to other branches of law. It therefore proposes a reinterpretation of the law based on the conception of human beings and their relationships with others. It seeks to update the "economics of law." [...] The Economic Analysis of Law revisits the very rationale for the existence of legal institutions (Mackaay; Rousseau, 2015, p. 7).

Among the main exponents of this school is Ronald Coase, who, in his seminal article “The Nature of the Firm,” argues that the existence of transaction costs justifies the very constitution of firms as organizational units that are more efficient than markets for certain transactions. His theory of transaction costs has come to play a fundamental role in evaluating normative efficiency, considering that such costs, defined as those incurred by agents in conducting exchanges, directly influence the effectiveness of legal arrangements (Coase, 1960).

The main types of transaction costs include information asymmetries, negotiation costs, and legal and administrative expenses (Tabak, 2015). When high, these costs compromise the efficient allocation of resources, causing the economy to operate below its potential. In this context, the function of economic analysis is to identify and mitigate these systemic inefficiencies.

In light of the principles outlined, it is possible to examine how Economic Analysis of Law can be instrumental in evaluating high-impact socio-environmental events. A paradigmatic example is the environmental disaster caused by Samarco S.A. in 2015, when the Fundão dam in Mariana, Minas Gerais, collapsed. The incident resulted in the release of more than 39 million cubic meters of mining waste, causing the death of 19 people, the destruction of communities, and the contamination of the Doce River, with irreparable damage to biodiversity and water security in the region (Jankowsky; Mendonça; Freitas, 2024).

From the perspective of Economic Analysis of Law, such a tragedy raises fundamental questions. On the one hand, it questions to what extent business progress can be considered desirable when confronted with the resulting socio-environmental risks. On the other hand, it highlights that the transaction costs involved—here represented by environmental, social, and financial damages—must be incorporated into corporate decision-making and into the formulation of public policies for regulation and control (Cooter; Ulen, 2012).

The analysis of civil liability, especially in the context of high-risk activities such as mining, imposes on companies the obligation to repair damages caused, regardless of fault. This reflects the application of the strict liability theory, which presupposes the objective responsibility of the party causing the harm (Grau, 2024). However, in practice, reparation has proven slow and insufficient, revealing the limitations of the legal system in the face of large-scale, high-impact ventures.

This scenario, starkly illustrated by the Samarco case, allows for reflection on a broader phenomenon: the emergence of a global risk society. From the Industrial Revolution to the present day, marked by the digital economy, nanotechnology, and multinational conglomerates, the complexity and hazards associated with economic development have increased considerably. As Ulrich Beck (2016) describes, we live in a true “risk society,” where investment decisions assume global proportions and externalities can compromise the integrity of entire ecosystems or, ultimately, human survival itself.

This risk is fueled by a market logic that prioritizes economic growth and technological innovation, even in the face of uncertainties regarding the sustainability of adopted practices. The challenge, therefore, is to reconcile development promotion with environmental preservation and social justice. It is within this context that Economic Analysis of Law, combined with civil liability, becomes instrumental for constructing a more balanced legal and regulatory model.

Understanding business decisions through the lens of economic analysis requires considering theoretical models that capture the strategic logic involved. Game theory, in this sense, proves particularly useful. Faced with highly profitable opportunities, companies tend to accept high levels of environmental risk, driven by expectations of returns and the possibility of diffusing responsibilities. From this logic also emerges a “safety market,” centered on insurance, guarantees, and compensation mechanisms, whose function is to financially mitigate the negative impacts of such decisions.

Legally, this implies recognizing that the voluntary assumption of risks by economic agents generates expanded objective liability, especially when the damages exceed their capacity for prevention or control. In cases of omission, negligence, or recklessness, the analysis also incorporates subjective elements, assessing whether the required standards of care were effectively observed.

Considering the risks and externalities discussed, there is a direct reflection in the judicial sphere, where society turns to the State to resolve complex conflicts through the judicial system. This problem is exacerbated by the fact that, in many similar cases, divergent decisions have been issued, resulting in conflicting jurisprudence on the same issue. Beyond legislative innovations aimed at creating laws attentive to their social impact, it is also necessary to raise awareness among stakeholders about the need to transcend the limits of the specific dispute.

Although the concept of "Justice" has been controversial since the beginning of the legal organization of society, it remains an ideal to be pursued regardless of the direction taken. It is undeniable that justice is incompatible with the existence of different and contradictory decisions for similar cases. With the implementation of the Repetitive Demand Resolution Incident (IRDR) in Brazilian legislation, judges and society now have the possibility to resolve their disputes quickly and securely, reducing the burden on the parties involved and minimizing strain on the judiciary itself.

These theoretical considerations provide the necessary foundation to understand the regulatory and economic challenges faced by the Brazilian energy sector. Economic Analysis of Law proves especially relevant in formulating normative solutions that balance efficiency, legal certainty, and social justice. In light of this framework, it is possible to advance to the analysis of the legal and institutional structures that regulate the adoption of technological innovations, particularly energy storage systems such as Megapacks.

3 Regulatory Structure of the Brazilian Energy Sector

The Brazilian energy sector is characterized by a complex regulatory web composed of laws, decrees, resolutions, and public policies aimed at ensuring the expansion of the electricity matrix with safety, continuity, affordable tariffs, and environmental respect. The insertion of new technologies, such as large-scale energy storage systems, represents an additional challenge to this regulatory framework, which has historically been structured around conventional sources, especially hydroelectric and thermoelectric plants.

In this context, it is essential to examine the current legislation regulating both the operation of thermoelectric plants and the legal framework of Megapacks, especially in light of recent regulatory restructuring promoted by instruments such as Federal Decree No. 11,120/22, Law No. 14,300/22, and Bill No. 1,224/22. The analysis of these instruments will make it possible to assess whether the national regulatory environment offers incentives or barriers to the adoption of these new technologies and to what extent it aligns with the principles of economic efficiency and sustainability, as outlined in the previous chapter.

3.1 Challenges and Prospects for the Integration of the Energy System in Northeastern Brazil

The integration of the energy system in Brazil presents a significant challenge, especially considering the regionalization of energy aspects. In particular, the Northeast region faces considerable fluctuations and disconnections in the energy sector, highlighting the need for a more cohesive and efficient system. Anjos *et al.* (2024) point out that the predominance of intermittent renewable energy sources, such as solar and wind, in this region demands more integrated strategies to ensure stability in energy supply.

The energy integration process involves the physical connection of energy infrastructures, as well as the harmonization of policies and regulations among different states and regions. Trevisan and Oliveira (2024) emphasize the importance of cooperation between state governments and the federal government to overcome regulatory and infrastructure challenges. According to the authors, expanded cooperation can result in a more efficient and resilient energy distribution system, benefiting all states in the Northeast.

For this integration to be effective, Oliveira *et al.* (2019) argue that various policies and regulations need to be harmonized, such as energy tariffs, tax incentives for the development of renewable sources, and safety and operational standards for transmission networks. Differences in energy tariffs between states, for example, can create market distortions where some regions become more competitive than others.

Another regulatory challenge involves the harmonization of tax incentive policies for renewable energy generation, such as solar and wind power. Some states offer more attractive incentives than others, resulting in an unequal distribution of investments in renewable infrastructure. Harmonizing these policies is essential to facilitate the expansion of clean energy throughout the Northeast, promoting sustainable development (Anjos *et al.*, 2024).

In this regard, standardizing safety and operational standards for transmission networks is crucial to ensuring the efficiency and resilience of the integrated energy system. The absence of unified standards can compromise the interconnection of networks, making it difficult to transmit energy between states during critical moments (Akuru *et al.*, 2017). Therefore, cooperation between state and federal governments in harmonizing these policies and regulations is vital for the success of energy integration in the Northeast.

Furthermore, effective integration of the energy system requires significant investments in technology and infrastructure. Oliveira and Costa (2023) argue that implementing smart grids and energy storage systems

represents a promising solution to mitigate fluctuations in energy generation, particularly in regions with a strong presence of wind and solar energy. These technologies not only facilitate energy supply management but also foster sustainability in the sector.

Finally, Oliveira and Costa (2023) emphasize the importance of investing in innovative technologies, such as smart grids and energy storage systems, to address the variability of renewable energy generation. These technologies are essential to balancing energy supply and demand, especially in a region with great potential for intermittent sources like solar and wind energy.

3.2 Regulation

The restructuring of the Brazilian electricity sector, initiated in the 1990s, was primarily motivated by the need to attract private investment to reverse the decline in financial contributions observed since the 1980s. This decline threatened universal access to electricity, culminating in the 2001 energy crisis. Between 1950 and 1980, the sector experienced an average annual growth of 9.8% in generation capacity. However, between 1981 and 1993, this growth decreased to an average of 4.1% per year, lower than the consumption expansion of 5.3% per year. Studies pointed out that the inefficiency of the regulatory structure, the unsatisfactory performance of state-owned companies, and investment restrictions resulting from fiscal adjustments contributed to this stagnation (Ferreira, 2000).

Several factors compromised the technical and allocative efficiency of the sector, including distorted incentives, administrative difficulties associated with state control, political interference, tariff distortions due to price equalization policies, cross-subsidies, and return rate-based regulation. The financial situation of state-owned companies worsened due to a combination of low operational efficiency and debt accumulation, exacerbated by artificially reduced electricity tariffs as an inflation control mechanism since the 1970s.

The decision to attract private investors was consolidated in 1992 when distributors such as Light and Escelsa were included in the National Privatization Program. Regulatory reform began with the enactment of Law No. 8,631/1993, which established the “account settlement” mechanism to financially rebalance local distributors, resulting in a US$26 billion disbursement by the National Treasury. This legislation eliminated price equalization and the guaranteed return rate system, allowing companies to set their own tariffs, subject to approval by the National Department of Water and Electricity. This process was complemented by Law No. 8,987/1995, which addressed public service concessions, and Law No. 9,074/1995, which covered concession renewals, culminating in the privatization of companies like Escelsa and Light between 1995 and 1996.

In 1996, the National Electric Energy Agency (ANEEL) was created, beginning its operations in 1997 without a fully defined regulatory model. To establish this model, the government contracted the company Coopers & Lybrand in 1997, whose proposal led to the creation of the Wholesale Energy Market (MAE) and the National System Operator (ONS) in September 1998, institutions that became pillars of the new regulatory framework. The analysis of these regulatory changes highlights the importance of reforms for the development and stabilization of the energy sector in Brazil.

In this context, it is relevant to consider the analysis of Bastos (2019), who highlights the complexity of the Brazilian electricity sector’s regulatory space and the need for effective coordination among various stakeholders to ensure the effectiveness of public policies and sector stability.

The regulatory reform of the Brazilian electricity sector had as one of its central pillars the promotion of competition. To this end, it promoted the unbundling of state-owned companies, separating generation, transmission, and distribution activities at both federal and state levels. In this process, ANEEL imposed market concentration limits and established a progressive liberalization schedule, allowing the free market to expand to more consumers. The objective was to stimulate free negotiation between generators and distributors, enabling more flexible contracts and strengthening a competitive environment.

Despite initial structural advances, the Brazilian experience demonstrated that mere privatization does not, by itself, guarantee the expected benefits. Although there were efficiency gains, such as reduced technical losses and excess personnel, as well as infrastructure revitalization, the electricity sector did not undergo the same transformation observed, for example, in the telecommunications sector. The 2001 energy crisis exposed this asymmetry, showing that generation capacity expansion remained timid even after nearly a decade of reforms.

This mismatch between expectations and reality partly stems from advancing privatizations without consolidating a new regulatory framework. While the debate over new institutional foundations occurred, the sale of public assets

intensified. Between 1997 and 1998, eighteen state energy companies were privatized before the formalization of the MAE and ONS, generating a regulatory vacuum that compromised institutional transition coherence.

This misalignment damaged the credibility of regulatory institutions. As rules were gradually created and shaped by already signed concession contracts, ANEEL's actions became, in many cases, ad hoc and reactive, weakening its image among sector agents and civil society.

The comparison with the telecommunications sector illustrates the peculiarities of the electricity reform process. Asset ownership was more dispersed: while the federal government controlled generation and transmission, subnational entities controlled most distributors and some vertically integrated companies with significant participation in other segments. This institutional fragmentation imposed additional obstacles to coordinating the reform (Ferreira, 2000).

Additionally, electricity companies had higher debt levels. Unlike telecommunications companies, which financed expansion through share sales and revenue anticipation, state-owned electricity companies heavily relied on long-term loans. With artificially reduced tariffs—an inflation containment tool in the 1970s—self-financing became unfeasible. Still, financing was guaranteed by the National Treasury, which, while facilitating access to external credit, resulted in high fiscal risk.

In many cases, state governments used energy companies as instruments of indirect fiscal policy, worsening their financial situation. The result was widespread default, particularly affecting state distributors and federal generators, leading to investment paralysis and economic deterioration in the sector. As Ferreira (2000, p. 181) summarizes, the combination of ownership structure and high indebtedness compromised the possibility of broad and coordinated privatization.

Given this scenario, privatization began with distributors, whose performance was particularly critical, and whose fragility generated uncertainty about business viability for new investors. This strategy also facilitated the entry of independent power producers, promoting minimal pluralism in the sector. In light of this repositioning, it is possible to state that privatization achieved partial success: by the late 1990s, two-thirds of electricity distribution was under private control, representing a structural shift compared to the statist scenario of the early decade.

However, the slowdown of the privatization agenda from 1999 onwards had profound effects. As privatization drove regulatory reconfiguration, its stagnation compromised the implementation of the new model, particularly the functional separation between generation and transmission, a vital element for establishing a truly competitive market.

Even without full model implementation, reformist rhetoric persisted until the 2001 energy rationing. Strategic sector decisions continued based on the assumption that privatization of installed capacity, mostly state-owned, would soon occur. This institutional uncertainty hampered long-term planning and exacerbated the effects of public investment contraction.

Moreover, fiscal constraints and political instability surrounding privatization, coupled with market power exercised by vertically integrated state-owned companies such as Furnas, Chesf, Eletronorte, Cemig, and Copel, imposed additional barriers to competition. These companies maintained dominance over significant portions of power generation, often exceeding concentration limits set by ANEEL, hindering new private entrants.

This overlap of functions, with the state acting simultaneously as regulator and economic agent, increased regulatory risks and compromised investor confidence. As Monteiro (2020) argues in Revista Pensar, the Brazilian regulatory environment, by failing to clearly distinguish institutional roles, becomes vulnerable to conflicts of interest and decision-making instability, elements that discourage efficient capital allocation in the energy sector.

The dominant presence of vertically integrated state-owned companies in the electricity sector worsened perceived risks for private investors. These state-owned companies, over which the regulator had limited control, owned strategically located hydroelectric plants with low operational costs and, in many cases, fully depreciated assets. This configuration provided substantial competitive advantages to public companies, compromising equality among sector agents.

As a result, while energy from older projects was sold at lower prices, so-called "new energy" from recent hydroelectric or thermoelectric plants was offered at significantly higher tariffs. This price disparity, coupled with the possibility of anti-competitive practices such as dumping or price manipulation by state generators, discouraged new private players from entering the generation segment.

The contrast between the telecommunications and electricity sectors is illustrative. In the former, privatization was preceded by market liberalization, forcing the former state-owned Telebrás to compete directly with private companies, accelerating restructuring. In the electricity sector, however, the long-term marginal cost curve has

a positive slope. This characteristic provides a structural advantage to state-owned companies with access to cheaper energy, making it difficult for private competitors to enter, especially in an environment still marked by regulatory asymmetries.

From the 2000s onwards, institutional instability worsened. After the 2001 energy crisis and the 2002 election cycle, uncertainties about the reform agenda intensified. The election of the Workers' Party (PT) in 2002 politically blocked the continuation of privatizations. On the other hand, returning to a state-dominated model was impractical due to fiscal limitations and the difficulty of resuming the public investment levels of the 1980s. Literature indicates that public spending would need to increase by at least 0.5% of GDP to reverse underinvestment in Eletrobrás—an economically unviable scenario.

Faced with this impasse, a hybrid model was proposed, maintaining public control over strategic state-owned companies while introducing a new regulatory arrangement aimed at attracting private capital. This proposal sought to create a more stable institutional environment, less susceptible to political interference, capable of ensuring legal predictability for economic agents.

In 2003, the formulation of the new institutional model for the sector began, implemented from 2004 onwards. Its guidelines included intensifying the Ministry of Mines and Energy's role in strategic policy definition and reducing the exclusively competitive focus, with renewed emphasis on planning and energy security. Significant reforms were implemented, such as restructuring the National Electric System Operator (ONS), dissolving the Wholesale Energy Market (MAE), and creating three new bodies: the Electric Sector Monitoring Committee (CMSE), the Electric Energy Commercialization Chamber (CCEE), and the Energy Research Company (EPE).

Institutional changes were accompanied by a new tariff policy aimed at bringing energy prices closer to the long-term marginal cost. To this end, a segmented market was introduced, with "old" and "new" energy contracts coexisting, featuring different tariffs. Final consumers were subject to a tariff system based on the weighted average acquisition cost, providing greater rationality to the tariff structure.

At the regulatory level, the sector's restructuring consolidated the role of the National Energy Policy Council (CNPE) as the policy-making body under the supervision of the Ministry of Mines and Energy. Linked to the CNPE, ANEEL assumed a more robust role in regulating and supervising the sector. From 2004 onwards, various regulations were enacted to strengthen institutional governance and ensure greater regulatory security.

In the context of the Brazilian electricity sector's institutional restructuring, consolidating a robust, technically oriented regulatory framework was a decisive step in restoring private investor confidence and modernizing energy governance. In this process, various legal and regulatory measures were implemented to provide greater legal predictability, reinforce regulatory authority, and stimulate competition based on clear, stable norms.

Law No. 10,848 of March 15, 2004, established fundamental guidelines for electricity commercialization, structuring contracting mechanisms and defining the operating criteria for the Electric Energy Commercialization Chamber (CCEE). By enhancing transparency in sector commercial relations, this law strengthened the regulated competitive environment and increased legal security margins for new investors. In the same year, ANEEL Resolution No. 63 of May 12 complemented this framework by regulating the sanctions regime applicable to concessionaires, permit holders, and authorized entities that violated sector norms.

This measure reinforced the regulator's oversight authority and deterrent power while consolidating a culture of accountability among regulated agents. In the same regulatory cycle, Law No. 11,488 of June 15, 2007, established the Special Incentive Regime for Infrastructure Development (REIDI), which suspends the application of PIS/PASEP and COFINS taxes on goods and services destined for infrastructure projects, reducing investment costs and fostering national installed capacity expansion.

The adoption of this regulatory framework aimed to restore state planning and regulatory capacity, reducing legal uncertainty and creating institutional conditions for strengthening a mixed energy development model anchored in public-private collaboration. As Barbosa (2018) highlights in Revista Pensar, the new institutional model largely depends on regulatory stability and clarity of institutional competencies to avoid investment withdrawal and decision-making fragmentation.

In addition to these structural milestones, other specific regulations were also implemented to address technical and regional sector particularities. ANEEL Normative Resolution No. 343 of December 9, 2008, established criteria for the preparation, acceptance, analysis, and approval of Small Hydroelectric Plant (SHP) projects, promoting diversification of the energy matrix based on smaller-scale, lower environmental impact projects.

Similarly, Law No. 12,111 of December 15, 2009, regulated electricity services in isolated systems, ensuring supply to communities in remote or hard-to-reach areas, thus promoting greater territorial equity in energy access. Also in 2009, ANEEL Normative Resolution No. 389 established general conditions for granting authorizations to independent producers and self-producers of electricity, detailing the technical, legal, and environmental requirements for these agents to enter the market.

These regulatory measures, although distinct in scope, share the objective of consolidating a more efficient, sustainable, and legally stable electricity sector. By promoting greater transparency, stimulating productive investment, and ensuring uniform regulatory standards, the sector's new legal framework repositioned the state as an institutional coordinator and promoter of economic rationality while maintaining its role in technical regulation and public interest protection.

4 Regulatory Challenges for the Use of Megapacks in Brazil

4.1 What Are Megapacks?

The implementation of new technologies aims to assist the Electric Power System (EPS) in reducing energy costs, especially during peak demand periods, as well as contributing to system stability and minimizing instability rates. Since 1991, lithium-ion batteries have been used in small electronic devices, and currently, these batteries are employed to supply energy to EPS consumers. One of the notable advantages of lithium-ion batteries is that they do not suffer from the "memory effect" and do not need to be completely discharged to maintain their efficiency.

The Energy Research Company (EPE, 2021) highlights the main advantages of lithium-ion batteries, which include the ability to supply energy quickly, high efficiency, low operating cost, high energy density, a lifespan exceeding 15 years, and compatibility with photovoltaic and wind energy generators.

WEG (2021) demonstrated that the combination of batteries can generate high power. The cells can reach up to 300W, and groupings of these cells form a module of up to 7 kW. A rack, consisting of modules, can vary from 40 kW to 60 kW of power. A container, which groups several racks, can reach power levels of 2 MW to 3 MW. More than one container can be combined to achieve the required power, with batteries having a lifespan of 4,000 to 6,000 cycles, depending on thermal control.

In comparison terms, Tesla offers Energy Storage Systems (ESS) of different capacities. According to Lambert (2021), the Megapack model reaches up to 3 megawatt-hours (MWh), with an approximate cost of R$ 5,512,069.40. Ten Megapacks, totaling 30 MWh, cost around R$ 44,596,833.40, resulting in a price per kWh of R$ 1,690.45. For 100 Megapacks, the price per kWh drops to approximately R$ 1,445.74. This solution is justified by ease of installation, reduced space requirements, shorter installation time, and lower costs compared to other energy sources, in addition to a 20-year warranty.

Caurio (2021) highlights that the installation cost per MWh of ESS is more economical compared to other sources. The cost is approximately R$ 3,010,816.59, while for small hydroelectric plants the amount is R$ 7,044,960.55, and for wind energy, it is R$ 4,315,289.33.

4.2 Regulatory Challenges for the Use of Megapacks in Brazil

The consolidation of energy storage technologies in Brazil, particularly systems known as Megapacks, faces a significant set of barriers that go beyond the high initial implementation costs. Although the economic factor remains relevant, various regulatory, institutional, and operational obstacles have hindered the full integration of these resources into the National Interconnected System (SIN). In this context, a "barrier" is understood as any technical, regulatory, or economic obstacle that prevents, restricts, or limits the adoption of a given technology, whether by making its revenue unfeasible, delaying its implementation, or imposing dysfunctional requirements on its operation (Bhatnagar *et al*., 2013).

The slowness in defining regulatory frameworks and the lack of clarity regarding the role of storage systems within the Brazilian electricity sector exacerbate the scenario of legal uncertainty, discouraging the entry of new economic agents. This reflects the structural limitations that permeate the national regulatory environment. As pointed out by Medeiros and Feitosa (2023), the absence of functional differentiation between the legal, political, and economic systems undermines institutional autonomy and weakens democratic stability, directly affecting strategic sectors such as electric energy.

The second difficulty arises from functional restrictions imposed by rigid regulatory classifications and the compartmentalized allocation of costs. These limitations prevent a single storage system from operating in a transversal manner, for example, by accumulating functions related to generation, transmission, and distribution, which compromises its economic and technical viability. Added to this is the disparity between operational rules of different regional and sectoral markets, which hinders simultaneous operation across multiple environments, creating uncertainties regarding remuneration and performance of the services provided.

Another fundamental obstacle concerns remuneration mechanisms for ancillary services. Currently, storage systems are not properly compensated for services such as frequency regulation, fast load response, and spinning reserve, which limits their competitiveness compared to conventional technologies. This undervaluation compromises the development of sustainable business models, especially in a sector still dominated by traditional tariff structures. The absence of clear pricing for services such as inertial response, black-start capability, and reactive power supply also prevents the proper integration of Megapacks into energy planning mechanisms.

In addition to these structural difficulties, there are technical and institutional challenges related to the knowledge and analytical capacity of regulatory agents and system operators. In many cases, decision-makers have limited knowledge about the functioning, benefits, and risks associated with storage technologies, reducing their consideration in sectoral planning. Moreover, the modeling tools used for investment evaluation often lack adequate parameters to compare these technologies with conventional alternatives, compromising the recognition of their added value.

Finally, the cost structure of storage technologies remains high in some cases, reinforcing the preference for more established, albeit less efficient, solutions. Regulatory instability, combined with the absence of clear economic signals such as prices and incentives, exacerbates this scenario, making the Brazilian institutional environment less favorable to the diffusion of energy innovations.

Overcoming these barriers requires coordinated efforts among the State, the productive sector, research centers, and the financial community. The creation of specific regulatory frameworks, the definition of adequate pricing mechanisms, the promotion of research and technological development, and the introduction of market incentives are essential measures for the feasibility and expansion of storage systems in the country. As recognized by international studies, the consolidation of energy storage as a strategic element of the energy transition requires integrated public policies, long-term vision, and institutional willingness to review technical and regulatory paradigms that have, until now, favored centralized and inflexible models (Bhatnagar *et al*., 2013).

4.3 Economic Analysis of Law: Is It Advantageous to Regulate New Energy Storage Methods?

The Economic Analysis of Law is a powerful tool for assessing the relevance and impacts of regulating new energy storage methods. These rapidly advancing technologies have the potential to significantly transform the production, storage, and consumption of energy. However, before establishing regulations, it is essential to conduct a detailed examination of various aspects related to these methods.

A key aspect is the assessment of the costs and benefits involved in regulating these new energy storage methods. This evaluation should consider specific implementation costs, such as the investments required for installing storage infrastructure, including lithium-ion batteries, control and monitoring systems, and the adaptation of power grids for integrating these technologies (Silva, 2024). Operational costs, such as maintenance, thermal management of batteries, and waste management at the end of the devices' useful life, must also be included in the analysis.

The societal effects considered in the analysis include, firstly, the environmental impact of battery manufacturing and disposal, which may involve the emission of pollutants and the contamination of soil and water by heavy metals. Additionally, socioeconomic impacts must be considered, such as job creation in the technology and energy industries, broader access to renewable energy sources, and effects on energy prices for consumers (Oliveira; Costa, 2023).

Another important factor is environmental sustainability. New energy storage methods can significantly reduce greenhouse gas emissions and decrease dependence on polluting energy sources. Therefore, regulation should encourage the adoption of these clean technologies and contribute to mitigating climate change.

Moreover, the impact of regulations on the safety and stability of the electricity system must be evaluated. The integration of new storage methods may present technical and operational challenges that need to be addressed to ensure a safe and reliable energy supply.

It is also necessary to consider both the positive and negative externalities associated with these technologies. For example, energy storage can increase the resilience of the electricity system during extreme weather events, but

it may also generate negative impacts, such as environmental degradation resulting from the extraction of materials required for battery production.

In summary, the Economic Analysis of Law is essential to ensure adequate regulation of new energy storage methods, considering the various aspects involved, from economic to environmental and social factors. This promotes the transition to a more sustainable, efficient, and innovative energy system.

5 Concluding Remarks

Based on the Economic Analysis of Law applied to new energy storage methods, it is concluded that regulating these technologies is fundamental for the advancement of the energy sector. The rapid evolution of these methods represents a unique opportunity to transform energy production and consumption, making them cleaner, more efficient, and more accessible.

The assessment of costs and benefits indicates that the potential gains extend beyond the economic sphere, including the reduction of greenhouse gas emissions and decreased dependence on polluting energy sources, which is advantageous for environmental sustainability and combating climate change. To promote competitiveness in the energy market, it is crucial that regulation prevents the formation of monopolies and encourages healthy competition. Examples of successful regulations include incentives for new market entrants and the creation of competitive auction mechanisms, which have been used in countries like Germany and the United States to expand access to innovative energy storage technologies.

Additionally, it is necessary to consider the technical and operational challenges related to integrating these technologies into the electricity system, as well as the externalities, both positive and negative. While benefits such as greater system resilience are evident, it is equally important to address potential environmental and social impacts, such as waste management and the use of rare materials in batteries.

In conclusion, the Economic Analysis of Law suggests that regulating new energy storage methods is essential for the sustainable development of the energy sector, supporting the transition to a cleaner, more efficient, and resilient energy matrix. Recommended regulatory measures include the adoption of harmonized technical standards, tax incentives for low environmental impact technologies, and the creation of public-private partnerships for infrastructure development.

Achieving this goal requires the joint efforts of governments, industry, universities, research centers, companies, and the financial community, adopting a collaborative approach to regulating and adopting these innovations. Regulation in countries such as Japan, which invests in storage systems for grid stability, and Australia, with incentives for battery installation in homes, can serve as models. Thus, it will be possible to build a more promising energy future, contributing to a more sustainable and resilient world in the face of 21st-century challenges.

References

AGÊNCIA NACIONAL DE ENERGIA ELÉTRICA. **Relatório de atividades da ANEEL 2010**. Brasília, DF: ANEEL, 2010.

AKURU, U. B.; ONUKWUBE, I. E.; OKORO, O. I.; OBE, E. S. Towards 100% renewable energy in Nigeria. **Renewable and Sustainable Energy Reviews**, [*s. l.*], v. 71, p. 943-953, 2017. DOI: https://doi.org/10.1016/j.rser.2016.12.123

ANJOS, K. C. D.; CORREIA, L. S.; SILVA, L. R.; HOSSOÉ, H. S.; SILVA, J. P. da; CARVALHO, T. de S. N.; BEZERRA JÚNIOR, J. T.; SANTOS, A. V. Energias renováveis no nordeste brasileiro: desafios e oportunidades. **Contribuciones a Las Ciencias Sociales**, [*s. l.*], v. 17, n. 6, p. 1-19, 2024. Disponível em: https://ojs.revistacontribuciones.com/ojs/index.php/clcs/article/view/7556. Acesso em: 12 jul. 2024.

ARAÚJO, C. R. R. de. **Bentham, o utilitarismo e a filosofia política moderna**. São Paulo: EDUSP, 2006.

BECK, U. **The metamorphosis of the world:** how climate change is transforming our concept of the world. Cambridge: Polity Press, 2016.

BENTHAM, J. **Uma introdução aos princípios da moral e da legislação**. Trad. Luiz João Baraúna. São Paulo: Editora Abril, 1974.

BHATNAGAR, D.; CURRIER, A.; HERNANDEZ, J.; MA, O. **Market and policy barriers to energy storage deployment**: a study for the Energy Storage Systems Program. Albuquerque: Sandia National Laboratories, 2013. Available from: https://www.sandia.gov/ess-ssl/publications/SAND2013-7606.pdf. Access in: 1 ago. 2024.

BRASIL. **Decreto nº 11.120, de 5 de julho de 2022**. Permite as operações de comércio exterior de minerais e minérios de lítio e de seus derivados. Brasília, DF: Presidência da República, 2022a. Disponível em: https://www.planalto.gov.br/ccivil_03/_ato2019-2022/2022/decreto/d11120.htm#:~:text=DECRETO%20N%C2%BA%2011.120%2C%20DE%205,que%20lhe%20confere%20o%20art. Acesso em: 1 ago. 2024.

BRASIL. **Lei nº 8.631, de 4 de março de 1993**. Dispõe sobre a fixação dos níveis das tarifas para o serviço público de energia elétrica, extingue o regime de remuneração garantida e dá outras providências. Brasília, DF: Presidência da República, 1993. Disponível em: https://www.planalto.gov.br/ccivil_03/leis/L8631.htm. Acesso em: 1 ago. 2024.

BRASIL. **Lei nº 8.987, de 13 de fevereiro de 1995**. Dispõe sobre o regime de concessão e permissão da prestação de serviços públicos previsto no art. 175 da Constituição Federal, e dá outras providências. Brasília, DF: Presidência da República, 1995a. Disponível em: https://www.planalto.gov.br/ccivil_03/leis/l8987cons.htm. Acesso em: 1 ago. 2024.

BRASIL. **Lei nº 9.074, de 7 de julho de 1995**. Estabelece normas para outorga e prorrogações das concessões e permissões de serviços públicos e dá outras providências. Brasília, DF: Presidência da República, 1995. Disponível em: https://www.planalto.gov.br/ccivil_03/leis/l9074cons.htm. Acesso em: 01 ago. 2024.

BRASIL. **Lei nº 10.848, de 15 de março de 2004**. Dispõe sobre a comercialização de energia elétrica, altera as Leis nºs 5.655, de 20 de maio de 1971, 8.631, de 4 de março de 1993, 9.074, de 7 de julho de 1995, 9.427, de 26 de dezembro de 1996, 9.478, de 6 de agosto de 1997, 9.648, de 27 de maio de 1998, 9.991, de 24 de julho de 2000, 10.438, de 26 de abril de 2002, e dá outras providências. Brasília, DF: Presidência da República, 2004. Disponível em: https://www.planalto.gov.br/ccivil_03/_ato2004-2006/2004/lei/l10.848.htm. Acesso em: 1 ago. 2024.

BRASIL. **Lei nº 11.488, de 15 de junho de 2007**. Cria o Regime Especial de Incentivos para o Desenvolvimento da Infra-Estrutura – REIDI. Brasília, DF: Presidência da República, 2007. Disponível em: https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2007/lei/l11488.htm. Acesso em: 1 ago. 2024.

BRASIL. **Lei nº 12.111, de 9 de dezembro de 2009**. Dispõe sobre os serviços de energia elétrica nos Sistemas Isolados; altera as Leis nos 9.991, de 24 de julho de 2000, 9.074, de 7 de julho de 1995, 9.427, de 26 de dezembro de 1996, e 10.848, de 15 de março de 2004; revoga dispositivos das Leis nos 8.631, de 4 de março de 1993, 9.648, de 27 de maio de 1998, e 10.833, de 29 de dezembro de 2003; e dá outras providências. Brasília, DF: Presidência da República, 2009. Disponível em: https://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2009/Lei/L12111.htm. Acesso em: 1 ago. 2024.

BRASIL. **Lei nº 14.300, de 6 de janeiro de 2022**. Institui o marco legal da microgeração e minigeração distribuída, o Sistema de Compensação de Energia Elétrica (SCEE) e o Programa de Energia Renovável Social (PERS); altera as Leis n.º 10.848, de 15 de março de 2004, e 9.427, de 26 de dezembro de 1996; e dá outras providências. Brasília, DF: Presidência da República, 2022b. Disponível em: https://www.planalto.gov.br/ccivil_03/_ato2019-2022/2022/lei/l14300.htm. Acesso em: 1 ago. 2024.

BRASIL. **Projeto de lei nº 1.224, de 2022**. Dispõe acerca da atividade de armazenamento de energia no âmbito do Sistema Interligado Nacional (SIN). Brasília, DF: Câmara dos Deputados, 2022c. Disponível em: https://www.camara.leg.br/proposicoesWeb/fichadetramitacao?idProposicao=2322803. Acesso em: 1 ago. 2024.

CAURIO, A. P. **Análise da aplicação de sistemas de armazenamento e sistemas fotovoltaicos para redução de custos de energia elétrica de clientes do grupo A**. 2021. Monografia (Bacharelado em

Engenharia de Energia) – Escola de Engenharia, Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, 2021. Disponível em: http://hdl.handle.net/10183/224413. Acesso em: 1 ago. 2024.

COASE, R. H. The problem of social cost. **The Journal of Law & Economics**, Chicago, v. 3, p. 1-44, out. 1960. Available from: https://www.jstor.org/stable/724810. Accessed in: 1 aug. 2024.

COOTER, R.; ULEN, T. **Law and economics**. 6. ed. Boston: Pearson, 2012.

EMPRESA DE PESQUISA ENERGÉTICA. **Relatório anual de baterias e armazenamento de energia**. Brasília, DF: Ministério de Minas e Energia Secretaria de Planejamento e Desenvolvimento Energético; EPE, 2021.

EMPRESA DE PESQUISA ENÉRTICA. **Plano de decenal de expansão de energia 2027**. Brasília, DF: Ministério de Minas e Energia Secretaria de Planejamento e Desenvolvimento Energético; EPE, 2021. Disponível em: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/Documents/PDE%20 2027_aprovado_OFICIAL.pdf. Acesso em: 20 jul. 2024.

ESPOSITO, R. **Law, community and the political**. London: Routledge, 2015.

FARNSWORTH, E. A. Comparative Contract Law. *In:* REIMANN, M.; ZIMMERMANN, R. (eds.). **The Oxford handbook of Comparative Law**. Oxford: Oxford University Press, 2012. p. 899-936. DOI: https://doi.org/10.1093/oxfordhb/9780199296064.013.0029

FERRAZ JÚNIOR, T. S. **Introdução ao estudo do Direito:** técnica, decisão, dominação. 10. ed. São Paulo: Atlas, 2018.

FERREIRA, C. K. L. Privatização do setor elétrico no Brasil. *In:* PINHEIRO, A. C.; FUKASAKU, K. **A privatização no Brasil:** o caso dos serviços de utilidade pública. Brasília: BNDES, 2000. p. 179-220. Disponível em: https://web.bndes.gov.br/bib/jspui/bitstream/1408/2222/1/2000_A%20privatiza%C3%A7%C3%A3o%20no%20Brasil_P.pdf. Acesso em: 01 ago. 2024.

GRAU, E. R. **A ordem econômica na Constituição de 1988:** interpretação e crítica. 21. ed. São Paulo: Editora JusPodivm, 2024.

JANKOWSKY, M.; MENDONÇA, J. T.; FREITAS, R. R. de. Changes and challenges in artisanal fishery: unpacking the impact of a mining waste disaster. **Ocean and Coastal Research**, São Paulo, v. 72, p. 1-15, 2024. DOI: http://doi.org/10.1590/2675-2824072.23165

JESUS, T. A. C. de; CHAVES, W. A.; NASCIMENTO, W. N. do; GUIMARÃES, C. A. G. Análise econômica do Direito: considerações sobre a Teoria Econômica do Crime a partir da obra de Gary Becker. **Revista do Mestrado em Direito da Universidade Católica de Brasília**, Brasília, v. 17, n. 1, p. 108-124, jan./jun. 2023. Disponível em: https://portalrevistas.ucb.br/index.php/rvmd/article/view/14619/11735. Acesso em: 10 ago. 2024.

JONES, O. D.; O'CONNOR, E. O.'H.; STAKE, J. E. Economics, behavioral biology, and law. **Supreme Court Economic Review**, [*s. l.*], v. 19, p. 103-145, 2011. Available from: https://scholarship.law.vanderbilt.edu/faculty-publications/1068. Access in: 22 jul. 2024.

KAZMI, H.; MUNNÉ-COLLADO, I.; MEHMOOD, F.; SYED, T. A.; DRIESEN, J. Towards data-driven energy communities: a review of open-source datasets, models and tools. **Renewable and Sustainable Energy Reviews**, [*s. l.*], v. 148, p. 1-47, 2021. DOI: https://doi.org/10.1016/j.rser.2021.111290

LAMBERT, F. Tesla reveals megapack prices: starts at $1 million. **Electreck**, 26 jul. 2021. Tesla. Disponível em: https://electrek.co/2021/07/26/tesla-reveals-megapack-prices/. Acesso em: 10 ago. 2024.

LEFF, E. **Ecologia política:** desconstruindo o capital e territorializando a vida. São Paulo: Editora Unicamp, 2021.

MACKAAY, E.; ROUSSEAU, S. **Análise econômica do Direito**. 2. ed. São Paulo: Atlas, 2015.

MAHONEY, P. G. Adam Smith, prophet of Law and Economics. **The Journal of Legal Studies**, Chicago, v. 46, n. 1, p. 207–236, 2017. DOI: https://doi.org/10.1086/691629

MEDEIROS, M. X. L. de; FEITOSA, M. L. P. de A. M. Desafios do estado democrático de direito no Brasil: entre crises institucionais e a pandemia da COVID-19. **Pensar – Revista de Ciências Jurídicas**, Fortaleza, v. 28, n. 3, p. 1-13, jul./set. 2023. DOI: https://doi.org/10.5020/2317-2150.2023.12530

MORETTINI, F. T. R.; GONÇALVES, O. O. Análise econômica do controle judicial dos contratos de concessão e sua importância para o desenvolvimento. **Revista de Informação Legislativa**, Brasília, v. 51, n. 203, p. 73-89, jul./set. 2014. Disponível em: https://www12.senado.leg.br/ril/edicoes/51/203/ril_v51_n203_p73.pdf. Acesso em: 1 ago. 2024.

NUSDEO, F. **Curso de Economia:** introdução ao Direito Econômico. 11. ed. São Paulo: Revista dos Tribunais, 2021.

OLIVEIRA, C. E.; COSTA, H. **Inovação e sustentabilidade no setor energético:** o caso do Nordeste. Fortaleza: Universidade Federal do Ceará, 2023.

OLIVEIRA, I. T. M.; VEIGA, P. da M.; RIOS, S. M. C. P.; RIBEIRO, F. J. da S. P. **The political economy of trade policy in Brazil**. Brasília, DF: IPEA, 2019. Available from: https://repositorio.ipea.gov.br/bitstream/11058/9529/1/The_political_economy_of_trade_policy_in_brazil.pdf. Access in: 25 jul. 2024.

PARREIRA, L.; BENACCHIO, M. Da análise econômica do Direito para a análise jurídica da economia: a concretização da sustentabilidade. **Prisma Jurídico**, São Paulo, v. 11, n. 1, p. 179-206, 2012. Disponível em: https://periodicos.uninove.br/prisma/article/view/4031. Acesso em: 25 jul. 2024.

PIRES, J. C.; GOLDSTEIN, A. E. Agências reguladoras brasileiras: avaliação e desafios. **Revista do BNDES**, Brasília, v. 8, n. 16, p. 3-42, dez. 2001. Disponível em: http://web.bndes.gov.br/bib/jspui/handle/1408/17043. Acesso em: 1 ago. 2024.

POSNER, R. **A economia da justiça**. São Paulo: Editora WMF Martins Fontes, 2010.

SILVA, C. M. A.; FERREIRA, A. B. S.; GOMES FILHO, T. A.; NASCIMENTO, L. D.; ACRUZ, C. S.; MARQUES, F. R. V.; SILVA, L. H. P.; PEREIRA, D. D. de M.; LIMA, L. A. T. de; SILVA, G. P. G. da. Sustainable energy in Brazil: challenges and opportunities for the coming years. *In:* SEVEN EDITORA (org.). **Exploring the field of agricultural and biological sciences.** São José dos Pinhais: Seven Editora, 2024. p. 330-345. DOI: https://doi.org/10.56238/sevened2023.001-026

SUNSTEIN, C. R. Nudges.gov: behavioral economics and regulation. **Oxford Handbook of Behavioral Economics and the Law**, [*s. l.*], v. 1, p. 1-46, 2013. DOI: http://dx.doi.org/10.2139/ssrn.2220022

TABAK, B. M. A análise econômica do direito: proposições legislativas e políticas públicas. **Revista de Informação Legislativa**, Brasília, v. 52, n. 205, p. 321–345, 2015. Disponível em: http://www2.senado.leg.br/bdsf/handle/id/509955. Acesso em: 1 ago. 2024.

TREVISAN, R.; OLIVEIRA, M. M. L. P. Ex nihilo nihil fit – Cidades novas como infraestruturas territoriais no Brasil e em Portugal. **Revista Brasileira de Estudos Urbanos e Regionais**, [*s. l.*], v. 26, n. 1, p. 1-40, 2024. DOI: https://doi.org/10.22296/2317-1529.rbeur.202428pt

WEG. **Sistema de Armazenamento de Energia em Baterias (BESS).** Santa Catarina: WEG, 2021. Disponível em: https://static.weg.net/medias/downloadcenter/h0e/h3c/WEG-ESSW-sistema-de-armazenamento-de-energia-50100243-pt.pdf. Acesso em: 29 jul. 2024.