A critical review of the Trading of Surplus Renewable Energy in the context of a proposal for a universalization system.

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Abstract: The growing participation of prosumers in the energy matrix has challenged the traditional models of regulation of the Brazilian electricity sector. This article presents a critical review of the current legislation, especially Law 14,300/2022, which regulates distributed micro and minigeneration, allowing credit compensation for the surplus of energy generated, but without enabling its free commercialization in the market. The limitations of the current remuneration model and the legislative proposals under discussion in Brazil are explored, such as Bill 4530/2019 and the sectoral reform planned for 2025–2028. In this context, it is proposed the development of a System for the Universalization of the Commercialization of Renewable Energy Surpluses, which is intended to unify and streamline the management of distributed generation credits, with the possibility of fostering innovation and sustainability in the Brazilian electricity sector.
Keywords: Distributed generation; Prosumers; Free energy market; Unified Renewable Energy System; Energy regulation.

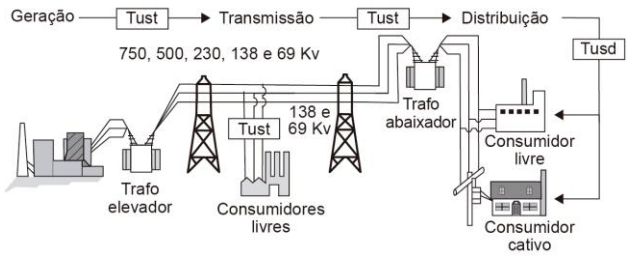
1. Introduction.

Electric Power Systems (SEP) are integrated networks that include power plants, substations, transmission lines and consumers, connected to generate, transmit and distribute electricity. Generation takes place in strategically positioned plants: hydroelectric plants take advantage of rivers and lakes, thermal plants are installed in places of easy control, wind power in windy areas, and solar power in regions with high solar radiation. Thus, SEP covers the entire process, from production to the supply of energy to end users [1].

SEP are systems designed to provide quality electricity at the required time, serving from large to small consumers. Its essential requirements include: continuity (uninterrupted supply), compliance (compliance with standards), flexibility (adaptation to change), safety (protection of users) and maintenance (rapid recovery from failures). Its structure is divided into three main stages: generation (conversion of energy into electricity), transmission/distribution (energy transport) and consumption (use in homes, industries, etc.) [1].

Figure 1 illustrates the typical topology of a SEP [2]. Clarifying that, TUST stands for Tariff for the Use of the Transmission System [2]; TUSD is the Tariff for the Use of the Distribution System [2]; o Elevator trafo: its purpose is to increase the voltage of the electric energy, ideal for the transmission of electricity over long distances [2]; The step-down trafo has the function of lowering the voltage of the electric energy, making it suitable for general use [2].

Figure 1. Typical topology of a SEP: generation, transmission, and distribution.



As recipients of the production of electricity, there are basically free and captive consumers [3]. Free consumers must have a minimum contracted demand of 2,500 kW to purchase energy from any source, and as of January 2020, this requirement will be reduced to 2,000 kW, according to Ordinance 514/2018 of the Ministry of Mines and Energy [19].

The global trend in the electricity market is to promote competition by allowing consumers to choose their suppliers, while the use of technologies such as smart *meters* advances to replace data-limited management with real-time energy trading in a liberalized market [2, 4].

At the same time, the expansion of distributed generation (such as solar panels and wind turbines close to loads, driven by the need to reduce greenhouse gas emissions) is transforming energy flows, which were once unidirectional, into multidirectional, with many consumers starting to produce energy (*prosumers*, a combination of "*producer*" and "*consumer*"), called *prosumers* [2, 4].

This shift replaces the traditional passive role of consumers with an active participation in the electricity system, while localized generation and microgrids open up new business opportunities in the sector [2, 4].

The Brazilian legislation that authorizes prosumers to sell the surplus of their production to distributors is Law 14,300, of January 6, 2022, known as the Legal Framework for Distributed Generation [6]. This standard establishes the conditions for the electricity compensation system, allowing consumers who generate energy from renewable sources, such as solar photovoltaics, to inject the surplus into the electricity grid and be compensated for it, through credits or remuneration [5, 6].

The legislation defines the criteria for microgenerators (up to 75 kW) and mini-generators (above 75 kW up to 5 MW), in addition to presenting transition rules for those who already operated under the old ANEEL regulation (Normative Resolution 482/2012) [11]. The new law aims to bring greater legal certainty and encourages the expansion of distributed generation in the country [6].

The "*Sun Rate*" was a popular term used to refer to the collection of the Tariff for the Use of the Distribution System (TUSD) [16] for consumers who have micro and mini-generation systems of electricity [17, 18], not being a tax, but a tariff for

the use of the infrastructure of the distribution network.

This tariff was instituted by Law 14,300/2022, which establishes the legal framework for distributed generation in Brazil, regulating the Electric Energy Compensation System (SCEE) and allowing renewable energy producers to inject the surplus into the grid and be compensated for it [17, 18].

According to the Law, systems with a request for connection to the grid until January 6, 2023 maintain the exemption from charging TUSD Fio B until 2045, while for new installations (as of January 7, 2023), the charge is implemented progressively, starting at 15% in 2023 and reaching 100% from 2029 [18]; the Law also provides for exemptions for shared generation and for low-income consumers registered in social programs [18].

On the other hand, captive consumers can only buy energy in the Regulated Contracting Environment (ACR), being obliged to contract from the local distributor, with tariffs set by Aneel and without the possibility of negotiation, a group that includes all residential consumers, in addition to most commerce, small industries and rural properties [4].

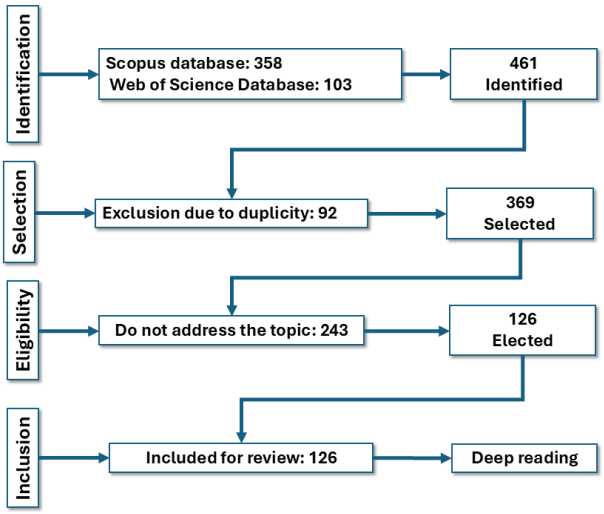
2. Review methodology

The methodology was divided into four phases. The first occurred with the bibliographic review of scientific literature in the two main bases for the dissemination of scientific productions. The second phase occurred with the verification of the legislation in force in Brazil, with the purpose of analyzing the current regulatory limits on the subject. The third phase occurred in the examination of the bills, in progress in the Brazilian legislative branch with the purpose of knowing which regulatory proposals orbit the proposed theme. The fourth and last phase consists of critical analysis and proposing an alternative to the problem pointed out.

2.1. Bibliographic review of scientific literature.

Regarding the review of scientific productions on the subject, studies were searched in the *Web of Science* and *Scopus databases*, and the data were collected on June 5, 2025. Thus, in the query to the Scopus database, 358 records were located, while the Web of Science 103, both submitted to the search terms "*energy transition, renewable energy, regulation*", using the Boolean operator "*and*", for the terms contained in the fields "*title*" and "*abstract*"", without applying filters. In a total of 461 records, 126 were selected that address the theme proposed in this project, and, therefore, will be the object of further reading to extract relevant points for the research.

Figure 2. Flowchart of the bibliographic research.



2.2. Gaps in scientific productions.

The gap lies in the identification that none of the works directly addresses the design of a unified system, as will be the proposal for a system of universalization of the commercialization of renewable energy surpluses. In this opportunity, it is worth highlighting the identification of 05 (five) productions developed in Brazil, as we can see in Table 02.

Table 2. Analysis of the approaches with the proposed theme.

Title	Approach analysis
A Regime Complex and Technological Innovation in Energy System: A Brazilian Experience [11]	It examines the Brazilian experience in the energy transition, focusing on innovation and the evolution of the country's laws and regulations to promote carbon-free growth, which aligns with the context and objectives of a unified system in Brazil.
Amazon energy transition: The need to accelerate emission reduction by the extensive adoption of solar photovoltaics and storage in Brazil [12]	It analyzes the energy transition in Brazil, with a focus on the Amazon, and discusses energy policies and new regulations to promote the adoption of renewable technologies, which directly relates to the national scope of a unified system in Brazil.
Energy transition in Brazil: Is there a role for multilevel governance in a centralized energy regime? [13]	It examines the energy transition in Brazil, addressing multilevel governance in a centralized energy regime and the need to integrate local capacities in the formulation of policies and regulations to promote the transition, which is directly relevant to the context of a unified system.
Impact of the net-metering policies on solar photovoltaic investments for residential scale: A case study in Brazil [14]	It analyzes the impact of Brazilian net-metering rules on investments in residential photovoltaics, which is directly relevant to the Brazilian context of Law 14.300/2022 and the proposal for a unified system in Brazil.
The policy dimension of energy transition: The Brazilian case in promoting renewable energies (2000–2022) [15]	It examines the political dimension of the energy transition in Brazil, analyzing the design and implementation of public policies and the configuration of sectoral governance based on regulations, which is central to the context and objectives of a unified system in Brazil.

All research data in the scientific databases can be found at the link (*https://drive.google.com/drive/folders/1E25l1qM0-FUEM28G1LUXk_s22dMMIJET?usp=sharing*).

2.3. Verification of the legislation in force in Brazil.

Considering that, currently, the Brazilian legislation in force through Law 14,300/2022 [6], does not allow prosumers (micro and mini-generators) to freely trade their surplus electricity in the market, being restricted to the compensation system with the distributor. However, there are several legislative proposals in progress that aim to expand this possibility, as we can see in Table 1.

Table 1. Comparative Legislative Proposals.

Project	ACL	Target audience	Other effects
PL 4530/2019	Yes	Micro (≤ 75 kW) / Mini (≤ 5 MW)	Bilateral trading of surplus
Industry reform (2025–28)	Yes	All voltages (until 2028)	Full ACL opening for low voltage
PL 189/2021	No	Micro up to 100 kW	Exemption from network usage fees
PL 1709/2022	No	New microgenerators	Withdrawal of exemptions and increase of charges
PL 624/2023	No	Low-income consumers	Social stimulus, reduction of technical limitation

2.4. Gaps in current legislation and proposals in Brazil.

Other proposals, such as PL 189/2021 [8], aim to encourage microgeneration through tax exemptions, but without directly dealing with commercialization in the free market. PL 1709/2022 [9] proposes adjustments to Law 14,300 to increase the collection of charges for new generators, while PL 624/2023 [10] seeks to reduce limitations imposed by distributors on energy injection, especially for the low-income population. In turn, PL 4530/2019 [7], deals with the bilateral commercialization of the surplus for micro and min energy generators, as well as the reform of the energy sector, proposed by Provisional Measure 1,300 of 2025 [20], address the Free Contracting Environment (ACL), but do not address the ideal of a unified system. Thus, a gradual legislative movement is observed that may make it possible, in the near future, for the full integration of prosumers into the free electricity market.

3. Conclusions.

Law 14,300/2022, which establishes the legal framework for distributed microgeneration and minigeneration in Brazil, does not create a free energy market for prosumers in the traditional way. The current model allows participation in the electricity compensation system, in which the surplus generated can be injected into the distributor's network and converted into credits to reduce the consumption of active electricity in other consumer units of the same holder,

including at another address, or in shared generation systems, such as consortia and cooperatives. valid for up to 60 months.

However, the current model does not authorize the direct sale of the surplus to any entity, nor the use of credits in commercial or financial transactions or forums of the distributor's regulated environment, and participation in the ACL remains restricted to consumers with minimum contracted demand and registration with the Electric Energy Trading Chamber (CCEE).

With regard to the initiatives of bills, we have the highlights for Bill 4530/2019 [7] which proposes to allow generators of up to 5 MW to directly sell their surplus in the ACL, which represents an important advance towards the liberalization of the energy market for small producers. In addition, the reform of the electricity sector planned for 2025–2028, led by the federal government, proposes the opening of the free market to all consumers, including low voltage consumers, by March 2028, which would include homes and small businesses, however they do not provide for the unification of a single system, while the proposal for a unified system would emerge as an alternative to expand the possibilities of commercialization, and not be attached to the local generation distributor.

As normative alternatives, and possible advances, there are discussions about the transformation of energy assets over the surplus of renewable energy generation, and new trading models that could expand the use of credits or allow more flexible transactions, although still without legal support in the current model. Thus, the model provided for in Law 14,300 seeks to encourage distributed generation with regulatory certainty, but without configuring a free market environment for prosumers, as well as the legislative proposals do not make such a forecast, in the same way as scientific productions, especially in Brazil.

In this context of integration of prosumers into the free market of renewable electricity, the proposal of regulatory advances for the development of a unique environment is urgent and necessary. In this scenario, the ideal of the development of the universalization of the commercialization of renewable energy surpluses arises in order to unify the possible regulation of the free market for microgeneration and minigeneration of electricity from renewable sources. Thus, the use of public data, such as ANEEL (National Electric Energy Agency), EPE (Energy Research Company), and IBGE (Brazilian Institute of Geography and Statistics), seeks to model scenarios through modeling and planning technologies, such as MATLAB [21], to be used for modeling, simulation and analysis of renewable energy systems, and PLEXOS [22] to be applied in the optimization of the planning and operation of renewable energy markets. including the integration of renewable sources, with the

purpose of demonstrating the thesis of the usefulness of a single model of commercialization of renewable energies.

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