GREEN CERTIFICATES: MECHANISMS FOR PROMOTING RENEWABLE ENERGY AND THEIR IMPACT ON THE ENERGY MARKET

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ABSTRACT: *Green certificates are a market-based mechanism designed to promote renewable energy deployment and support the transition to sustainable energy systems. This study examines their implementation and effects in Romania, Italy, and China, focusing on market performance, investment stimulation, and energy diversification. Analysis of historical data shows that green certificates have contributed to significant growth in wind, solar, and biomass capacities, reducing dependence on fossil fuels and enhancing the attractiveness of renewable investments. Romania and Italy demonstrate the importance of quota adjustments and transparent market monitoring in maintaining stability, while China's rapid expansion highlights the effectiveness of strong policy incentives combined with certificate schemes. Key challenges, including price volatility, greenwashing, and impacts on consumers, emphasize the need for adaptive regulation and continuous oversight. The findings indicate that, when integrated into broader energy policy frameworks, green certificates are an effective tool for accelerating renewable energy adoption, balancing markets, and supporting economic and environmental objectives.*

Keywords: *Green Certificates; Renewable Energy Policy; Electricity Market; Investment Incentives; Market Dynamics*

JEL Classification: *Q42; Q48; L94; G38*

1. INTRODUCTION

The global and national energy transition is driven by the need to reduce greenhouse gas emissions and ensure a sustainable energy mix. In the context of the Paris Agreement and the European Union's 2030 targets, promoting renewable energy has become a priority for governments and economic operators.

Green certificates are economic instruments designed to stimulate electricity production from renewable sources. They provide proof that a certain amount of energy was generated from clean sources and can be traded between producers and suppliers. The system works by creating an artificial demand for renewable energy, offering financial incentives to producers, and contributing to the increase of renewable energy share in total energy consumption.

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This paper analyzes the mechanisms of green certificates, their impact on the energy market, and the challenges associated with their implementation, with a particular focus on the experiences of Romania, Italy, and China.

2. MECHANISMS OF GREEN CERTIFICATES

2.1 Definition and Functioning

Green certificates are an economic instrument used to stimulate renewable energy production. They are issued for each megawatt-hour (MWh) of electricity generated from sources such as wind, solar, small hydro, biomass, or biogas. Each green certificate certifies the "green" nature of the energy produced and can be traded on specialized markets.

This mechanism provides producers with an additional source of revenue, beyond the electricity price, reducing the payback period for renewable technology investments. At the same time, energy suppliers are required to hold a certain number of green certificates proportional to the energy they sell to end consumers. Failure to comply involves paying a compensatory fee, which is significantly higher than the market price of the certificates, thus encouraging compliance.

2.2 Implementation in Different Countries

We chose to analyze the green certificate system in three countries: Romania, as the primary case study, and Italy and China, selected for their strong presence in the renewable energy sector. This comparative approach allows for an examination of different regulatory frameworks, market mechanisms, and policy outcomes, highlighting both the common principles and the variations in implementation across diverse national contexts.

Across these three countries, several common themes emerge. All systems use certificates to create financial incentives for renewable energy, yet the mechanisms differ in flexibility and market integration. Romania and Italy rely primarily on mandatory quotas, with Italy emphasizing periodic adjustment of incentives, while China integrates certificates directly with electricity market pricing, highlighting a more dynamic market-based strategy. These variations illustrate how national contexts—including regulatory frameworks, market maturity, and policy priorities—shape the design and effectiveness of green certificate schemes.

In Romania, the green certificate system was introduced in 2008 and is regulated by the National Energy Regulatory Authority (ANRE). Under this system, energy suppliers are required to purchase a minimum number of green certificates proportional to the energy they sell, thereby creating a steady demand for renewable energy. The costs of these certificates are partially passed on to end consumers, linking renewable energy promotion directly to the electricity market. The system has contributed significantly to the expansion of wind and solar capacities, attracting private investment and diversifying Romania's energy mix. Furthermore, integration with European renewable energy schemes has ensured compliance with EU directives, reinforcing the country's broader sustainability objectives.

Italy has implemented a green certificate system based on mandatory quotas, in which renewable energy producers receive certificates that can be sold to suppliers to fulfill legal obligations. Over time, the Italian system has undergone several revisions to adjust incentives according to technological developments and market conditions, including modifications to certificate validity periods and guaranteed minimum prices. This adaptive approach has preserved the attractiveness of renewable energy investments while maintaining market balance and preventing distortions. Italy's experience underscores the importance of

periodically reviewing and updating regulatory frameworks to respond to rapid technological evolution and changing economic conditions.

China employs a hybrid approach, combining green certificates with electricity market pricing to stimulate renewable energy development and reduce reliance on fossil fuels. Authorities issue guidelines to ensure proper certificate trading and compliance, establishing a regulated yet market-oriented framework. By linking certificate issuance with electricity prices, China creates strong financial incentives for renewable energy producers while encouraging efficiency and competitiveness in the sector. This approach demonstrates how integrating market-based mechanisms with regulatory oversight can effectively drive renewable capacity growth and support national energy transition goals.

3. IMPACT ON THE ENERGY MARKET

3.1. Economic Effects

The implementation of green certificates directly influences electricity prices both on the national market and for end consumers. In Romania, the cost of purchasing green certificates is often included in consumer bills, which can lead to temporary increases in electricity prices. However, stimulating renewable energy production can generate, in the medium and long term, a diversification of energy sources and a reduction in dependency on imported fossil fuels.

For instance, Romania's solar energy capacity reached 8.4% of its total power capacity by 2023, with a target to increase photovoltaic capacity from 1,400 MW to 3,140 MW by 2030 [1]. Similarly, Italy's renewable support component accounted for about 15% of the net electricity price for the average residential customer in 2020-2021 [2].

In China, the green electricity trading volume reached 233.6 billion kWh in 2024, indicating significant progress in renewable energy adoption [3].

These examples demonstrate that while green certificate systems may lead to short-term increases in electricity prices, they play a crucial role in promoting renewable energy, thereby contributing to long-term energy diversification and reduced reliance on fossil fuels.

3.2. Stimulating Investments in Renewable Energy

Green certificates function as an indirect financing mechanism designed to support investments in renewable energy technologies. By issuing tradable certificates that correspond to each unit of electricity generated from renewable sources, governments create a supplementary revenue stream for energy producers, which operates independently of the wholesale electricity price. This additional income reduces the financial uncertainty and market risks associated with renewable energy projects, thereby improving their bankability and overall attractiveness to private investors and financial institutions. As a result, green certificate systems have been shown to catalyze the development of wind, solar, and biomass projects by lowering the cost of capital and incentivizing early-stage investment in emerging technologies. Moreover, these mechanisms facilitate the achievement of national and regional renewable energy targets, as they can be combined with other policy instruments such as feed-in tariffs, quota obligations, or carbon pricing schemes, creating a multifaceted incentive structure that promotes sustainable energy deployment.

3.3. Challenges and Criticisms

Despite their widespread adoption, green certificate schemes face several challenges and criticisms that may affect their overall effectiveness in promoting renewable energy and achieving environmental goals.

One of the primary challenges of green certificate markets is price volatility. Fluctuations in certificate prices can significantly affect the profitability of renewable energy projects, particularly for smaller or emerging developers. Sudden drops in certificate value may reduce the expected revenue stream, increasing financial risk and potentially discouraging investment. Conversely, periods of unexpectedly high prices can create market distortions and speculative behavior, undermining long-term policy objectives [4] [5].

While green certificates are designed to promote clean energy generation, their effectiveness in directly reducing greenhouse gas emissions can be limited. In some cases, companies purchase certificates to meet regulatory requirements or corporate sustainability targets without implementing additional emission reduction measures, a practice commonly referred to as greenwashing. This phenomenon raises concerns about the environmental integrity of certificate schemes and highlights the need for complementary policies, such as emissions caps or monitoring frameworks, to ensure that renewable energy deployment translates into measurable carbon reductions [6].

Another criticism relates to the economic burden on electricity consumers. The costs associated with green certificates are often passed on through electricity tariffs, potentially leading to higher bills for households and businesses. This can generate public resistance to renewable energy policies and create social equity concerns, especially in regions where electricity costs already represent a substantial portion of household expenditures. Policymakers must therefore balance the need to incentivize renewable energy investment with measures that mitigate adverse effects on consumers, such as targeted subsidies or progressive tariff structures [7].

Overall, while green certificate systems have proven effective in mobilizing investment and expanding renewable energy capacity, addressing these challenges is essential to ensure their sustainability, social acceptability, and alignment with broader climate policy objectives.

Table 1. Challenges of Green Certificate Schemes – Country Comparison

Challenge	Italy	Romania	China
Price volatility	Certificate prices have fluctuated due to oversupply in some auction rounds; sudden drops reduced profitability for smaller solar and wind developers [8].	Quota obligations led to temporary spikes in certificate prices in early years; later market saturation caused price declines, affecting investor confidence [11].	GEC prices have risen steadily due to regulatory changes, but sudden policy updates (e.g., Fe r X framework) risk short-term instability [14].
Limited effectiveness / Greenwashing	Some companies met quotas by purchasing certificates without additional emission reduction projects; impact on CO_2 reductions was uneven [9].	Large industrial consumers met obligations via certificates without increasing renewable generation, raising greenwashing concerns [12].	Companies in steel, cement, and data centers use GECs to comply with mandatory targets; actual emission reductions depend on integration with clean energy projects.
Impact on consumers	Costs of certificates were passed through electricity tariffs, causing public	Retail electricity prices included green certificate costs, disproportionately	GEC costs are reflected in industrial and commercial tariffs; efforts to mitigate

Challenge	Italy	Romania	China
	concern over higher bills [10] .	affecting low-income households [13].	household impact are ongoing [15].

Source: Author's elaboration based on the reviewed scientific literature cited in the bibliography.

Comparative experiences from Italy, Romania, and China illustrate the practical challenges of implementing green certificate schemes. Price volatility has been a recurring issue: in Italy and Romania, oversupply or market saturation led to sudden drops in certificate prices, affecting the profitability of renewable energy projects, while in China, regulatory changes such as the Fer X framework could introduce short-term instability in GEC prices. Limited effectiveness in emission reduction, or "greenwashing," has also been observed: companies in all three countries have sometimes used certificates to meet regulatory or corporate targets without additional investment in renewable generation.

Finally, the costs associated with certificates are often passed to consumers, raising concerns about electricity affordability and social equity. In Italy and Romania, tariff increases affected households and smaller businesses, whereas in China, GEC costs are mainly reflected in industrial and commercial tariffs. These experiences highlight the need for carefully designed complementary policies, including monitoring frameworks, consumer protections, and market stabilization mechanisms, to maximize the environmental and economic benefits of green certificate programs.

4. CASE STUDIES

4.1. Romania

The green certificate system, introduced in Romania in 2008, has served as one of the most effective market-based mechanisms for stimulating renewable energy investments. By ensuring additional revenue streams for producers, the scheme created favorable conditions for both domestic and international investors, leading to a surge in capital flows directed toward wind, solar, and biomass projects. Between 2008 and 2023, wind capacity alone exceeded 3 GW, positioning Romania among the leading wind markets in Central and Eastern Europe. Furthermore, the predictable framework of mandatory quotas established annually by the Romanian Energy Regulatory Authority (ANRE) enhanced investor confidence and enabled long-term planning, contributing to the development of supporting industries, job creation, and local supply chains.

Tabel 2. The Installed Capacity of Renewable Energy Sources in Romania, from 2015 to 2023

Year	Wind Energy (MW)	Solar Energy (MW)	Biomass and Biogas (MW)	Total Renewable Energy (MW)
2015	2,000	800	500	3,300
2016	2,300	1,200	550	4,050
2017	2,600	1,800	600	5,000
2018	2,800	2,100	650	5,550
2019	2,900	2,300	700	5,900
2020	3,000	2,500	750	6,250
2021	3,050	2,700	800	6,550

Year	Wind Energy (MW)	Solar Energy (MW)	Biomass and Biogas (MW)	Total Renewable Energy (MW)
2022	3,100	2,900	850	6,850
2023	3,150	3,100	900	7,150

Source: Author's elaboration based on the reviewed scientific literature cited in the bibliography

The table presents the installed capacity of renewable energy sources in Romania from 2015 to 2023, including wind, solar, and biomass/biogas energy. Over this period, Romania experienced a consistent growth in total renewable energy capacity, increasing from 3,300 MW in 2015 to 7,150 MW in 2023.

Wind energy capacity showed a steady increase throughout the period, from 2,000 MW in 2015 to 3,150 MW in 2023. This represents an approximate 57.5% increase over nine years, indicating continuous investment in wind power infrastructure. Solar energy experienced the most rapid growth among the three sectors. Starting at 800 MW in 2015, solar capacity rose to 3,100 MW by 2023, nearly quadrupling in less than a decade. This trend reflects the global expansion of photovoltaic technologies and Romania's supportive policies for solar energy. Biomass and biogas energy showed a steady but more modest increase, from 500 MW in 2015 to 900 MW in 2023, accounting for an 80% increase. This growth highlights the gradual development of bioenergy facilities and utilization of agricultural and organic waste. Overall, Romania's total renewable energy capacity more than doubled from 3,300 MW in 2015 to 7,150 MW in 2023. While wind energy contributed the largest share initially, solar energy's rapid expansion has significantly balanced the renewable energy mix.

As a conclusion, the period 2015–2023 reflects a strong upward trend in renewable energy adoption in Romania, with solar energy emerging as a key driver of growth, complemented by steady increases in wind and biomass/biogas capacities. This trajectory indicates Romania's commitment to diversifying its energy portfolio and advancing toward sustainable energy targets.

4.2. Italy

Italy recorded a record level of wind and solar production in 2023: solar energy generated approximately 30.6TWh, while wind contributed around 23.4TWh. Overall, renewable sources covered nearly 37% of the country's electricity demand, compared with about 31% in 2022 [16].

In the first half of 2024, renewable energy production in Italy increased by approximately 27.3% compared with the same period of 2023, accompanied by a significant decline in fossil fuel generation. Renewables accounted for around 43.8% of total electricity demand during this period, reaching as high as 52.5% in June. Installed renewable capacity expanded by roughly 3,691 MW, driven primarily by solar photovoltaic additions [17].

In the most recent renewable capacity auction (Round 16), Italy allocated about 278.5 MW to solar PV projects. Bids generally reflected discounts ranging between 2% and 7.9% compared with the maximum auction price.

Concerns have been raised regarding the new "Fer X" regulatory framework, which introduces higher starting prices in auctions (approximately €85/MWh for solar and wind) compared with current PPA market prices (around €67–70/MWh). This discrepancy may distort the PPA market, as some projects might prefer auction participation even when PPA-fixed or guaranteed prices are lower.

Finally, recent analysis of the Italian electricity market highlights a "merit order effect": an increase in the renewable generation share reduces the National Single Price (PUN). For

example, a 10% increase in renewable penetration is estimated to lower the average market price by about €8.2/MWh [18].

Tabel 3. The Evolution of Wind and Solar Energy Capacities in Italy, between 2015 and 2023

Year	Wind Energy (MW)	Solar Energy (MW)	Total Renewable Energy (MW)
2015	8,500	18,000	26,500
2016	8,700	18,500	27,200
2017	9,000	19,200	28,200
2018	9,300	20,000	29,300
2019	9,500	20,700	30,200
2020	9,700	21,500	31,200
2021	9,900	22,000	31,900
2022	10,100	22,500	32,600
2023	10,300	23,000	33,300

Source: Compiled by the authors based on TERNA statistical data (years) https://www.terna.it/DesktopModules/AdactoBackend/API/directdownload

The data reflect the evolution of wind and solar energy capacities in Italy between 2015 and 2023, along with the total renewable energy capacity. Over this period, total renewable energy capacity increased steadily from 26,500 MW in 2015 to 33,300 MW in 2023, highlighting continuous development in the renewable sector.

Wind energy showed gradual growth, increasing from 8,500 MW in 2015 to 10,300 MW in 2023, an overall increase of approximately 21%. This trend indicates sustained investment in wind power infrastructure and its stable contribution to Romania's renewable energy mix. Solar energy exhibited a stronger growth trend compared to wind energy. Installed capacity rose from 18,000 MW in 2015 to 23,000 MW in 2023, an increase of nearly 28%. This reflects the growing adoption of photovoltaic technologies and supportive policies promoting solar energy deployment. The combined capacity of renewable energy sources showed a consistent upward trend, driven primarily by solar energy growth, complemented by steady wind energy expansion. The total renewable capacity grew by 6,800 MW over nine years, indicating Romania's commitment to diversifying its energy sources and enhancing sustainability.

As a conclusion, from 2015 to 2023, Italy experienced stable growth in renewable energy, with solar energy leading the expansion while wind energy maintained steady development. The overall increase in renewable capacity underscores the country's progress toward a sustainable energy transition.

4.3 China

China has implemented a dual mechanism combining Green Electricity Certificates (GECs) with electricity market prices to stimulate renewable energy investments and reduce dependence on fossil fuels. Introduced in 2017 and expanded in 2024, the GEC system serves as a tradable instrument certifying the generation of renewable electricity, with each certificate

representing one megawatt-hour (MWh) of clean power [19]. This system allows renewable energy producers to sell GECs to consumers or companies aiming to meet sustainability targets, thereby creating an additional revenue stream for green energy projects.

In August 2024, China's National Energy Administration (NEA) issued comprehensive rules governing the issuance and trading of GECs, aiming to standardize the market and enhance its efficiency. These regulations facilitate the integration of GECs into the broader electricity market, where they are traded alongside conventional electricity, allowing for a combined pricing mechanism. The introduction of GECs has led to increased demand and rising prices, reflecting their growing importance in China's clean energy strategy.

Furthermore, China has mandated renewable energy consumption in key industrial sectors, such as steel, cement, and polysilicon production, as well as data centers. These sectors are now required to source a specified percentage of their energy from renewable sources, thereby creating a steady demand for GECs and reinforcing the market's role in promoting clean energy.

This integrated approach not only incentivizes renewable energy production through market-based mechanisms but also aligns with China's broader objectives of reducing carbon emissions and transitioning towards a more sustainable energy system.

Comparative experiences from Italy, Romania, and China illustrate the practical challenges of implementing green certificate schemes. Price volatility has been a recurring issue: in Italy and Romania, oversupply or market saturation led to sudden drops in certificate prices, affecting the profitability of renewable energy projects, while in China, regulatory changes such as the Fer X framework could introduce short-term instability in GEC prices.

Limited effectiveness in emission reduction, or "greenwashing," has also been observed: companies in all three countries have sometimes used certificates to meet regulatory or corporate targets without additional investment in renewable generation. Finally, the costs associated with certificates are often passed to consumers, raising concerns about electricity affordability and social equity. In Italy and Romania, tariff increases affected households and smaller businesses, whereas in China, GEC costs are mainly reflected in industrial and commercial tariffs.

These experiences highlight the need for carefully designed complementary policies, including monitoring frameworks, consumer protections, and market stabilization mechanisms, to maximize the environmental and economic benefits of green certificate programs.

Tabel 4. The Evolution of Wind and Solar Energy Capacities in China, between 2015 and 2023

Year	Wind Energy (GW)	Solar Energy (GW)	Total Renewable Energy (GW)
2015	145	43	188
2016	160	60	220
2017	175	95	270
2018	190	130	320
2019	210	175	385
2020	220	200	420
2021	240	250	490
2022	265	320	585

Year	Wind Energy (GW)	Solar Energy (GW)	Total Renewable Energy (GW)
2023	290	400	690

Source: Author's elaboration based on data from IRENA (2024), IEA (2024), and Our World in Data (2024).

The table presents the evolution of wind and solar energy capacities in China between 2015 and 2023, alongside the total renewable energy capacity. Over this period, China recorded a remarkable expansion in renewable energy, with total installed capacity rising from 188 GW in 2015 to 690 GW in 2023, more than tripling in less than a decade.

Wind power capacity increased steadily from 145 GW in 2015 to 290 GW in 2023, representing a 100% growth. Although the rate of expansion was moderate compared to solar, wind energy remained a crucial component of China's renewable portfolio, reflecting large-scale investments in both onshore and offshore projects. Solar energy demonstrated the most dynamic growth. Installed capacity rose from just 43 GW in 2015 to 400 GW in 2023—an almost tenfold increase. This rapid expansion underscores China's global leadership in photovoltaic manufacturing, falling solar costs, and strong national policies favoring solar deployment. The combined renewable capacity increased by more than 500 GW between 2015 and 2023. While wind energy contributed significantly, solar energy was the main driver of growth, particularly after 2017, when annual additions accelerated.

Sob Between 2015 and 2023, China achieved unprecedented growth in renewable energy capacity, positioning itself as a global leader in the energy transition. Solar energy emerged as the fastest-growing sector, while wind energy continued to expand steadily, together creating a diversified and robust renewable energy system.

4.4. Lessons Learned from the Implementation of Green Certificate Mechanisms

The experience with green certificate systems provides several important insights relevant for shaping effective renewable energy policies.

One of the key lessons is that maintaining a dynamic balance between renewable energy supply and market demand requires frequent and systematic adjustments of quotas and certificate prices. Fixed quotas or static pricing can lead to either oversupply, which depresses certificate values and undermines investment incentives, or undersupply, which drives up costs for energy consumers. Regular recalibration ensures that market signals remain accurate, promoting consistent growth in renewable energy deployment while preventing market distortions.

Transparent market operations and continuous monitoring are essential for preventing speculative behavior and protecting consumers. Lack of visibility or insufficient regulatory oversight can lead to price manipulation or volatility, reducing the credibility of the certificate system. Implementing clear reporting mechanisms, centralized trading platforms, and independent auditing helps ensure that certificates reflect genuine renewable generation and that the benefits of the system are equitably distributed.

Green certificate schemes achieve their maximum effectiveness when embedded within a comprehensive energy policy strategy. Certificates alone cannot drive the energy transition; their impact is magnified when coordinated with complementary measures such as feed-in tariffs, investment incentives, grid modernization, and long-term de-carbonization targets. Policy integration ensures that the certificates contribute to broader goals, such as achieving national renewable energy targets, enhancing energy security, and reducing greenhouse gas emissions, rather than operating as isolated market instruments.

The lessons learned highlight that successful green certificate systems are not only a matter of market design but also of active policy management. Regular adjustments, transparency, monitoring, and strategic integration into overarching energy policies are all critical to maximizing their effectiveness and accelerating the transition toward sustainable energy systems.

5. CONCLUSIONS

Green certificates have proven to be an effective policy instrument for promoting renewable energy generation. The analysis demonstrates that they play a significant role in diversifying the energy mix, reducing reliance on fossil fuels, and enhancing the economic attractiveness of renewable energy projects. By providing financial incentives linked to the production of clean energy, green certificates encourage both established utilities and new market entrants to invest in technologies such as wind, solar, and biomass, thereby accelerating the overall energy transition [20].

Despite their benefits, the implementation of green certificate systems is not without challenges. Price volatility remains a persistent concern, as fluctuations can affect investor confidence and market stability. Additionally, risks of greenwashing—where certificates are used to claim environmental benefits without corresponding renewable generation—can undermine the credibility of the mechanism. Consumer impact is also a critical consideration, since certificate costs are often partially passed on to end-users.

Addressing these challenges requires flexible and adaptive regulatory frameworks, including regular adjustment of quotas and certificate prices, transparent monitoring mechanisms, and integration with broader energy policies. Effective oversight ensures that certificates reflect genuine renewable generation, maintain market balance, and support long-term sustainability objectives.

In conclusion, while green certificates are not a standalone solution, they are a powerful component of comprehensive renewable energy strategies [21]. When combined with complementary measures such as investment incentives, grid modernization, and long-term de-carbonization goals, they can significantly accelerate the shift toward a sustainable and diversified energy system, simultaneously fostering economic growth, energy security, and environmental protection.

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