

About time: How incorporating timestamped energy certificates into electricity markets could accelerate the energy transition

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1. Executive summary

The combination of electrification and decarbonization of the electricity sector will be responsible for addressing over 70% of all global carbon emissions¹. Although this transition is well underway, without a significant acceleration we will far exceed the 1.5C global warming threshold. Therefore, it is essential to harness the contributions of every individual and organization that is willing to act. One of the most significant actions that any individual or organization can take to reduce their carbon-emissions and support the energy transition is to choose to use carbon-free electricity over fossil-fuels.

Energy Attribute Certificates (EACs) have existed for over 20 years as the mechanism for consumers to reliably attribute electricity from a particular source without the risk of double counting or other fraud. These certificates have been incorporated into European legislation as ‘Guarantees of Origin’ (GOs) since 2006. Like nearly all EACs today, GOs are still based on ‘annual matching’ of supply and demand. This means that solar energy produced during daylight hours in summer can be claimed at any point throughout a 12-month window. Transitioning this system to a sub-hourly matching period would support more credible green energy products and create an important new price signal for energy storage and flexible resources. This concept is rapidly gaining widespread support².

This paper explores the application of time-stamped energy certificates (also called granular certificates or GCs) in electricity market design and the potential for this to price signals that accelerate the deployment of technologies delivering clean energy when it is most needed. The key findings may be summarized as follows:

- Once available, granular energy certificates based on electricity metering data are likely to become an essential instrument for the electricity sector. Previously separate and unconnected wholesale power markets and energy certificate markets will become increasingly aligned.
- As tradeable instruments, time and location-based pricing for carbon-free energy certificates will create new incentives for actions and technology investments that are essential for grid-balancing and decarbonization, such as energy storage, clean dispatchable generation and demand flexibility.
- The effectiveness of these price signals can be enhanced by incorporating these instruments into electricity market design. Several example use-cases for granular certificates in market design are explored including:
 - Providing a locational value
 - Distinguishing between green and grey power markets
 - Demand-side response incentives

This paper is intended for energy policy makers, regulators, and other relevant industry stakeholders.

2. Introduction: “Parallel Systems”

¹ <https://ourworldindata.org/emissions-by-sector>

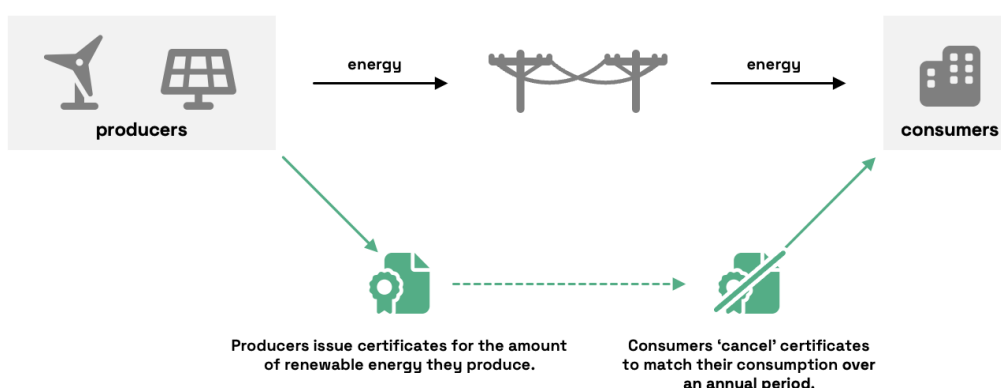
² Examples of relevant recent publications on the topic;

- ENTSOE paper on timestamped certificates <https://www.entsoe.eu/2022/07/20/views-on-a-future-proof-market-design-for-guarantees-of-origin/>
- EnergyTag Whitepaper <https://energytag.org/publications/>

As electricity markets around the world started to liberalize over 40 years ago, new market mechanisms emerged to co-ordinate the growing number of market actors and to meet various system needs.

Wholesale power markets were initially developed to facilitate effectively balancing the grid. They now play a critical role in coordinating producers and consumers to match their supply and demand in periods of typically 1-hour or shorter time units (known as imbalance periods) and to manage their risks. While volume risk is managed through the spot markets, derivatives and physical forward products help market participants to hedge price risks. Various trading venues facilitate transactions that can help participants minimize their imbalances and hedge their price exposure. By design, since all submissions are ‘pooled’ there is no traceability mechanism for buyers to determine the specific origin of their transactions. This is essentially the reason why energy attribute certificates were developed and are necessary.

Energy attribute certificates emerged over 20 years ago to address a different need; they enable consumers to choose between electricity from different sources, primarily those from renewable or carbon-free sources. Energy Attribute Certificates (EACs) work by certifying each unit of energy as it is produced and comes on the grid, so consumers can then claim that unit of energy against their own consumption by buying and retiring the corresponding certificate. The certificates are generally recorded in a centralized registry, often overseen by a regulator, grid operator or other central body, to remove the risk of double counting.



Energy attribute certificate systems now exist in nearly all mature energy markets. In Europe they are known as Guarantees of Origin and incorporated into legislation. EACs are the legal basis for all ‘green offers’ from energy suppliers and can be used for carbon accounting as part of Scope 2 market-based inventory calculations in the GHG Protocol methodology (The GHGP is the international accounting standard used for the vast majority of carbon emissions reporting and is at present undergoing a major revision process³ that is very relevant to the subject of this paper). Global demand for EACs is growing rapidly, already reaching \$12bn and expected to climb to \$100bn by 2030⁴.

These two market systems have so far existed in parallel, largely unconnected to each other, existing in separate areas of energy policy and often involving different organizations. While one is focused on system-wide *balance* of offer and demand, the other addresses the assets-to-consumers *attribution* of clean electricity.

³ https://ghgprotocol.org/survey-need-ghg-protocol-corporate-standards-and-guidance-updates?utm_medium=email&utm_source=publication&utm_campaign=ghgprotocol

⁴ <https://www.precedenceresearch.com/renewable-energy-certificate-market>

Now, however, due to a movement to add a timestamp to energy certificates systems to make them more closely represent the real-world availability of clean energy, these two regimes are becoming more closely aligned.

3. Time-based certificates and 24/7 clean energy

Typically, consumers use energy attribute certificates to match their consumption with renewable electricity produced within a 12-month window to support claims of being “100% renewable.” This approach is accepted by most existing certificate standards today and by the Green House Gas (GHG) Protocol Scope 2 guidance. As has been pointed out⁵ this ‘annual matching’ approach does not reflect the physical reality of modern grids, which experience high levels of renewable energy at certain times and much lower levels at others. Such levels of intra-day volatility were not present 20 years ago when the first certificate systems were introduced. This is becoming one of the primary challenges facing deeper grid decarbonization efforts.

Annual matching in effect means that a consumer can purchase all their certificates from any time in a 12-month window, for instance from a solar PV plant in summer, and claim them against their consumption throughout the year, including at night-time during the winter. This discrepancy with the physical reality of the grid is leading to distrust in existing certificate systems and accusations of ‘greenwashing.’ Indeed, the Advertising Standards agency in Ireland recently ruled that energy companies following existing standards to offer 100% renewable energy products are misleading the public⁶.

Furthermore, the fact that certificates are priced irrespective of time of day means they do not deliver an effective price signal to the market, based on real-world supply and demand levels. Put simply; carbon-free energy should be cheap when it is in oversupply and more expensive when in undersupply. That is not the case today with a system which ignores the time-value of clean energy.

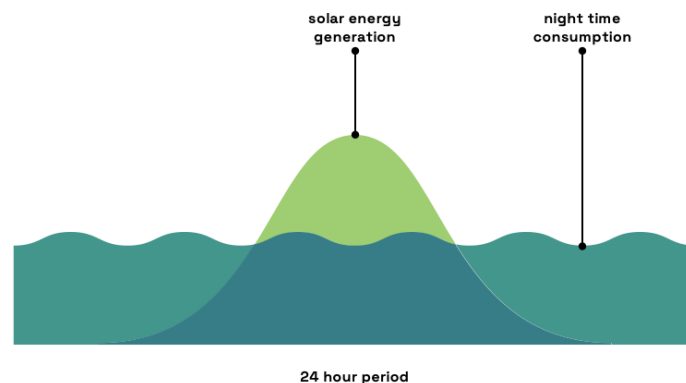


Figure 1: As an example, on an annual or monthly basis consumption at night can be matched with generation at noon.

Recently, a movement has emerged calling for existing energy certificate systems to move from ‘annual matching’ to more granular ‘sub-hourly matching.’ This involves adding a timestamp to energy certificates indicating the time-window when the electricity was produced. These certificates

⁵ Why 100% Renewable Energy is not Enough (Stanford) [https://www.cell.com/joule/fulltext/S2542-4351\(19\)30214-4](https://www.cell.com/joule/fulltext/S2542-4351(19)30214-4)

⁶ <https://www.euronews.com/green/2023/02/10/why-have-irish-energy-companies-been-told-to-drop-misleading-100-renewable-claims>

can then be used by consumers to match their consumption with production in the same time-period. Moving to more time-granular certificates could have multiple benefits:

- Fixing the trust issue – linking production to consumption in both time and distance better represents the physical grid and supports more robust carbon accounting frameworks.
- Creating a price signal for flexibility, ‘clean-firm’ generation and storage⁷, in addition to more renewables – by enabling these assets to capture the spread between low and high-priced hours.

Interest in and demand for these new time-based certificates is being driven by several factors:

- Consumer demand: Google and Microsoft have both made commitments to reach ‘24/7 clean energy’ by 2030. This new energy procurement standard involves an energy consumer seeking to match their energy consumption with clean energy production in as many hours as possible. Other organizations have since announced interest in and commitment to 24/7 clean energy sourcing, notably the US federal government⁸, as well as some of the largest cities in the world⁹.
- New research: several industry bodies and academic institutions have published papers in favour of timestamped certificates after conducting analysis on the topic. Examples of industry bodies include the International Energy Agency (IEA), UN Energy, ENTSOE (The association of European electricity system operators) and research papers such as those from TU Berlin and Princeton University.
- Regulation: regulatory changes are likely to enable and require the use of timestamped energy certificates. Some examples of these regulatory processes:
 - The upcoming Renewable Energy Directive from the European Union is expected to remove the 1MWh threshold for Guarantees of Origin and set a clear direction to more time-granular Guarantees of Origin.
 - The rules for hydrogen to be considered “green” in UK and EU have both been published recently and require hourly matching and the US methodology is also considering enforcing hourly matching.
 - Some utilities in the US have already received the required state approval to create green supply offers including hourly matching.
 - Industry standards are also playing a role in supporting the development of time-based energy certificates and hourly matching.
 - EnergyTag is a non-profit standards body that provides a framework for the issuance of time-stamped energy certificates. It has developed and published a standard for the issuance of time-based energy certificates which ensures compatibility with existing EAC systems by preventing double counting. By providing this standard, EnergyTag supports the development of a voluntary market for time-stamped certificates ahead of regulatory changes.
 - The Greenhouse Gas Protocol Scope 2 guidance sets out the framework by which companies report the carbon emissions associated with their energy consumption. At present, this guidance supports annual matching of energy attribute certificates with consumption under the ‘market-based’ approach. This guidance is now under review - this methodology is one of the aspects being examined.

⁷ <https://acee.princeton.edu/24-7/>

⁸ <https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/>

⁹ <https://www.c40.org/news/c40-and-google-launch-24-7-carbon-free-energy/>

4. Our vision

Hourly or sub-hourly tracking everywhere

The market size for energy attribute certificates is growing rapidly in most developed energy markets driven by both a rise in the total volume of clean energy generation and the demand for clean energy from consumers. Developing the ability to add a timestamp as an attribute to EACs appears to be readily achievable for many of the existing registries responsible for issuing them. Several projects from established registry providers are already underway to add timestamps as an attribute on certificates, notably from MRETs, Evident, PJM GATs and Unicorn systems¹⁰. Combined, these registries represent a significant portion of the global EAC industry.

As this trend continues, an increasing portion of EACs will be issued with sub-hourly level timestamps. It is highly likely that the data used for adding a timestamp to certificates will come from smart meters and be the same as the interval metering data used in wholesale power market settlement.

EACs today sometimes use different metering data standards compared to the wholesale power market – indeed, sometimes entirely different meters are used for submitting to the EAC registry and the power market operator. *The move to time-stamped certificates is likely to harmonize the metering data used in both systems.* This will be further facilitated if the timestamp on the certificate is aligned to the imbalance period in the wholesale power market, as has been proposed recently in Europe¹¹.

Our vision is that eventually all generation should be tracked and that it should be made mandatory for electricity consumers (or their electricity suppliers) to prove the origin of all their electricity consumption through Timestamped Energy Attribute Certificates, whether renewable or not. This concept is called consumption “full disclosure” and is already implemented in the Netherlands¹² and Austria. It becomes even more important when moving to hourly or sub-hourly matching, as consumers are then unlikely to be 100% covered by renewable energy sources. It would also enable consumers to make a conscious choice on the origin of the remaining electricity not covered by renewable energy, rather than relying on a “grid residual mix”.

It is also important that certificate transfers between countries or bidding zones are limited, to ensure that cross-zonal certificates transfers are linked to the commercial power flows happening in the power market. We strongly support ENTSO-E's view¹³ that “the absence of a locational dimension is currently causing negative side effects as large-scale RES deployment may be installed in areas without the consideration of effectively available transmission capacities between geographical areas. ENTSO-E, therefore, recommends including a locational dimension to GOs.” Further detailed analysis on this topic has been published by the Energy Track and Trace initiative¹⁴.

In general, we expect that the advent of timestamped energy certificates will lead to increased alignment between power markets and energy certificate markets, ultimately enabling coupling or ‘bundling’ of all energy certificate transactions with wholesale power market settlement. Once

¹⁰ <https://www.utilitydive.com/news/pjm-to-offer-time-matched-renewable-energy-certificates-as-demand-for-247/643135/>

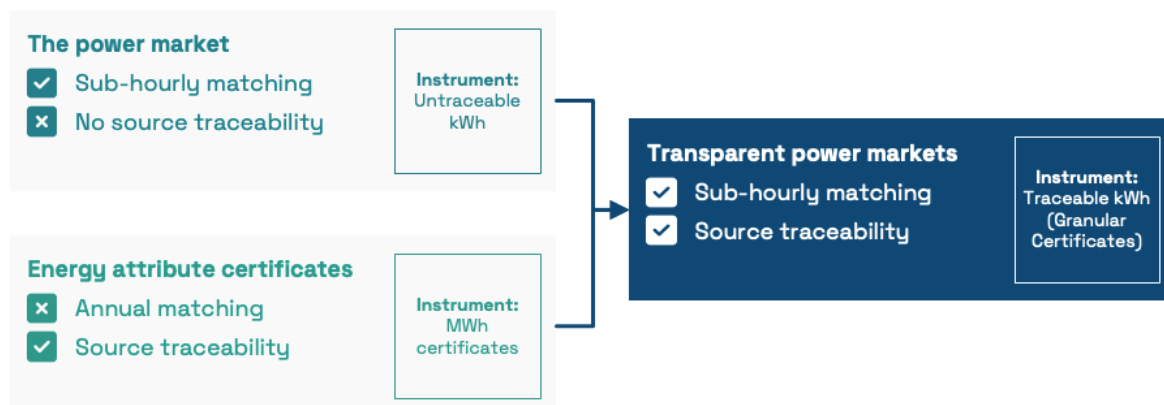
¹¹ <https://www.entsoe.eu/2022/07/20/views-on-a-future-proof-market-design-for-guarantees-of-origin/>

¹² https://recs.org/download/?file=Full-Consumption-Disclosure-in-the-Netherlands.pdf&file_type=documents

¹³ : "Views on a Future-Proof Market Design for Guarantees of Origin", ENTSO-E, July 2022

¹⁴ https://energytrackandtrace.com/wp-content/uploads/2022/09/ETT_Locational-Matching_22-09_final_01.pdf

timestamped energy certificates based on metering data that is also used in wholesale power markets are available, it is possible that they will begin to play an enhanced role as an accounting instrument in the electricity industry.



This transition could have a fundamental impact on the way electricity markets function...

Markets and contracts for hourly certificates sourcing

Spot trading: a single day-ahead auction common for power and EAC taking into account interconnection capacities from the Transmission System Operators and order books from power exchanges

Creating a spot market for granular certificates would bring much needed transparency and create a strong price signal to incentivize consumption and renewable production to be flexible and able to adjust on an hourly basis. We expect a correlation between power prices and certificate prices, as hours where renewable energy is abundant are usually already low power price hours. However, the transfer limits would lead to different prices in different bidding zones, incentivizing renewable investments in areas with high certificate prices.

As market participants will need simultaneously to balance their portfolio of power and their portfolio of granular certificates, it would be easier for them to use the same tool to trade both at the same venue. That is why our vision is that a fully integrated day-ahead auction should combine certificates and power, enabling market participants to buy green power (power and certificate as a bundle). A certificate auction, separate from the day-ahead power market, could be an interim step but ultimately, certificate trading should be incorporated into the Single Day-Ahead Coupling (SDAC) auction to maximize liquidity and implicitly transfer certificates across bidding zones. When granular certificates have been integrated with the day-ahead auction, the natural next step would be to incorporate them into the European intraday markets. This would allow the trading of combined power and EAC close to delivery of the actual power significantly increasing portfolio balancing possibilities, while reducing the risk of imbalance of power and/or certificates.

Derivatives: alignment to power structure with an hourly deliverable

With certificate values becoming non-negligible, market participants will consider hedging against their price volatility. As in power markets, forward markets for GCs will be required to provide buyers and sellers with an important tool for hedging and managing price risk.

As granular certificates will have similar characteristics as power, we expect derivative and forward markets for granular certificates to be quite similar to those for wholesale power, with similar standard products traded: calendar, quarter, month, baseload, peakload, etc.

As for spot markets, being able to buy blocks of power and certificates would facilitate market participants' trading. We envision the possibility of buying standalone power forwards and derivatives as currently, but also "green" power forwards and derivatives (power and certificate).

In countries implementing support schemes such as Contracts for Difference (CfD), the design of such CfD should also embrace the price of certificates: a power producer entering a CfD should be able to hedge both certificates and power prices at the same time.

Power Purchase Agreements: less need for corporate PPAs and more unbundled certificates as GCs align to power markets

Corporate consumers have been looking at PPAs as they are aware of the flaws of the current EAC systems and want to go beyond the minimum carbon offsetting requirements set by regulation or international carbon accounting standards. As the current issues with EAC systems are corrected, granular certificates will become a more reliable tool to accurately match consumption with green electricity every hour of the day through GCs. PPAs with annual matching will no longer be sufficient to enable corporates to claim zero carbon emissions. When using GCs to match consumption, it becomes clearer when shortfalls of renewable energy supplies happen. GCs provide a truthful indication to the consumer on how to shift their consumption to hours where green electricity is abundant; with PPAs combined with current EACs, the information remains hidden and a corporate can find itself needing to cover part of its load with fossil-based electricity.

A better alternative would then be to procure both power and its energy attributes via a competitive market, where demand and supply set the price. In this way corporates have the option to procure from the market the renewable energy exactly matching the hours of their consumption. At the same time, this would lead to a more transparent market for energy attributes pricing and more fair allocation. Most importantly, a market for GCs will open possibilities for smaller consumers to access timestamped GOs and prove their electricity consumption is green, without the need to enter into a cumbersome and onerous process to sign a PPA (currently limited to large consumers due to bankability issues). This will also enable smaller consumers to have a real impact without needing to take long-term price or volume risk, since the demand signal will support more resources being added to the grid.

Value of granular certificates volatility leading to revenues for Demand Side Response and storage

Bringing GCs to the market at times when energy buyers are committed to sourcing renewable energy in as many hours as possible would mean offering a tradable instrument, the price of which is transparent and varies according to supply and demand. The value of GCs would reflect the equilibrium between consumers' willingness to pay for a 24/7 Carbon-Free Energy supply and the availability of renewable energy at a specific hour and location. A low price would indicate an oversupply of clean energy, while more expensive certificates would characterize the hours of clean energy scarcity. Thus, GCs price could significantly fluctuate within the day, or from one season to another, incentivizing investment in new technologies which could fill the clean energy scarcity gaps left by the traditional wind and solar generation.

Among those, a revenue opportunity can be foreseen for dispatchable carbon-free generation such as dispatchable renewable production, nuclear, carbon capture, storage and demand side response (DSR). These could reshape demand to align with carbon-free generation availability and at the same time leverage on the spread between low- and high-priced hours. Specifically, storage could charge at times when carbon-free energy is abundant and GCs prices are low, proceeding to discharge when demand for green energy is high but supply is low, i.e. when GCs are high-priced. Because of storage

and DSR reaction to GCs price signals, a natural help in balancing and stabilization of the grid is also achieved. A mechanism by which energy storage devices can effectively ‘store’ GCs from times of oversupply to times of undersupply, has been proposed in the EnergyTag use-case guidelines¹⁵.

5. Example use cases for granular certificates

Once a traded market for GCs has been established, there are many different use cases for a variety of stakeholders in the market including: i) utilities and energy suppliers ii) flexibility aggregators iii) grid operators and iv) policy makers and regulators. A few example use cases are listed here, however this is very much non-exhaustive and we expect there are many more such cases that have not yet been conceived.

Next-generation green energy supply offerings

Energy suppliers can use GCs to create offers for customers that deliver unprecedented transparency to their customers. Using GCs, they can create offers for customers based on specific technologies and locations, down to the hourly level. These offers enable consumers to achieve their decarbonization goals, helping them to eliminate fossil fuels from their electricity supply mix.

Flexibility providers

Once a market for GCs is established and hourly price formation has begun, flexibility providers such as ‘virtual power plant operators’ can seek to participate in this market and create value through storage and demand-side response.

- Battery storage: as described previously, battery storage can capture value by storing GCs from times of oversupply to times of undersupply hence capturing the spread between low and high price hours.
- Demand-side response: one of the lowest cost methods through which a consumer can improve their level of hourly matching or ‘CFE score’ is to shift consumption from times of low availability of GCs to times of high availability.

Green product labelling

Electricity-intensive products are coming under increasing scrutiny to demonstrate that they are low carbon. This applies to many aspects of electrification such as transport, heating and cooling, production of alternative fuels or materials such as aluminium or steel. Production of hydrogen via electrolysis is particularly relevant, given that several governments are preparing to subsidise construction of H2 electrolysis facilities. The UK and EU have both set requirements for electrolyzers to be matched hourly with renewable energy in order to ensure that the embodied carbon of green H2 is indeed lower than blue or grey hydrogen derived from processing fossil fuels directly. This issue is also being actively debated in the US¹⁶. GCs are the natural instrument to verify the origin of electricity at an hourly level.

Locational value of power and benefits for electricity networks

Since, as with all energy attribute certificates, GCs hold a geographical tag, the value of a GC can be used as a locational price signal. This would be a simple, elegant way to ensure that for some

¹⁵ <https://www.energytag.org/wp-content/uploads/2022/03/20220329-GC-Use-Case-Guidelines.pdf>

¹⁶ <https://www.washingtonpost.com/business/2023/03/03/green-hydrogen-inflation-reduction-act/>

locations, GCs direct additional revenue, even if there continues to be a liquid zonal market for wholesale power.

Consumers willing to pay for local renewable power in a certain geography would be able to, whether they are individual consumers or in local communities. The 2019 European Clean Energy package incentivizes the creation of local energy communities¹⁷ and granular certificates would be the perfect tool to create financial incentives through grid tariff, for these communities.

Distribution network operators and their regulators can use GCs in a wide variety of applications to grid integration of clean energy. As renewable energy development accelerates, grid operators are facing a number of pressures such as:

- Interconnection queues
- Local congestion
- Lack of appropriate incentive tools

GCs make it extremely easy for regulators to create incentives that help address these problems. These incentives can be used to drive the right behaviour and investments from network users. For instance, regulators could provide an incentive for consumption of locally produced renewable energy around a medium voltage substation on a sub-hourly basis. Such an incentive could, for instance, be applied easily by reducing network charges for consumers that match a certain portion of their load with local renewables on a sub-hourly basis using GCs. This price signal could lead to increased levels of demand response and energy storage which could in turn reduce pressure on other parts of the network, by ensuring improving load balancing on a local level.

6. Progress so far

GC availability

As mentioned in section 3, significant progress and interest is being made in the development of GC markets. EAC registries covering a large portion of the global EAC market are already in the process of developing the capability to add a timestamp to EACs. Such registries include;

- MRETS (USA)
- WREGIS (USA)
- PJM GATs (USA)
- Unicorn Systems (Europe)
- Evident (International)

A wide variety of projects involving GCs have also been announced, involving large consumers, utilities, grid operators and other service providers. Many of them are following the EnergyTag standard, which ensures standards for GC markets.

NordPool and Granular Energy UK project

The authors of this report, European power market Nord Pool and Granular Energy, are leading a project in the UK to establish a framework for GCs. Other project partners include National Grid, Elexon, Unicorn Systems, Energy Systems Catapult and PwC.

¹⁷ https://energy.ec.europa.eu/topics/markets-and-consumers/energy-communities_en

There are three primary goals of the project:

- Create a framework to issue, trade and cancel hourly certificates
- Allow storage and flexibility to participate in the mechanism
- Demonstrate trading of certificates

Significant progress has been made by project partners and participants since launch in 2022:

- A detailed market rulebook has been developed, setting out the principles of the market and the scheme is in the process of being audited by the EnergyTag standard.
- The project involves many of the UK's leading energy suppliers representing a significant portion of the UK market.
- As part of the project participants have so far uploaded 9 TWh of data to establish their market positions using the Granular Energy platform. End-customers are already receiving reports on the level of hourly matching between their consumption and generation.

The participants and partners of the projects are now looking in more detail at how storage can participate in the mechanism and what a first trading venue could look like.

7. Implications for policy makers

Very recent regulations have already given clear direction and removed potential hinderances to the adoption of timestamped energy certificates.

The upcoming RED III will remove the fixed size of 1 MWh for Guarantees of Origin in the European Union, which was the main regulatory barrier for granular certificates, and will also set a clear direction of travel by indicating that Guarantees of Origin will need to align with imbalance settlement periods in the future.

The recently released Delegated Act on Renewable Fuel from Non-Biological Origin requires hourly matching to prove the origin of the renewable electricity used to generate green hydrogen from 2030 onwards. EU Member States have the possibility to individually bring this forward to 2027. Hourly Guarantees of Origin will be needed before those dates.

The EECS rules and the draft revision of the CEN standard EN16325 that together form the framework for guarantees of origin in the European Union are already compatible with hourly issuance.

It's now up to each Member State to accelerate and implement local regulations as soon as possible to:

- i. Issue hourly certificates to provide all stakeholders with the tools for claims at an increased time-granularity
- ii. Track location of both origin of electricity and where it is retired, implementing cross-border trade rules as discussed above
- iii. Enforce or promote hourly matching for claims
- iv. Enforce or promote hourly matching for claims of "green energy supply offers"

8. Areas of further development

Continued improvements to data access

Despite the high penetration of smart metering on renewable generation, in most countries the issuance of guarantee of origin is still done manually by producers entering or sending the data to the registry. Moreover, producers often only access the data at the earliest at the end of the month. Due to this, issuance of certificates usually happens a few months after the actual injection of electricity into the grid. This creates multiple issues, such as consumers having to wait a long time after the end of a financial year to have a view on their certificate allocation and their Scope 2 carbon accounting. It also creates issues for trading, with the delivery of certificates only possible months after generation. Earlier issuance would facilitate spot trading closer to the generation period.

Integrating storage in the certificate systems

Although not needed when matching generation and consumption annually, storage will be essential to reach a high level of hourly matching. With some exceptions, like pumped storage in Austria, storage is not currently integrated in certificate systems. Integrating storage in certificate systems while balancing trust in the system and limiting complexity for storage operators is a complicated task. The latest version of the EnergyTag standard laid the foundations, but there is still significant work required by the industry to, for example, detail how losses should be considered, or how certificates are released from the storage asset.

Market design aspects

There are some major market design considerations to be addressed as GCs are incorporated into energy policy and integrated into future electricity market designs;

- One design question is whether all hourly certificates should eventually be ‘bundled’ with wholesale power market settlement contracts or continue to be treated as separate instruments. As mentioned previously, annual energy certificates and power market settlement are today entirely separate systems, however some participants already choose to voluntarily contract for both wholesale power market settlement and energy certificates together as part of ‘bundled’ PPAs. Initially, we envision that some participants will also choose to ‘bundle’ GCs with power market settlement contracts. In future it is possible that that regulators could incentivize or even require this behaviour. This has significant implications for trading in both wholesale power and certificates.
- The second design question is whether GCs should be geographically restricted within energy price zones (or even a smaller area, e.g. some definition of local energy community) or whether trading should continue to be freely permitted across price borders. If cross border (price area) trading of GCs is restricted, there are further questions over whether GC trades should be limited to the actual flows of energy. Exchange-based energy trading is conducted at the local price area, and cross-border trades are linked to power flows between regions – equivalent restrictions could be applied to GC trading.

Initially, the form of trading for carbon-free commitments is simply the certificate itself (voluntarily bundled or unbundled from the wholesale power market) and there is no need for co-optimization between energy and the certificates, but the timestamped certificates themselves can still influence dispatch and market outcomes. The level of demand for certificates across price areas will affect the relative value of the certificates in each country (at different times) but this does not change the basic mechanics of energy trading in conventional spot marketplaces.

The interaction between the trading of wholesale power and GCs with market dispatch and the use of interconnection capacity is complex and has not been fully explored in the literature to date. Today, the EU Internal Market for Energy allows the co-optimization of energy and transmission capacity, enabled by the CACM process. Ultimately the spot markets of the Internal Market for Energy (day-ahead, intraday and work-in-progress balancing) each deal simultaneously with energy and network usage. The use of hourly matched carbon-free energy could – depending on the design choices – fundamentally change these methodologies, potentially requiring a different type of three-way co-optimisation between energy, carbon-free energy and network capacity.

If the form of trading for GCs is of a differentiated ‘bundled’ energy product (traded in parallel to fossil energy), then potentially the mechanics of the traded markets could change: the market algorithm might simultaneously need to balance energy, GCs and network capacity. If the trading of GCs energy is restricted within a single price area, then the mechanics of this could be accommodated within the existing European marketplaces with a separate marketplace(s) for GCs. However, if GC trading allows cross border trading which is connected to actual energy flows, then some more sophisticated market integration processes may be needed.

9. Conclusions

It is becoming clear that it is a case of when rather than if, energy attribute certificates will transition from annual matching to sub-hourly matching. Indeed, it is already possible to use GCs on a voluntary basis. As this paper has highlighted, this transition – which effectively means that all clean energy will be digitally ‘tagged’ – will have a profound impact, not only on how existing certificate markets work, but also on how power markets work and on how all consumers buy energy.

Much further research is needed on the potential implications of this transformation and on the myriad of potential use cases and their benefits.

For any relevant stakeholders interested in either learning more or getting actively involved in the rapidly growing voluntary GC market, please get in touch with NordPool and Granular Energy at info@granular-energy.com.

About NordPool

Nord Pool, Europe’s leading power market, delivers efficient, simple and secure trading across Europe. In 2023 the company, which is majority owned by Euronext, celebrates 30 years of powering the market. Nord Pool offers day-ahead and intraday trading, clearing and settlement, and additional services, to customers regardless of size or location. Today 360 businesses from 20 countries trade on Nord Pool’s markets.

Nord Pool operates markets in the Nordic and Baltic regions, Germany, Poland, France, The Netherlands, Belgium, Austria, Luxembourg and the UK. Nord Pool is a Nominated Electricity Market Operator (NEMO) in 15 European countries, while also servicing power markets in Bulgaria, Croatia and Georgia. In 2022 Nord Pool had a total turnover of 1077.35 TWh traded power.

Nord Pool’s three decades of power market experience built on offering flexibility, transparency, innovation, greater choice and participation to our customers

About Granular Energy

Granular Energy is a start-up software company that provides tools for energy companies to manage and trade energy certificates enabling the next generation of enhanced transparency green energy offers. Granular Energy's team are experts in power markets, energy certificates and energy software. Granular Energy's software is currently used by utilities in 6 countries, and is building the world's first spot market for timestamped energy certificates in partnership with NordPool.

About AFRY

AFRY Management Consulting is committed to accelerating change towards a sustainable world in the interest of future generations. With a passion for transforming industries and creating value for clients and society, AFRY Management Consulting works globally to address challenges and opportunities in the energy, bioindustry, infrastructure, industrial and future mobility sectors through:

- Forward looking market analysis
- Strategic advice
- Operational and digital transformation
- M&A and transaction services
- Sustainability consulting

With more than 600 consultants across over 20 offices on 5 continents, and supported by 19,000 experts at AFRY in engineering, design and digitalisation, AFRY Management Consulting is driven by the idea of helping clients find solutions to business-critical questions.

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