ENERGY TRACK&TRACE

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System Benefits of Granular Certification

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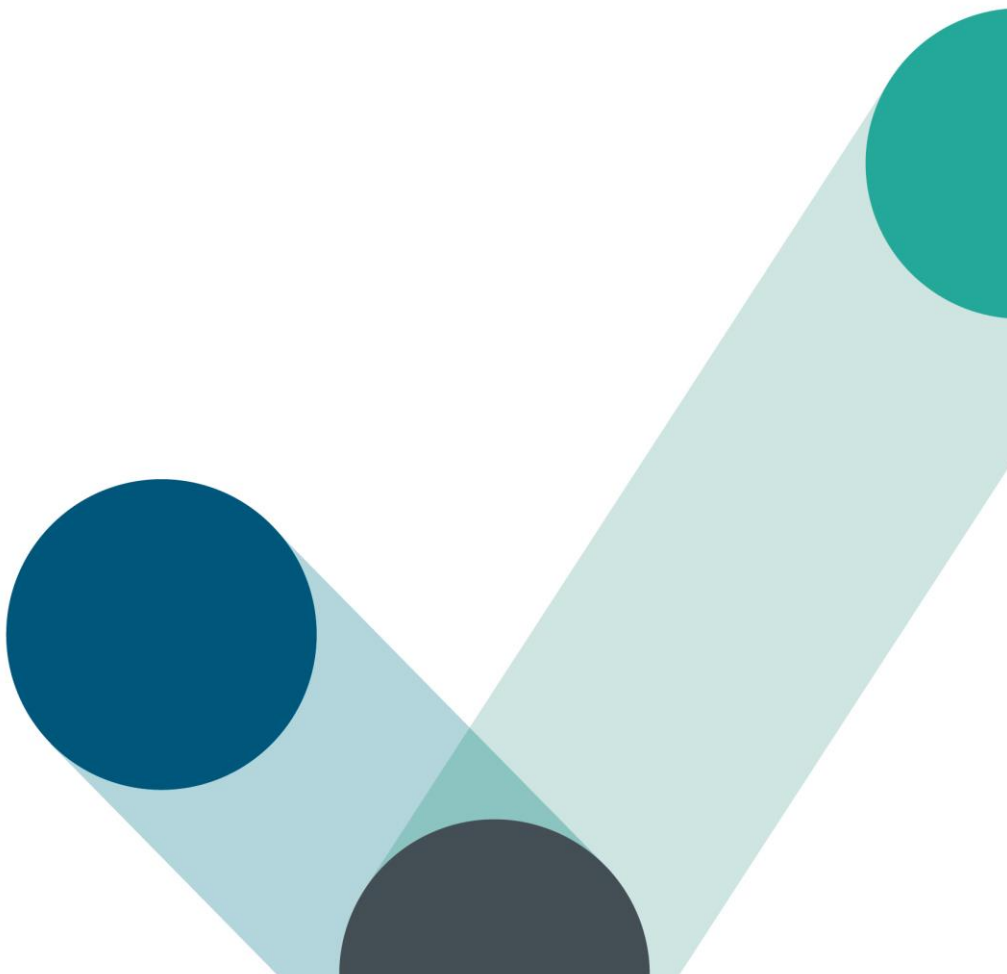


Content

Executive summary

The introduction of Granular Certification serves different purposes: first of all, it's a disclosure tool that creates more transparency and accuracy in energy tracking and thereby increases trust and satisfaction of consumers, allowing them to apprehend the intermittent aspect of renewable generation and get involved in the energy transition. Secondly, Granular Certification has effects on the behavior of the consumers and thus on the energy system as a whole.

The concept of Granular Certification proposes three essential improvements to the established GO system: temporal matching, locational matching and inclusion of storage. It is designed as an attribute tracking system that represents the power markets more realistically and it is expected to have positive feedback effects on the latter. This paper provides a first analysis of the different ways in which Granular Certification can impact the power system (both in terms of investment and operation) compared to the current GO scheme:

Investment in additional renewable production assets and diversification	⊕ ⊕ Depending on consumers' willingness to pay
Investments in demand side flexibility and energy storage	⊕ ⊕ Depending on consumers' willingness to pay
Maturation of demand side management and storage technologies	⊕
Spatial allocation of generation and flexibility resources	⊕
Short-term dispatch costs and related emissions	⊕ ⊕ With appropriate locational matching rules

A dark "+" indicates that Granular Certification has a positive impact on the corresponding aspect. A light colored "+" marks a benefit that may occur under certain conditions.

Impact on investments in RES and storage

- As it better reflects intermittency and the potential mismatch between generation and load profiles, the introduction of Granular Certification drives investments in additional renewable assets and increases the technological diversity of production portfolios. This impact highly depends on the adoption rate of Granular Certification and the willingness (or regulated demand) of consumers to reach 24/7 clean energy targets.
- Options for demand-side flexibility will be explored earlier in the transition and more investments in storage are incentivized. This will have beneficial learning-curve effects on long- and short-term storage and DSM technologies.
- The locational matching requirements of the Granular Certification system have an effect on the spatial allocation of new renewable assets in PPA agreements, with a stronger focus on production regions that are well interconnected with the areas of consumption.

Impact on operational dispatch behavior

- The introduction of Granular Certification creates incentives for producers and consumers to use flexibility to match renewable generation and load profiles. This individual optimization may deviate from the theoretical system optimum (achieved by a central price optimization only).
- Nevertheless, temporal generation matching in local or well-interconnected areas reduces the dispatch costs and leads to a considerable decrease in overall carbon emissions. A quantitative analysis shows a positive impact, regardless of the size of portfolios (from one wind farm to a large diversified portfolio) and different areas (with medium or high RES penetration).
- However, long-distance temporal generation matching (between less interconnected areas) does not necessarily contribute to reduce emissions, nor provide efficient dispatch incentives. Hence, mitigation measures need to be taken in order to limit long-distance temporal matching to a level that remains beneficial to the system.

The analysis presented in this document provides initial guidance and confirms the value of a GC system. Further analysis will be required to refine the design of the certification system: e.g., locational matching rules and integration of storage.

Introduction and scope

Context

As the 2022 IPCC report[1] stresses out the urgency of cutting GHG emissions, the decarbonization of the power sector via the development of renewable energy sources is of primary importance. The growth of the renewables share in the European electricity mix, from 15.9% in 2004 to 37.5% in 2020, and the ambitious goals set by the “Fit for 55” European green transition plan are a significant step in the right direction. This development also hints at future challenges related to the intrinsic intermittency of wind and solar: to reduce the volume of dispatchable fossil fuel generation needed to fill the gaps, and thus effectively decarbonize the power production, new solutions have to be developed and massively deployed.

Among the tools that can drive the maturation of such solutions, the methodology for determining the (renewable) origin of consumed energy and the resulting carbon accounting plays an important role as it reflects to all market participants (and rewards) the efforts towards RES integration and emissions reductions.

Introduced in the European regulation in 2009 and generalized in 2012, the Guarantees of Origin (GO) scheme demonstrates to final customers the share or quantity of energy from renewable sources in an energy supplier's energy mix and in the energy supplied to consumers on a monthly or yearly basis, depending on national regulation. While this system might have played a role for the early deployment of renewables on the continent, the need to fast-track the decarbonization and the increasingly prominent challenges posed by intermittency invite to reinvestigate the methodologies around green energy tracking. The shortcomings of the existing GO scheme, mainly the decorrelation with the physics of the power system and the resulting lack of credibility/transparency have been criticized and a demand for a new tool has emerged.

The Energy Track and Trace initiative

Energy Track and Trace (ETT) is an international cooperation aiming at providing verifiable, trustworthy insights and documentation of the energy origin to consumers, using Granular Certification, bringing three major evolutions compared to the current GO scheme:

- **temporal matching** reflects the intermittent aspect of renewable generation: it ensures that the green energy has been produced and consumed in the same market time unit (from 15 to 60 minutes, depending on the zone),
- **locational matching** reflects the physical “transportability” of the green energy from where it is produced to where it is consumed. Although this can only be approximated, locational matching brings the certification scheme closer to the physics of the grid and is key to ensure the trustworthiness of the tracking system, send adequate investments signals and exclude unrealistic situations that are detrimental to the credibility of the tracking system, e.g., the transfer of certificates between zones that are loosely or even not interconnected,
- **inclusion of storage** is a key aspect of Granular Certification. Time-stamped certificates allow tracking the in- and out-flux of renewable energy in batteries and other storage technologies in a trustworthy manner.

[1] Summary for Policymakers of the IPCC Working Group III report, Climate Change 2022: Mitigation of climate change

Thereby, storage units can be used to increase temporal generation matching and new value streams for storage operators are created.

These three evolutions imply an additional requirement: Granular Certification is based not only the green energy infeed but also on the consumption data, which is not the case with the current Guarantees of Origin.

By designing and implementing a demonstrator for a European Granular Certification system, the ETT cooperation aims at fulfilling the need of corporate consumers to accurately prove their efforts towards decarbonization and build trust around green energy tracking (from the perspective of the broader public, investors, media, NGOs…). But Granular Certification does not only provide a refined decarbonization effort metric, it is intended to provide stronger incentives for further RES integration and bring value to the system as a whole, contributing to accelerating the energy transition.

Purpose of the ETT System Benefits Paper

As it brings green energy tracking closer to the power system's physics, Granular Certification allows users to make trustworthy green consumption claims and generally raises the bar to reach "100% green" compared to the existing GO scheme. Therefore, reaching 24/7 green energy procurement should be seen as the end stage of the decarbonization journey and cannot be reached overnight.

From the perspective of European policy makers, the legislative and operational cost of change must be weighed against the social welfare increase brought by the new certification system and its contribution to the energy transition. It is thus essential to have a clear representation of the benefits of such a certification system.

This paper investigates the different ways in which Granular Certification can impact the power system (both in terms of investment and operation) compared to the current GO scheme by analyzing the changes induced in the behavior of participating corporate consumers. It provides a qualitative overview of these energy system benefits as well as first quantifications in terms of short-term dispatch.

This paper does not purport to deliver a definitive assessment of the system benefits associated with Granular Certification but constitutes a first attempt at describing, in a structured manner, its expected impacts on the power system. As the industry and academia gain knowledge, the demonstrator project makes progress and new insights are gained from stakeholders, this assessment will be iteratively refined.

The focus of the analysis presented in this paper is the added value from the social perspective. It provides neither an assessment of the benefits for individual market parties (consumers, producers…) nor an analysis of the costs associated with the implementation of a 24/7 green energy sourcing strategy or the operation of a Granular Certification system.

System Benefits of Granular Certification

By introducing temporal and locational matching, Granular Certification can impact following aspects of the power system's structure and operation:

- Investment in additional renewable production assets and diversification
- Investments in demand side flexibility and energy storage
- Maturation of demand side management and storage technologies
- Spatial allocation of generation and flexibility resources
- Short-term dispatch costs and related emissions

This paper provides a qualitative (and, for the dispatch aspect, quantitative) assessment of these different aspects in the sections below and proposes a first general conclusion on the attractiveness of Granular Certification from a social welfare perspective compared to the existing GO scheme.

Investment in additional renewable production assets and diversification

The characteristics of a Granular Certification scheme can have a significant impact on the investments in renewable assets:

- from the corporate consumer perspective, the criteria used for green labelling, together with the decarbonization ambitions of the companies, contribute to shape the required green energy procurement portfolio in terms of volume and energy sources: Granular Certification incentivizes consumers to look beyond Levelized Cost of Electricity (LCOE) in their decisions to invest in assets or engage in PPAs and take into account physical aspects (temporal and locational matching),
- from the project developer perspective, the revenues expected from the marketing of the green certificates could theoretically contribute to drive new investments.

These different aspects are further analyzed below.

Increasing green energy production

Granular Certification incentivizes consumers to source certificates and match their demand at a (quarter-)hourly resolution. Considering the intermittent production profiles of wind and solar, one lever for consumers to increase the share of (quarter-)hourly matching is to invest in more/larger renewable production assets or contract larger volumes in as-produced PPAs.

This increased renewable energy procurement results, in some time periods, in an excess of green production compared to the actual consumption. In that situation, the energy can be stored, or consumers (or their supplier or third-party service providers) can offer the additional certificates in the GC market (organized via clearing or continuous trading or OTC). This would ensure liquidity that would be profitable to other consumers to fill the gaps between the generation profile of their own PPAs / assets and their consumption, thereby reducing the need for them to over-invest in RES or flexibility.

The magnitude of renewable portfolios' enlarging related to the introduction of Granular Certification, and thus the speed increase towards a decarbonized system, is highly dependent on:

- the decarbonization ambitions of participating consumers and the scope 2 carbon accounting rules (Greenhouse Gas Protocol's Corporate Accounting and Reporting Standard),
- the ambition to comply with voluntary green standards and labels (best-in-class, low or net-zero product carbon footprint using e.g., the Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard) also driven by a higher demand and willingness to pay for green products,
- (future) regulatory obligations for specific energy uses: e.g., for the production of green hydrogen in compliance with the European delegated act on renewable fuels of non-biological origin (RFNBO).

Diversification of the green production portfolio

With the existing GO scheme, the generation profile does not influence the share of green energy that can be claimed by the consumer. Any type of renewable generation, being wind, solar, biomass or hydropower, can be

virtually cancelled against any consumption, even if the profiles do not match. Temporal matching reveals this potential mismatch and pushes consumers to select and combine renewable energy sources to better adhere to their consumption pattern – or to adjust their consumption profile (as analyzed in the section "Investment in demand side flexibility and energy storage"). Thereby, investment decisions are not only made based on the procurement costs (LCOE / PPA cost) of different technologies, but also take into account the profile coverage of each technology. Scaled at system level, the consistency between a diversified generation portfolio (properly balanced between technologies) and load profiles reduces the need for back-up capacities and flexibility, and paves the way for a 100% carbon-free power system.

Free floating certificates: an additional but uncertain revenue stream for renewable project developers

The marketing of green certificates (being GOs or GCs) theoretically provides an additional revenue to renewable power plant developers/marketers.

With the current GO scheme, average prices of green certificates in the European market (without requirements on location or additionality) are relatively low (from 0.1 to 0.4 €/MWh in 2020[2], reaching 2.2 €/MWh on average in April 2022[3]) compared to the average power market price (30.5 €/MWh in German day-ahead market in 2020 and 165.7 €/MWh in April 2022). Thus, the revenues coming from GOs are often seen as a windfall profit.

The introduction of Granular Certificates with hourly temporal matching would change the price structure. In a future GC market, it is likely that certificate prices would peak during periods where the renewable infeed is low and the demand is high. These price peaks can potentially increase the revenue perspectives for project developers and drive additional investment decisions.

The order of magnitude of these peaks and the associated expected revenues are dependent on multiple factors:

- possibility for subsidized renewable power plants to participate in the mechanism,
- locational matching requirements (that influence local liquidity),
- volume of companies engaging in 24/7 green energy sourcing (raising demand and prices),
- flexibility options deployed by customers or third parties (that would shave the price peaks).

Furthermore, to reduce financing costs, renewable project developers need long-term price guarantees. These guarantees are provided either by public support schemes (mainly in the form of contracts for difference or market premiums) or via private green Power Purchase Agreements (PPAs). Free-floating green certificates (GOs or GCs) provide a relatively uncertain volatile revenue that has to be significantly discounted in the financial planning of new installations.

For this reason, it is rather unlikely that the revenues from free floating Granular Certificates alone would constitute a significant driver for the development of new renewable projects. The investments would more likely be driven by the demand for green PPAs with bundled Granular Certificates.

[2] **Guarantees of Origin in 2020 – Seemingly higher demand but ever lower prices | Commerg**

[3] **French Auctions for Guarantees of Origin (eex.com)**

Investment in demand side flexibility and energy storage

As mentioned above, increasing the renewable portfolio size, diversifying generation technologies and procuring free-floating certificates are three major levers for consumers to increase their share of renewable energy consumption. Another opportunity to increase this share and eventually reach 24/7 green energy sourcing is to use flexibility either coming from the processes consuming the power or from external flexibility sources (energy storage).

Intrinsic process flexibility: additional push to explore and exploit flexibility potentials

Industrial and business processes are generally optimized to timely supply the demand and reach the required quality levels at the lowest energy costs. This results in specific consumption profiles and load shifting, if technically possible, can come with relatively high opportunity costs.

The growing penetration of renewables and the intermittent availability of power imposes a paradigm shift: large volumes of flexibility are necessary to keep a decarbonized power system in balance (complementing steerable capacities). Granular Certification makes this need explicit and provides an additional push to develop flexibility, on top of the incentives provided by the energy markets: spreads in day ahead and intraday markets, balancing products...

This incentive can lead customers to further explore flexibility potentials within their processes (and even redesign them to allow for a more flexible operation) and create a business case for developing that flexibility.

A drive for the development of energy storage

In the case where the processes cannot be made flexible or in combination with demand side flexibility, consumers, suppliers (as part of as-consumed PPA) or third-parties might invest in energy storage solutions to match green production and consumption. This would drive the development of short- and long-term storage which will play an essential role for the integration of RES.

Maturation of demand side management and storage technologies

Storage technologies and a flexible demand management are essential components of a fully decarbonized energy system. Short-term storage (e.g., batteries) and long-term storage (e.g., underground energy storage) in combination with demand-side flexibility increase the utilization factor of volatile RES, especially in energy systems beyond 80% renewables where high supply volatility could otherwise lead to grid- and market-based curtailments and extreme prices.

While on- and off-shore wind and photovoltaics have already reached a high maturity level, storage and demand side flexibility still have a large development potential which will fully pay off in energy systems with a very high share of renewable.

The introduction of granular certification creates an early and additional demand for flexibility (see previous section). The subsequent investments accelerate the learning curve and thus reduce costs significantly on the long term. To give an example: the German renewable energy law (EEG) has contributed strongly to the maturation of RES technology and countries throughout the world are benefiting from this effect[4]. Even though the EEG was not a market-based instrument (guaranteed feed-in tariffs instead), it can be assumed that similar effects can be achieved with market-based instruments such as granular certificates and 24/7 matching targets.

Early investments in energy storage and flexibility are expected to have a beneficial long-term effect on costs, scalability and decarbonization speed.

[4] Fischer, Andreas / Kube, Roland, 20 Jahre EEG – Investitionsmotor und Kostentreiber, IW-Kurzbericht, Nr. 99, Köln

Spatial allocation of generation and flexibility resources

While temporal matching reflects the volatility of RES infeed and incentivizes consumers to expand and diversify their green power procurement portfolio to further reduce their emissions, locational matching aims at better reflecting the physics of the grid and take into account the “transportability” of the green power between the point where its produced and the point where its consumed. The locational matching rules in a Granular Certification system set the conditions under which GCs can be exchanged between geographical areas. Thereby, these rules are expected to have an effect on the location of PPA investments as well as a steering effect through regionally differing certificate prices.

It should be further noted that the current GO system has been criticized in the press and by NGOs for disregarding this aspect[5], allowing for instance transfers of certificates between non-interconnected zones (e.g., Iceland and continental Europe).

Locational matching can be implemented in different ways in a Granular Certification system: the system could foresee explicit rules for the transfer or cancellation of certificates between congested zones (for instance based on physical interconnection capacity) or, if the system does not apply explicit rules, consumers can voluntarily decide to limit their green power procurement to areas from which the power could physically be imported. Based on the findings of this paper and the expectations of consumers, the ETT initiative is aiming at identifying the optimal locational matching rules to be implemented in a prototype solution.

Local GC supply and demand: a rather limited impact on investment decisions

The balance between demand and supply of GCs in each area would lead to diverging prices, sending locational incentives for the development of new RES projects or flexibility resources where the supply of green certificate is low, or additional consumption where the supply is high. Though, it is uncertain whether this price component would play a significant role in investment decisions, which are mainly driven by the LCOE and energy market price forecasts in the bidding zone. As described in the section “Investment in additional renewable production assets and diversification”, it is unlikely that regionally differing free-floating certificate prices will have a considerable effect on locational investment decisions.

Furthermore, at least in a first step, not all renewable assets will be participating in the GC scheme, because they are already engaged in another scheme or the regulation does not allow them to participate (e.g., subsidized RES in Germany). Similarly, the demand of GC, driven by decarbonization ambitions of individual companies, also does not reflect the total need for clean energy in the bidding zone. In that situation, the local supply-demand balance of GCs will not necessarily reflect the overall tension for green energy procurement and is not necessarily an optimal indicator for investment needs.

[5] Examples: **Guarantees of origin for renewable power set for (overdue) scrutiny – EURACTIV.com, Electricité verte : des garanties d'origine qui ne garantissent rien | Les Echos**

A credible alternative to local green energy procurement

From the buyer's perspective, local procurement (on-site or near-site RES or regional procurement) is currently often seen as the only way to increase the credibility and public understanding of climate-neutrality claims. This approach restricts the investment options to local sites while the transmission capacity might actually allow to procure green energy from further locations with lower LCOE.

By providing transparent locational matching rules or indicators reflecting the physics of the power system, Granular Certification provides forerunners with a credible green energy consumption proof even if the generation is not directly located next to the consumption site: in a different region within the bidding zone or even across bidding zones if the interconnection capacity is sufficient. GC provides an alternative to local procurement and enables consumers to profit from existing transmission capacities while ensuring credibility. This approach is consistent with the European electricity market integration where imports and exports are made possible at scale. Doing so, consumers can become 100% green in a much more efficient, yet trustworthy way.

Short-term dispatch costs and related emissions

Granular Certification can have a positive impact on the short-term generation dispatch due to new investments in renewable generation assets and flexibility options. But, as GC is reflecting the share of green consumption of individual consumers, it would incentivize to shift load or use storage capacities to match the generation profile of individual RES portfolios, or in the best case, from the renewable assets participating in the GC market, which are a subset of the total available assets. In that sense, the use of flexibility in the context of Granular Certification might potentially deviate from the system optimum in terms of minimization of costs of the entire generation stack. Therefore, it is necessary to assess to which extent the development and use of flexibility to match a given RES portfolio (as incentivized by GC) still results in an improved generation dispatch compared to the current GO scheme. This section details the qualitative impact of GC on the short-term dispatch and presents an initial quantitative assessment of the benefits compared to the status-quo.

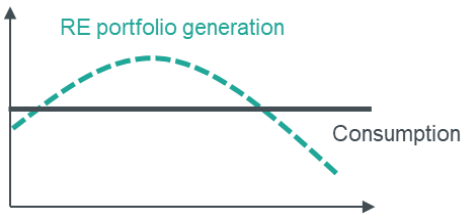
First quantitative assessment

When assessing the system impact, two different aspects must be considered: the impact on overall electricity production costs representing the economic welfare and on CO_2 emissions. This leads to the following research question: how much CO_2 emissions and generation costs are saved by adding flexibility following the renewable generation profile from a given portfolio?

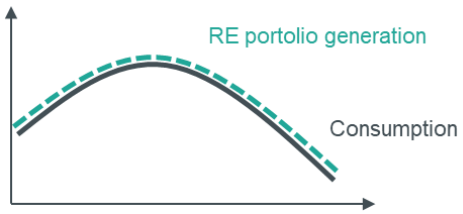
Methodology

We calculated the system costs and emissions related to a given consumption profile for different scenarios:

- A baseline scenario (current GO scheme) with baseload consumption and no flexibility,



- A Granular Certification scenario, including flexibility used to increase the match with a given renewable portfolio (different portfolio compositions are analyzed).



We then computed the difference in costs and emissions between the two scenarios to assess the impact of Granular Certification.

Assumptions/simplifications

We assumed that without a Granular Certification solution (in the baseline scenario), industrial consumers do not react to price or emission signals and have a flat consumption profile.

With the GC system, the company invests in new flexibility sources such as demand side management or storage. Here we considered two different flexibility configurations:

- "full flexibility": the load is made entirely flexible to match the generation profile in every hour of the year,
- "2-hour flexibility": the flexibility potential allows to shift 2 hours of the average consumption.

In both configurations, the flexibility potential is used to maximize the share of green consumption against different renewable portfolios.

Hourly day ahead prices and average CO_2 emissions are considered unchanged (static) in the overall energy system: only the behavioral change of one single participant (small volume) is analyzed (marginal approach). The results depict the costs/emissions reduction related to the last MWh consumed. As the participation to Granular Certification increases and the use of flexibility starts having significant feedback on prices/emissions, the marginal benefits are expected to be lower that the values presented in this paper. For that reason, the absolute values are less relevant than the direction shown by the analysis.

Data sources

For this first quantitative assessment, we used German and Danish day ahead prices and hourly average CO_2 grid emissions (production based). The hourly wind and solar infeed of the different RES portfolios is simulated based on Renewables Ninja[6]. Analyses are based on data for 2019.

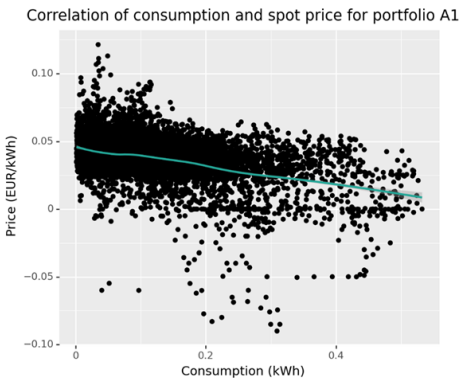
Even with small RES portfolios, the correlation between infeed and market prices / system emissions ensures value creation

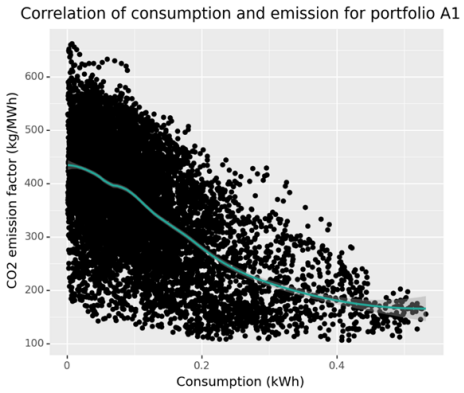
In the first GC scenarios (A1 and A2), a consumer located in the German bidding zone optimizes its flexibility to increase the match with the infeed of a single windfarm also located in Germany. As the graphs below show, we observe a correlation between the infeed of this single windfarm and the overall generation costs/emissions in Germany. The costs associated with the marginal 1 MWh yearly consumption are reduced by 0.23% and the emissions by 0.46% with a 2-hour load shifting flexibility. If the consumption is made entirely flexible and perfectly matches the generation profile ("full flexibility" configuration), the cost reduction reaches 14.2% and the emissions reduction 15.9%.

[6] **www.renewables.ninja**

[1] Pfenninger, Stefan and Staffell, Iain (2016). Long-term patterns of European PV output using 30 years of validated hourly reanalysis and satellite data. Energy 114, pp. 1251-1265. doi: 10.1016/j.energy.2016.08.060

[2] Staffell, Iain and Pfenninger, Stefan (2016). Using Bias-Corrected Reanalysis to Simulate Current and Future Wind Power Output. Energy 114, pp. 1224-1239. doi: 10.1016/j.energy.2016.08.068



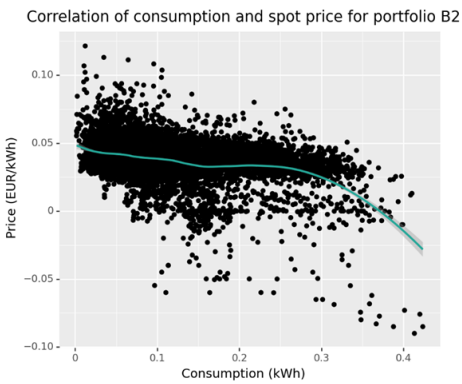


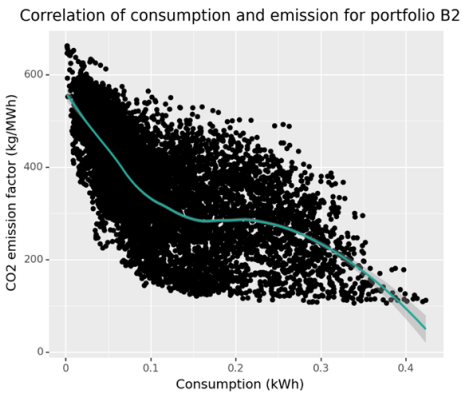
In conclusion, generation-matching within the same bidding zone reduces system costs and emissions, even with a small portfolio. It can be expected that this result can also apply to highly connected bidding zones (frequent price convergence).

Generation-matching is similarly beneficial for larger portfolios but the technology mix has an impact

In the second GC scenario (B1), we considered a larger RES portfolio consisting of several wind farms distributed across Germany. Costs and emissions reductions are similar to the previous scenario (single wind farm): respectively 0.32% and 0.49% with 2-hour flexibility, 11.7% and 13.2% with full flexibility.

In a third GC scenario (B2), we added solar PV production in southern Germany to the portfolio. This tends to add incentives to shift the load from the morning and evening hours where the total consumption and thus market prices are high. Therefore, the advantage of having a larger flexible capacity option increases. However, the correlation between the portfolio infeed and the German market situation deteriorates, as shown in the graphs below. The cost reduction drops to 0.05% (2-hour flexibility) and 9.2% (full flexibility).

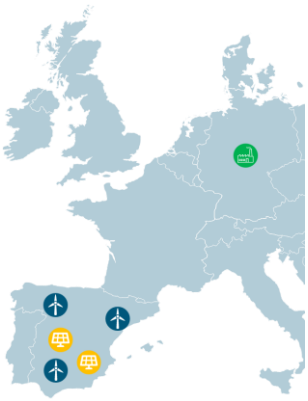




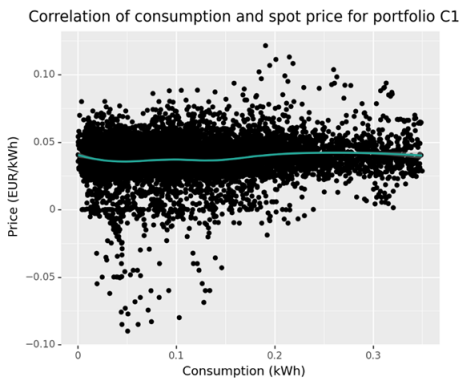
GC provides similar benefits in areas with a high RES penetration

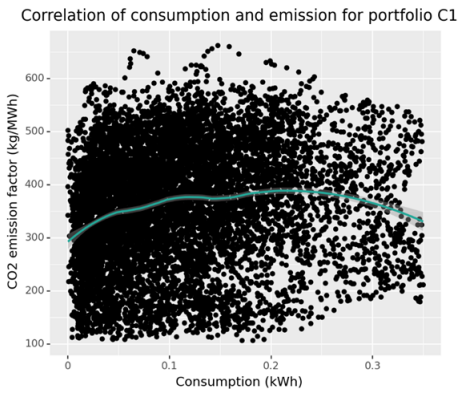
In areas with high RES penetration (Denmark in this example), we see similar benefits both in terms of costs and emissions reductions. Aligning the load to the infeed of a wide portfolio of wind and solar in the DK1 bidding zone leads to a 0.41% reduction of costs and 0.97% reduction of emissions in the 2-hour flexibility configuration, and respectively 8.7% and 17.5% in the full flexibility configuration.

Cross-border generation-matching between distant areas with low interconnection does not necessarily make sense from the dispatch perspective



In a last scenario (C2), we assessed the impact of matching consumption in Germany to wind and solar generation in Spain. As shown in the graph below, the portfolio generation is not correlated with the situation in the German market (prices and emissions). Without any restrictions applied to the transfer of certificates between the two bidding zones, we observe a value destruction: system costs increase by 0.08% (2-hour flexibility) or 2.3% (full flexibility), emissions increase respectively by up to 1%.





This first result indicates that following the RES generation in other bidding zones with low interconnection capacity is not only sub-optimal, but it can even worsen the dispatch compared to current GO scheme.

Cross-border generation-matching between distant areas with low interconnection generates additional procurement costs for the concerned consumers and should in theory not be economically attractive for them. But yet, it cannot be completely excluded. Consumers may engage in this behavior if they have PPAs with producers in a remote, low LCOE exporting zone and want to comply with regulatory requirements (e.g., production of green hydrogen) and voluntary standards (low product carbon footprint).

Locational matching rules are an option to mitigate this negative effect and ensure a positive impact on short-term dispatch. A liquid Granular Certificates market in the participating countries/bidding zones could also provide an alternative for consumers to this expensive cross-border matching, since it reduces the need to perform transfers over long distances.

Conclusions of the first quantitative assessment of the impact on short-term dispatch

The table below provides a summary of the results obtained in the different scenarios described above. It presents the evolution of the dispatch costs and emissions associated with 1 MWh of load engaging in Granular Certification, compared the baseline (Guarantees of Origin providing no incentives for flexibility):

	Full flexibility		**2-hour flexibility**	
Scenario	**Costs**	**Emissions**	**Costs**	**Emissions**
A1: single onshore wind farm in Germany (site A)	-5.36 € (-14.2 %)	-57.3 $kgCO_2$ (-15.9 %)	-0.09 € (-0.23 %)	-1.7 $kgCO_2$ (-0.46 %)
A2: single onshore wind farm in Germany (site B)	-4.05 € (-10.7 %)	-44.2 $kgCO_2$ (-12.3 %)	-0.11 € (-0.29 %)	-1.3 $kgCO_2$ (-0.36 %)
B1: large onshore wind portfolio in Germany	-4.43 € (-11.7 %)	-47.5 $kgCO_2$ (-13.2 %)	-0.12 € (-0.32 %)	-1.8 $kgCO_2$ (-0.49 %)
B2: large onshore wind and solar portfolio in Germany	-3.46 € (-9.2 %)	-49.5 $kgCO_2$ (-13.7 %)	-0.02 € (-0.05 %)	-5.0 $kgCO_2$ (-1.37 %)
DK1: total wind and PC in Denmark	-3.34 € (-8.7 %)	-27.0 $kgCO_2$ (-18.5 %)	-0.16 € (-0.41 %)	-1.4 $kgCO_2$ (-0.97 %)
DK2: total wind and PC in Denmark	-2.75 € (-6.9 %)	-16.1 $kgCO_2$ (-12.1 %)	-0.13 € (-0.33 %)	-0.5 $kgCO_2$ (-0.38 %)
C1: large onshore wind portfolio in Spain	+1.11 € (+2.9 %)	+11.0 $kgCO_2$ (+3.0 %)	+0.02 € (+0.06 %)	+0.6 $kgCO_2$ (+0.17 %)
C2: large onshore wind and solar portfolio in Spain	+0.86 € (+2.3 %)	+3.6 $kgCO_2$ (+1.0 %)	+0.03 € (+0.08 %)	-0.3 $kgCO_2$ (-0.08 %)

If generation and consumption are located in the same bidding zone (or in highly interconnected bidding zones), and the correlation between the RES portfolio infeed and the market prices/emissions is relatively high, Granular Certification (as it incentivizes the development and using flexibility to align load and RES portfolio's infeed) generally improves the system dispatch both in terms of generation costs and CO_2 emissions.

The size of the portfolio does not necessarily make a significant difference in terms of costs and emissions reduction: the resulting dispatch behavior can be similarly beneficial for small and large portfolios.

The generation technologies present in the portfolio (and their specific profiles), however, have an impact on the value created by the use of flexibility in a GC context.

In the specific case where load and generation are located in two different bidding zones with a large geographical distance and low interconnection capacity, a full generation-matching does not make sense in terms of system costs and emissions. Even if it would imply additional energy procurement costs, consumers might engage in this cross-border generation-matching if this is the only affordable option to comply with regulatory requirements (RFNBO) and voluntary standards (e.g., to produce low carbon products). Clear locational matching rules and a liquid GC market in the participating countries/bidding zones could mitigate this negative effect.

Conclusion on system benefits

As a Granular Certification system provides participating consumers with additional investment incentives in RES projects and flexibility options compared to the existing GO scheme, it can contribute to the integration of renewables. The order of magnitude of this contribution depends on the number of companies engaging in 24/7 green energy sourcing and their willingness to pay to reach their sustainability goals as well as on regulatory obligations.

Granular Certification incentivizes the use of flexibility to match RES consumption and can positively influence the efficiency of the system dispatch (both from the costs and emissions perspective). Companies engaging in 24/7 green energy sourcing activate their flexibility to optimize the share of green energy in their portfolio and do not seek a global optimum. Nevertheless, a first quantitative analysis shows positive results when consumption and generation are located in the same bidding-zone or in highly connected zones.

If load and generation are in distant bidding zones with low interconnection capacity, the use of flexibility to match the remote portfolio does not make sense from the dispatch perspective. Mitigation measures need to be introduced to limit this behavior and ensure a positive impact on dispatch. A liquid GC market will eventually bring the system back to its global optimum and is therefore a non-regret development.

The overall impact of granular certification at system-level is expected to be positive and is mainly dependent on the willingness of participating companies to pay and regulatory obligations.

The analysis presented in this document provides initial guidance and confirms the value of a GC system. Further analysis and stakeholders' feedback are planned to refine the design of the certification system:

- the Energy Track and Trace cooperation will further investigate the cross-border cases and publish a position paper on locational matching rules,
- different options to consider storage in a Granular Certification system will be assessed in order to select a design that maximizes system benefits,
- a demonstrator will be launched in Q3 2022 and will gather practical insights that will be used to refine the system benefits analysis.

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