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BUTS Caroline
https://orcid.org/0000-0002-1551-6611
Professor,
Brussels Centre for Competition Policy – Vrije Universiteit Brussel
Pleinlaan 2, 1050 Elsene (Brussels), Belgium
Caroline.Buts@vub.be

MAES Seppe
https://orcid.org/0000-0001-5072-9973
PhD (Researcher),
Brussels Centre for Competition Policy – Vrije Universiteit Brussel
Pleinlaan 2, 1050 Elsene (Brussels), Belgium
Seppe.Maes@vub.be

BOTREL LIMA Clara
https://orcid.org/0009-0004-5132-0802
Research intern Brussels Centre for Competition Policy
Brussels Centre for Competition Policy – Vrije Universiteit Brussel
Pleinlaan 2, 1050 Elsene (Brussels), Belgium
clarabotrel192@gmail.com

SONGYUE Li
https://orcid.org/0009-0005-2022-9966
PhD (Researcher),
Brussels Centre for Competition Policy – Vrije Universiteit Brussel
Pleinlaan 2, 1050 Elsene (Brussels), Belgium
Songyue.Li@vub.be

GREEN INDUSTRIAL POLICY: A CRITICAL EVALUATION OF STATE AID FOR RENEWABLES

Evaluating State aid measures is not only good practice contributing to the closed policy cycle, but it has also become a mandatory exercise for large aid schemes following the State Aid Modernisation initiative. Evaluations support some of the key State aid principles: i) verify incentive effect or to what extent the measure realises projects that would not materialise in the absence of the aid, ii) map proportionality or the minimum public funding needed to leverage the level of required private resources, and iii) analyse the appropriateness of the

БУТС Каролайн
https://orcid.org/0000-0002-1551-6611
професор, Брюссельський центр з питань конкурентної політики – Брюссельський Вільний Університет
Плейнлаан 2, 1050 Ельсене (Брюссель), Бельгія
Caroline.Buts@vub.be

МАЕС Сеппе
https://orcid.org/0000-0001-5072-9973
доктор філософії (дослідник), Брюссельський центр з питань конкурентної політики – Брюссельський Вільний Університет
Плейнлаан 2, 1050 Ельсене (Брюссель), Бельгія
Seppe.Maes@vub.be

БОТРЕЛ ЛІМА Клара
https://orcid.org/0009-0004-5132-0802
дослідницький стажер, Брюссельський центр з питань конкурентної політики
Брюссельський центр з питань конкурентної політики – Брюссельський Вільний Університет
Плейнлаан 2, 1050 Ельсене (Брюссель), Бельгія
clarabotrel192@gmail.com

СОНГЮЕ Лі
https://orcid.org/0009-0005-2022-9966
Доктор філософії (дослідник), Брюссельський центр з питань конкурентної політики – Брюссельський Вільний Університет
Плейнлаан 2, 1050 Ельсене (Брюссель), Бельгія
Songyue.Li@vub.be

ЗЕЛЕНА ПРОМИСЛОВА ПОЛІТИКА: КРИТИЧНА ОЦІНКА ДЕРЖАВНОЇ ДОПОМОГИ ДЛЯ ВДЕ

Оцінка заходів Державної допомоги є не лише гарною практикою, що сприяє замкненому циклу політики, але також стала обов'язковою процедурою для великих схем допомоги в рамках ініціативи Модернізації Державної Допомоги. Оцінки підтримують деякі ключові принципи Державної допомоги: і) перевіряти ефект стимулювання або в якій мірі захід реалізує проєкти, які не відбулися б за відсутності допомоги; іі) оцінювати пропорційність або мінімальний обсяг державного фінансування, необхідного для залучення потрібного рівня

measure to achieve the policy objectives in the least distortive way. This Article reviews the ex-post evaluations of large schemes for renewables that have been carried out and are kept in the systematic catalogue of the Commission's Competence Centre on Microeconomic Evaluation. After detailing the case selection process, a descriptive analysis outlines the renewables aid schemes that have been evaluated per energy type, duration and evaluation methods. In addition, we present a timeline with the diverse evaluation steps and point to common pitfalls. Finally, we review the results of the evaluations and present the main takeaways and challenges for aid schemes supporting the transition to renewable energy. By systematically reviewing these ex-post evaluations, we aspire to present a comprehensive list of good practices as well as actions to avoid and as such to contribute to more efficient 'clean' policies in support of the energy transition.

Keywords: Renewable energy, State aid, Green transition, Industrial policy.

приватних ресурсів, та iii) аналізувати доцільність заходу для досягнення політичних цілей найменш спотвореним способом. У цій статті розглядаються фактичні оцінки великих схем підтримки відновлюваних джерел енергії, які були проведені та зберігаються у систематичному каталозі Центру Компетенцій Комісії з Мікроекономічної Оцінки. Після детального опису процесу відбору випадків проводиться описовий аналіз схем допомоги відновлюваним джерелам енергії (ВДЕ), які були оцінені за типом енергії, тривалістю та методами оцінки. Крім того, ми надаємо хронологію різних етапів оцінювання та вказуємо на типові помилки. Нарешті, ми розглядаємо результати оцінок та представляємо основні висновки та виклики для схем допомоги, що підтримують перехід до відновлюваної енергетики. Систематично переглядаючи ці фактичні оцінки, ми прагнемо представити комплексний перелік кращих практик, а також дій, яких слід уникати, і таким чином сприяти більш ефективним "чистим" політикам на підтримку енергетичного переходу.

Ключові слова: відновлювана енергія, державна допомога, зелена перехід, промислова політика

JEL Classification: D62, H54, L90, O14.

Introduction

The resurgence of industrial policy within the EU reflects a shift in policy thinking following geopolitical realignments. The EU's industrial strategy focuses on a transition to a green, digital and resilient economy. Central to the EU's evolving green industrial strategy is the acceleration of the energy transition, underpinned by the large-scale deployment of renewable energy sources. This shift is intended not only to meet climate neutrality targets but also to strengthen the EU's energy sovereignty and economic resilience in the face of increasing external dependencies.

To support this transformation, State aid has been used extensively to stimulate investment in renewable technologies such as solar, wind, and energy storage. While Member States had different types of aid schemes, practically all EU countries have aid schemes in place to support investment in renewables. However, as the scale and complexity of support mechanisms grow, so too does the importance of systematic evaluation. In this context, ex-post evaluation, the assessment of a policy after its implementation, is an essential component of a closed policy cycle. It enables policymakers to determine whether aid measures have achieved their intended objectives, assess their efficiency, and identify potential distortions to competition or unintended side effects.

Ex-post evaluations of State aid in the energy sector are particularly relevant, given the need to balance public support with internal market rules under Articles 107 and 108 TFEU (Article 107 TFEU, 1957; Article 108

TFEU, 1957). Evaluations typically examine multiple dimensions, including the incentive effect, whether the aid changed the behaviour of the recipient. Could the aid help realise projects that would not have been possible without the aid, or has the aid increased the scale or scope of a project. It is important that the aid triggers as much as possible additional projects, rather than crowding out private investment. Next to the incentive effect, an evaluation will also check the proportionality and appropriateness of an aid scheme. An encompassing evaluation entails an analysis of direct and indirect effects regarding the objectives of the aid, the affected markets and society. While such evaluations are only obligatory for selected large-scale aid schemes under the Commission's State Aid Modernisation initiative, and published via the EVALSA database, they represent a broader good practice in evidence-based policymaking (European Commission, 2014a; 2025a; 2026).

Extant literature on EU green industrial policy and energy State aid has examined, first, how the Commission's evolving guidelines recalibrated compatibility assessment toward market integration, competitive allocation, and stricter scrutiny of the incentive effect (Musardo, 2021; Nicolaides & Kleis, 2014). A closely related strand evaluates the legal status and steering function of soft-law instruments, such as guidelines and frameworks, in shaping Member States' scheme design, including the balance between environmental ambition and competition safeguards (Ezcurra, 2014; Banet, 2020). More recent contributions emphasise that "additionality" and the construction of a credible counterfactual are pivotal but operationally difficult in practice, particularly where firms may adapt project timing or structure to meet eligibility thresholds (Nicolaides, 2023a). Parallel work in energy and policy evaluation points to the importance of complementing scheme-level impact estimation with institutional and implementation analysis which covers administrative constraints, stakeholder incentives, and information asymmetries, when assessing effectiveness and proportionality (Haak & Brüggemann, 2016; Parcu et al., 2020). Finally, the literature increasingly situates renewable support within a broader governance environment, arguing that infrastructure bottlenecks, regulatory instability, and market volatility can dominate outcomes even where aid is well-targeted and formally compliant (Verschuur & Sbrolli, 2020).

In line with the rapidly expanding scholarship on EU green industrial policy and energy State aid, this Article situates itself within recent research that assesses how renewable support schemes perform against core compatibility benchmarks (most notably the incentive effect, proportionality, and appropriateness) while also examining wider market and system constraints (e.g. grid access, regulatory stability, and price volatility) that hinder policy effectiveness. The purpose of the article is to provide a structured, comparative synthesis of the most recent ex-post evaluations of large renewable energy aid schemes (solar, wind, and storage) published in the Commission's evaluation ecosystem (European Commission, 2026). We aim to distil lessons for future scheme design and, correspondingly, draw conclusions on good practices and recurrent pitfalls for more efficient "clean

energy" policies. Building on this purpose, the Article advances the following hypothesis: ex-post evaluations of renewable energy State aid systematically reveal (i) heterogeneous incentive effects across technologies and project characteristics (tending to be stronger for wind and storage than for stand-alone solar) and (ii) a predictable relationship between proportionality and project attributes (notably a negative relationship between aid intensity and project size).

This implies that proportionality safeguards are more effectively operationalised when aid design incorporates competition-enhancing mechanisms, such as variable aid intensities. Methodologically, we apply a structured qualitative review protocol to the available evaluation plans, interim reports and final reports. Against this backdrop, the present article contributes by systematically synthesising the Commission-linked ex post evaluation corpus for large renewables schemes, allowing cross-scheme comparison of incentive effects, proportionality patterns, and recurrent design pitfalls.

The remainder of this Article is structured as follows: Section 1 reviews the relevant literature and conceptual underpinnings. Section 2 outlines the methodology and data used. Section 3 presents the empirical findings regarding direct and indirect effects of aid for solar, wind and storage capacity. Section 4 offers policy conclusions and recommendations.

1. Fuelling the future: the evolving framework for energy State Aid

Notwithstanding the in principle prohibition under Article 107(1) TFEU, EU Member States have granted an enormous amount of aid in the energy sector over the past decades. The General Block Exemption Regulation (GBER) is one of the more general frameworks enabling Member States to develop aid measures where the benefits clearly outweigh potential distortions to competition (Commission Regulation (EU) No 651/2014, 2023). The GBER allows for example that aid for renewable energy production, energy efficiency, energy storage, charging infrastructure, and clean mobility is granted without ex-ante notifying the European Commission if it fulfils the conditions set out by the Regulation. Over time, the scope of the GBER has expanded to reflect evolving EU policy priorities, particularly the green and digital transitions. Recent amendments have further aligned its provisions with the European Green Deal and Fit for 55 objectives, facilitating swift and consistent rollout of energy aid across the Union (Council of the EU and the European Council, 2024; European Parliament, 2025).

Next to the GBER, energy specific rules were also developed in the early nineties and have been evolving since. In the energy sector, the evolution of EU State Aid guidelines also reflects the growing ambition of EU climate and energy policies, from early environmental protection goals to the current push for climate neutrality under the European Green Deal (Council of the EU and the European Council, 2024). The European Commission’s guidelines provide an operational framework for support to renewable energy, energy efficiency, and related infrastructure without

violating competition rules under Articles 107 and 108 TFEU. This section provides an overview of the policy context guiding State Aid to energy, starting with the sector specific guidelines, then going into other relevant developments of the State aid rules *(Figure 1).*

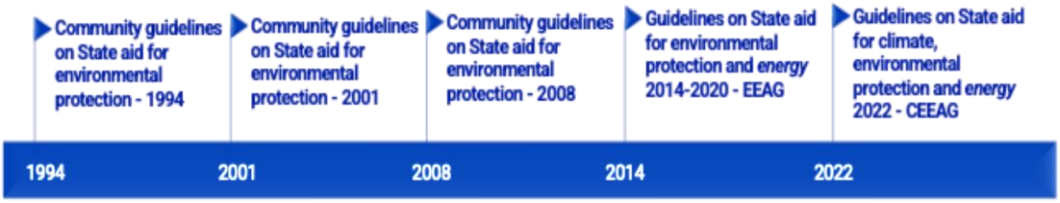

Figure 1. Energy sector specific State aid guidelines

Source: Constructed by the author based on the evolution of the guidelines.

The first relevant State aid guidelines on environment and energy can be traced back to 1994 (Community Guidelines on State Aid for Environmental Protection, 1994). These guidelines can be seen in the light of increasing environmental awareness and laid the foundation for later developments, introducing core principles such as necessity, proportionality, and the polluter-pays principle. While their scope was relatively limited compared to subsequent editions, they permitted aid for activities such as pollution abatement, the early adoption of environmental standards, and to a limited extent, the promotion of renewable energy and energy-saving technologies. At the time, support for renewables was considered primarily within the environmental context, rather than as part of a broader energy or industrial strategy. These guidelines remained in force until the adoption of the more expansive 2001 guidelines, which introduced clearer and more comprehensive provisions for aid to renewable energy and co-generation, responding to growing international climate commitments and the rising importance of sustainable energy policy in the EU (Community Guidelines on State Aid for Environmental Protection, 2008a).

The 2001 Guidelines on State Aid for Environmental Protection marked a significant expansion and clarification of the EU's framework, responding to increasing EU-level environmental ambitions in light of the Kyoto Protocol (Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1997) and the growing interest in supporting renewable energy, energy efficiency, and combined heat and power. While still grounded in the principles of necessity, proportionality, and avoiding undue distortions, the 2001 guidelines provided more detailed rules on investment and operating aid for environmentally beneficial projects. Notably, they allowed for aid to promote renewable energy generation, recognising environmental externalities (Community Guidelines on State Aid for Environmental Protection, 2001). In a way, they set the stage for the more transformative 2008 and 2014 guidelines, by introducing clearer eligibility criteria and acknowledging the role of public support in scaling up

clean technologies across Member States (Community Guidelines on State Aid for Environmental Protection, 2008a; Guidelines on State Aid for Environmental Protection and Energy 2014–2020, 2014a). At this early stage, support mechanisms such as feed-in tariffs (FiTs) were widely used, justified by the market failures associated with externalities from fossil fuel consumption. However, aid levels were capped, and the guidelines remained cautious in tone, particularly given the absence of binding EU-wide targets for renewable energy deployment.

The 2008 Guidelines updated the 2001 framework in light of the EU's growing climate commitments, particularly the adoption of the Climate and Energy Package targeting a 20% reduction in greenhouse gas emissions, 20% share of renewables, and 20% improvement in energy efficiency by 2020 (Community Guidelines on State Aid for Environmental Protection, 2008a). They permitted both investment and operating aid, including for biofuels, combined heat and power (CHP), and early adoption of higher environmental standards. The 2008 guidelines gave greater recognition to the role of public support in promoting market entry, acknowledging the continued cost gap between conventional and renewable energy. Overall, the 2008 guidelines represented an incremental but important evolution, offering Member States more flexibility while maintaining safeguards against overcompensation and undue distortion (Community Guidelines on State Aid for Environmental Protection, 2008). They served as a transition point between the environmental focus of earlier frameworks and the market-oriented approach that would define the 2014 guidelines.

The 2014 Guidelines on State Aid for Environmental Protection and Energy 2014–2020 (EEAG) marked a decisive shift, aligning it more closely with the goals of market integration, cost efficiency, and the maturing of renewable energy technologies (Guidelines on State Aid for Environmental Protection and Energy 2014–2020, 2014). Important to note is that they mention 'energy' explicitly for the first time in the title and introduced far-reaching reforms aimed at making support schemes more competitive, transparent, and harmonised. No consensus was reached in extant literature on the success of avoiding potential distortion on the market, as is for example in detail explained by Nicolaides and Kleis (2014), who called for, amongst others, a more robust application of the assessment of an incentive effect. Musardo (2021) also argues in favour of this concept, and notes that the EEAG had to adopt a more rigorous interpretation of the incentive effect, ensuring aid measures deliver additional environmental benefits beyond normal practice and align with Green Deal objectives. Only measures that achieve the intended outcome with minimal environmental harm would then be deemed compatible (Musardo, 2021). A key innovation of the EEAG was the general requirement for aid to renewable energy to be granted through competitive bidding processes (e.g. auctions), replacing administratively set

feed-in tariffs with market-based premiums.[1] Technology-neutral allocation became the default, with exceptions for emerging technologies or small-scale projects. The EEAG also introduced rules on support for energy infrastructure, capacity mechanisms, and exemptions for energy-intensive industries exposed to international competition. These changes reflected the increasing maturity and cost-competitiveness of wind and solar technologies. It laid the groundwork for an even more comprehensive CEEAG adopted in 2022.

The most recent and ambitious update came with the 2022 Guidelines on State Aid for Climate, Environmental Protection and Energy (CEEAG), which entered into force on 27 January 2022 (Guidelines on State Aid for Climate, Environmental Protection and Energy, 2022). The CEEAG can be seen within the context of the EU's heightened climate ambitions under the European Green Deal, the Fit for 55 Package, and the goal of climate neutrality by 2050. The guidelines expand the scope of eligible aid to include not only traditional areas such as renewables and energy efficiency but also to areas such as renewable hydrogen, energy storage, carbon capture and storage, and clean mobility. Competitive bidding remains the preferred mechanism for allocating aid, but exemptions are maintained for innovative or small-scale projects. The CEEAG reflects a broader shift in the Commission's thinking, viewing State aid not just as a correction for market failure but also as a strategic tool to support the EU's industrial and geopolitical goals, particularly in critical sectors relevant to energy security.

Alongside the formal guidelines on climate and energy, it is worth mentioning two sets of other important State aid rules related energy, i.e. Important Projects of Common European Interest (IPCEI) and the Temporary Crisis and Transition Framework (TCTF) (Criteria for the Analysis of the Compatibility with the Internal Market of State Aid to Promote the Execution of Important Projects of Common European Interest, 2021; Amendment to the Temporary Crisis and Transition Framework for State Aid Measures to Support the Economy Following the Aggression against Ukraine by Russia, 2023).

IPCEIs allow Member States to provide State Aid for cross-border projects that are strategically important for the EU and address clear market failures. Reinforced under the 2022 CEEAG, IPCEIs are particularly relevant for clean technologies such as hydrogen, batteries, and industrial decarbonisation. Projects must involve cooperation across countries, generate positive spillovers, and support key EU objectives like the Green Deal and strategic autonomy. By enabling large-scale, riskier investments that may not materialise otherwise, IPCEIs complement traditional aid instruments and play a growing role in Europe's green industrial policy.

The Commission has adopted several crisis frameworks in the past two decades, of which the one regarding the war with Ukraine is probably most relevant for energy. The TCTF directly targeted the energy crisis and

[1] Fixed tariffs provide a guaranteed price for renewable electricity, thus shielding producers from market fluctuations. This offers investment certainty, but the risk of overcompensation is larger. In contrast, market-based premiums supplement the market price.

expanded support for among others clean tech investments but also towards companies that are energy intense or are trading heavily with Ukraine. These temporary tools underscore the Commission's responsiveness to crisis contexts, also in the field of energy (Amendment to the Temporary Crisis and Transition Framework for State Aid Measures to Support the Economy Following the Aggression against Ukraine by russia, 2023).

Finally, the Commission has published guiding templates for aid under the Recovery and resilience facility, where also a lot of attention is being dedicated to energy measures, such as under the Power Up, Renovate, Refuel and Recharge initiatives.[2]

Over the past two decades, the EU's State aid guidelines for energy clearly have evolved to a comprehensive policy framework supporting the green transition and strategic autonomy. The move from fixed tariffs and administrative schemes to competitive, market-based instruments reflects both the maturity of renewable technologies and the EU's ambition to align industrial, environmental, and energy goals. As the green transition accelerates, the role of State aid will remain central to achieving climate neutrality while preserving fair competition within the internal market.

Following the positive policy context towards aid for renewable energy, Member States have been very active when it comes to designing aid schemes. The 2024 State Aid Scoreboard identifies environmental protection and energy savings as the main objective of State aid measures across Member States, surpassing other, more traditional goals, such as regional development and R&D&I. This trend continues to strengthen, with a 20% increase in related expenditure in 2023 compared to 2022. These measures now represent 30% of total State Aid expenditure in the EU (European Commission, 2025). Consequently, a strand of literature has developed on the evaluation of such support and has attracted increasing academic attention in recent years, especially as governments scale up investment in the green transition (Ezcurra, 2014; Haak & Brüggemann, 2016; Milne, 2017; Banet, 2020; Musardo, 2021). The literature spans economics, energy policy, and legal studies, and addresses both ex-ante and ex-post evaluations of aid schemes.

Many evaluations aim to assess the effectiveness of aid schemes in terms of increased renewable energy capacity, investment leverage, or cost reductions. These works often use econometric models focused on the counterfactual, or what would have happened in the absence of aid. While the literature on the evaluation of renewable energy support is clearly expanding, it is still rather fragmented across jurisdictions and specific aid schemes. Often, data limitations hamper rigorous evaluation and comparability of results across studies. More encompassing views are needed to soundly advise future aid schemes, integrating the results of several studies and combining best practices. In addition, the time for focusing support only to the push of renewables seems to have passed, and broader policy perspectives including regulatory change and attention for infrastructure bottlenecks are needed.

[2] State Aid templates regarding RRF can be retrieved at the website of the European Commission (2023).

2. Research questions and common methodologies

2.1. Research objectives, research scope and research questions

To contribute to a more evidence-based approach to green industrial policy, this Article undertakes a comparative review of multiple ex-post evaluations of State Aid schemes targeting solar, wind, and storage capacity. These technologies are not only central to the EU's climate and energy goals, but also increasingly interlinked within the broader energy system. By examining a diverse set of evaluations, the analysis aims to identify cross-cutting lessons, differences in design and effectiveness, and emerging trends in how aid influences investment behaviour and market outcomes. Such a review offers valuable insights into the incentive effect, proportionality and appropriateness of support measures. In doing so, it contributes to institutional learning, supports the refinement of future aid design, and provides input into the continuous development of EU State aid control. The findings also speak to the growing need for coherence and strategic alignment in how State Aid is used to support the green transition while ensuring efficient use of public resources and preserving competition in the internal market.

The literature review revealed a substantial interest to study aid for the green transition, including detailed evaluations of aid that aims to boost renewable energy. Projects. From a State aid policy perspective, the State Aid Modernisation (SAM) package, launched in 2012, has developed obligations for the ex-post evaluation of specific State aid schemes (EU State Aid Modernisation (SAM), 2012). The Member State that developed the scheme has to deliver evaluation reports to the Commission and is guided through the process by means of feedback on the proposed methods, analyses and draft reports. The purpose is to ensure that lessons learnt are taken forward into future policy cycles. These evaluation plans and (interim) report are published on the EVALSA website (European Commission, 2026). Filtering on the criterion "energy", leads to 44 cases where an evaluation has been carried out or is ongoing.[3]

Table 1

EVALSA energy evaluations per country

Country	Energy evaluations	Country	Energy evaluations
Austria	1	Poland	5
Belgium	1	Portugal	2
Czech Republic	1	Romania	2
France	2	Spain	3
Germany	14	Sweden	4
Ireland	1	Slovakia	1
Italy	4	UK	1
Netherlands	2	Total	44

Source: own composition based on EVALSA (European Commission, 2026).

[3] Latest search carried out on 19. April 2025.

Not all evaluations have been completed. We work with the available information in the evaluation plans, interim as well as final reports and other information that is available. The aid schemes under evaluation cover a broad range of aid instruments and supported technologies. The instruments entail diverse tax incentives as well as direct grants and loans. The supported technologies do not only cover solar, wind and storage capacity, but also include, among others, biofuels, capacity mechanisms, decarbonisation initiatives, emission trading systems and R&D&I. As many evaluations deal with aid instruments targeted at multiple objectives or technologies, we focus only on the findings that relate to the scope of this article, being solar, wind and storage and hence single out these sections of the available documents.

We provide an overview of most common research questions in these evaluations. Those are also the questions that will be answered in Section 4 Results. Most studies entail evaluation questions that are descriptive as well as analytical. They entail direct impacts of the aid, as well as indirect effects of the aid, and proportionality and appropriateness. Regarding the direct impact of an aid scheme, we focus on the following questions in line with the primary objective of the support mechanism:

- RQ1: Have the aid schemes increased investment in renewable energy projects, in terms of solar, wind and storage capacity?
- Regarding the indirect impact and other aspects of the aid schemes, we investigate both market effects and characteristics of the measure. We include the following questions:
- RQ2: Was the aid proportionate and appropriate? Where the former asks whether the aid is kept to the minimum necessary to reach its objectives, the latter wonders whether other policy measures would have been able to reach the same objectives in a less distortive way?

RQ3: Did the aid schemes and supported projects have an impact on the electricity market (such as energy prices, and energy mix)?

2.2. Common ex-post evaluation methodologies for aid to renewable energy

Ex-post evaluations of aid for renewable energy and storage projects cover a diverse range of methodologies, typically entailing quantitative, qualitative or mixed-method approaches.

Ex-post evaluations of State aid for renewable energy most frequently rely on quantitative methods to assess the causal impact of support schemes on measurable outcomes such as investment levels, installed capacity, cost efficiency, and emissions reduction. Among the most widely used approaches are counterfactual analyses, which estimate what would have happened in the absence of aid. Techniques that are commonly used include difference-in-differences (DiD) models that compare treated and untreated

groups over time, by means of matching techniques that pair beneficiaries to non-aided, comparable entities based on observable characteristics.[4] Regression-based models are also common, allowing for multivariate analysis of the relationship between aid and project-level or firm-level outcomes while controlling for confounding variables such as energy prices, policy stability, or firm size.

Complementing these quantitative approaches are a range of qualitative methods, which are essential for understanding how aid schemes are implemented and perceived, study their incentive effect, and for assessing dimensions that are harder to quantify. Semi-structured interviews with aid recipients, non-successful applicants, non-applicants, policymakers, regulators, and stakeholders (such as grid operators or financial institutions) provide valuable insights into how aid influences investment decisions, how eligibility criteria are interpreted, and whether aid is seen as proportionate and appropriate. Also focus groups or stakeholder workshops can deliver added value when group discussion dynamics can further finetune the insights, validate findings, gather feedback, and explore forward-looking policy options. Case studies allow for in-depth analysis of specific schemes, technologies, or regional contexts, revealing factors that may affect the effectiveness of the aid. Document analysis can be required to study how schemes were designed and whether they were implemented as planned.

Given the complexity of renewable energy markets and the multifaceted aspects of several State aid schemes, some evaluations adopt a mixed-methods approach. This integration of quantitative and qualitative methods allows for a more comprehensive understanding of policy outcomes and implementation processes. Quantitative techniques provide the empirical backbone for assessing effectiveness and efficiency, while qualitative insights help interpret the findings, validate assumptions, and uncover mechanisms that are not easily observable in the data. For example, a quantitative analysis may reveal that aid recipients increased their investment compared to a control group, while interviews explain that this response was due not only to financial support but can also highlight issues of regulatory uncertainty and grid access. By triangulating findings from multiple sources and methods, mixed-method evaluations offer a richer, more robust evidence base for improving aid design, reducing distortive effects, and aligning support measures with the evolving goals of EU energy and climate policy. Consequently, mixed-method evaluation is recommended.

[4] Matching techniques include, among others, propensity score matching, covariate matching, and synthetic control methods in cases of limited data. Propensity score matching constructs comparable groups of aid beneficiaries and non-beneficiaries with similar estimated probabilities of receiving the treatment. Covariate matching involves forming groups based on similarity in observed characteristics. The synthetic control method creates a counterfactual by combining untreated units into a weighted composite that closely replicates the treated unit's pre-treatment characteristics.

2.2.1. Results

This section discusses the results in three parts. We first discuss the main findings of the ex-post evaluations regarding effectiveness or incentive effect, i.e. did the aid trigger additional investment or realised projects that would not have been carried out in the absence of the aid. Next, we look into the question regarding proportionality of the aid and appropriateness. Finally, we present other findings regarding the industry that, while not being at the core of the support scheme, are nevertheless very relevant to take on board in future policy cycles.

2.2.2. Incentive effect of aid for solar, wind and storage capacity

Ideally, the aid disbursed enables beneficiaries to undertake investments that would not have occurred without. It generates additional investment in areas considered valuable by the aid grantor (Parcu et al., 2020). The incentive effect can be assessed through interactions with beneficiaries, non-beneficiaries, a combination of both, or exclusively via modelling approaches. Each method has distinct implications. For instance, one approach involves constructing a counterfactual based on beneficiaries' responses and their estimation of project size in the absence of aid. This method typically results in a relatively high response rate, as beneficiaries are often more inclined to participate in evaluation exercises, sometimes due to contractual obligations. [5] However, these beneficiaries have a clear incentive to provide responses favourable to the scheme. Ex-post evaluations of aid for renewable energy have demonstrated heterogeneous impacts across beneficiaries, particularly concerning the incentive effect. Broadly speaking, the results can be categorised into three distinct groups.

First, in the optimal case, the aid was found to be a decisive factor, indicating that, in the absence of such support, the initiatives would not have been implemented. In these cases, the aid demonstrated a strong incentive effect, as the scheme catalysed investments that were otherwise financially unviable or would not occur. In principle, each euro granted generated a corresponding additional investment equivalent to that euro. It is in these projects that a behavioural shift is observed, whereby the aid truly creates results that would not have been achieved in absence of the aid. This effect is observable not only in the realisation of projects but also quantifiable through indicators such as (the difference in) project scale, investment additionality, implementation timing, etc.

Second, in some cases the results are more nuanced, with a partial incentive effect observed. In these cases, projects would have proceeded regardless, but on a smaller scale or at a later date, underscoring the scheme's role in accelerating implementation or enhancing project scope. In such instances, the public expenditure generated additionality, though not equivalent to the full amount spent.

[5] See for example the following evaluation by the Swedish Environmental Protection Agency (2023).

Third, and in a non-negligible number of cases, beneficiaries indicate that projects would have occurred irrespective of the aid, often because they were already planned or in progress, partly driven by market factors such as volatile energy prices. These are precisely the cases to be avoided, as the public expenditure fails to generate substantial additional investment and the incentive effect cannot be demonstrated. The State Aid did not induce investment that would not have materialised otherwise, but instead acts as a market distortion, as beneficiaries perceive it as a business opportunity that reduces the payback period and enhances the return on investment (Werner & Verouden, 2025).

These results and the absence of a distinctive incentive effect in a number of cases, are largely in line with the suggestions put forward in extant literature. For example, Nicolaides argues that the current funding gap approach to assessing the presence of an incentive effect is only appropriate in case of discretionary projects.[6] Otherwise, an undertaking familiar with State Aid rules may simply adjust the timing of its investment plans to meet the eligibility criteria, even if the aid is not genuinely necessary (Nicolaides, 2023b).

Further analysis differentiates the presence of the incentive effect by project characteristics. Wind projects typically showed a stronger full incentive effect compared to solar, potentially due to higher average investment costs. Smaller projects (under 1MW) appeared more responsive to Aid, suggesting that financial constraints are more binding at lower capacity scales. Project destination (e.g. whether the renewable energy generated is for self-consumption or for sale) does not show a clear pattern of influence on the incentive effect, although many respondents struggled to isolate the role of aid in complex investment decisions. A common finding is that the incentive effect of aid is higher for projects with storage capacity. Whereas pure solar or wind project would often be carried out without aid, investment in storage would mostly not be possible without support considering the high costs and current state of technological advancement.

Interestingly, the financial characteristics of the beneficiaries such as turnover, net profit, or assets, do not seem to correlate significantly with the presence or absence of the incentive effect. This suggests that project-level factors, rather than firm-level financials, may better explain responsiveness to aid.

While the schemes did not universally trigger new investment, they played a crucial role in enabling and accelerating renewable energy deployment, especially among smaller-scale, wind, energy and storage projects. In cases where the aid did not have an incentive effect, it for sure increased the return on investment of the project, freeing resources for

[6] For example, if a project is critical to an undertaking's continued operation and would be pursued despite imposing a financial burden, the provision of State aid is unlikely to induce a behavioural change, as the undertaking would, in all likelihood, proceed with the project also in the absence of aid (Nicolaides, 2023a).

investments in additional projects. In practice, any aid scheme includes beneficiaries across all three categories. For some, the scheme served as a strong incentive for additional investment, while for others, it primarily was a business decision by enhancing the profitability of a project that would have proceeded regardless of the aid.

2.2.3. Proportionality and appropriateness

Next to incentive effect, a key objective of ex-post evaluations is to assess the proportionality and appropriateness of the State Aid scheme supporting investment in renewable energy projects. These concepts are central to EU State Aid control and reflect whether aid was limited to the minimum necessary to trigger investment (proportionality), and whether the aid was the most effective and least distortive means to achieve policy objectives (appropriateness).

2.2.4. Proportionality and aid intensity

Proportionality is probably one of the more interesting and complicated topics from an aid design and evaluation perspective. Whereas the incentive effect investigates whether aid is necessary for the project to go ahead, proportionality takes a more nuanced approach and aims to uncover the amount of aid minimum necessary to trigger the new investment. More precisely, it aims to uncover the minimum percentage of the full cost of the project that should be supported through State Aid for the project to be able to go ahead (Werner & Verouden, 2025). Because the results on effectiveness of the aid schemes are so diverse (three groups with no incentive effect, partial incentive effect, and full incentive effect), it does not make sense to fix one aid intensity. Often, the required aid intensity depends on the characteristics of the beneficiary and type of project.

Thereto, an innovative feature was detected, i.e. applicants are invited to propose their own desired aid intensity, or percentage of eligible costs for which they sought public funding. Aid intensity was then taken on board as one of the evaluation criteria to determine which company received aid. Suggesting own aid intensities and knowing that it influences chance of success, represents a self-assessment mechanism and introduces a competitive and reflective dimension, encouraging applicants to request only the aid deemed necessary. From a policy perspective, this feature aimed to enhance cost-efficiency, reduce overcompensation, and function as a safeguard for proportionality.

The projects that introduced such mechanism show a large range of proposed aid intensities, spanning from as little as 7% to as much as 98% of eligible costs. It is also clear that most companies agree that relatively modest aid intensities (40-60%) are sufficient to trigger investment, particularly for established technologies such as solar and wind. Importantly, the evaluations

show a negative relationship between aid intensity and project size. Larger projects, measured in terms of total budget, approved aid value, and capacity, tended to require lower aid intensities. This outcome aligns with economic expectations regarding economies of scale and greater access to capital among larger and more experienced firms. Conversely, no relationship is found between aid intensity and firm-level financial indicators such as turnover, assets, or profit. This suggests that project characteristics, rather than company characteristics, are more predictive of aid requirements. In addition, a positive relationship between aid intensity and cost per megawatt installed (aid per MW) suggests that higher aid levels are needed to compensate for more capital-intensive or technologically demanding projects. This is especially true for projects incorporating storage components, which often face higher costs and less mature market conditions. For storage, substantially higher aid intensities are necessary to ensure viability.

It is important to bear in mind that the mechanism allowing applicants to propose their own aid intensity involves a trade-off embedded in the scheme's design. Although the flexible model encourages reflection and competition, thereby constraining aid intensities and total aid amounts, it may also generate uncertainty or advantage more experienced participants, who are better equipped to estimate the maximum acceptable aid intensity than less experienced undertakings.

2.2.5. Appropriateness and aid instrument

Overall, State aid is considered to be an essential way to support and expedite investments in renewable energy. While removing other obstacles in the energy market would certainly help, they cannot replace the function of State Aid. When it comes to aid measures, diverse instruments have been chosen by the Member States to support investment in renewables, including direct grants, reimbursable expenses, soft loans and tax measures.

In terms of appropriateness, a reimbursable expenses model is widely regarded as effective. It offers both financial support and flexibility during implementation, but can be less fraud prone than for example a direct grant as it enables the granting authority to review the expenses before releasing the aid. Nevertheless, also alternative instruments are identified that could have supported renewable investment in a less burdensome or more accessible way, as reimbursable expenses require pre-financing. Implementing an advance-payment mechanism that disburses a portion of the aid ex-ante can reduce financing risk and catalyse co-financing by financial institutions, whereas a soft loan constitutes a valuable alternative, particularly for firms with constrained access to capital markets. This could be in addition to the reimbursable expenses model rather than replacing it. A loan by itself might not be able to sufficiently incentivise new projects. A minority of cases mentions tax deductions as a potentially attractive and less administratively complex alternative.

These preferences were particularly salient among small and young firms, which often face structural challenges in obtaining sufficient pre-financing. The evaluations also reveal that in some projects, potential beneficiaries were established as special purpose vehicles (SPVs), complicating the link between project characteristics and firm-level financial indicators. Such structures often render firms "small" in conventional datasets despite substantial off-balance-sheet support, complicating credit assessment procedures and impeding dialogue with financial institutions.

Beyond the choice of aid instrument, a significant number of cases emphasised the critical importance of grid infrastructure. Delays and limitations in grid connection were frequently cited as major bottlenecks, particularly in certain geographic regions. Even well-designed aid schemes may fall short if the physical infrastructure required to deliver renewable electricity is lacking. This underscores the need for policy complementarity, where financial support is accompanied by regulatory and infrastructure improvements.

2.2.6. Other findings

The evaluations of aid for renewables also highlight several critical factors that influence project success beyond the aid itself. *First*, grid infrastructure consistently emerges as a top priority, often seen as more critical than the financial support provided through aid schemes. The fact that companies do not have certainty on the possibility to connect their project to the grid, or might have to temporarily disconnect in peak times causes uncertainty about the feasibility, profitability and return on investment of new renewables projects. *Second*, clear communication and regulatory predictability are both essential for confidence and smooth project implementation. Multiple changes to the policy and regulatory environment have recently created too much instability for companies to confidently plan and invest. Certainly, the combination of regulatory changes, evolving energy policy objectives, changes to aid schemes and their evaluation, render it very difficult for companies to thrive. A *third* element in the broader findings of the evaluations concerns price stability. The last years have been characterised by extreme price instability for electricity. This constitutes an additional barrier to investment in renewables by undermining the return on investment and disrupts project planning. *Fourth*, the evaluations regularly document administrative hurdles, particularly in the permitting process and grid connection applications. These can significantly delay or even block renewable energy projects. Finally, the evaluation underlines the importance of early and transparent communication on data sharing, which is vital for conducting meaningful and accurate assessments. Without prior commitment of the aid applicants (beneficiary as well as unsuccessful applicants) regarding the sharing of data required for the evaluation, it becomes difficult to obtain the necessary input to carry out a sound evaluation.

Conclusions

This article reviewed evidence from ex-post evaluations of State Aid schemes aimed at supporting investment in renewable energy projects, with a particular focus on solar, wind, and storage technologies. We focus on the assessment of the effectiveness of aid schemes in triggering additional investment, and its proportionality and appropriateness characteristics. The aim was to generate evidence on how public support has influenced project decisions on renewable energy and to inform the future design of aid measures that contribute to the EU's green transition goals in an efficient and targeted manner.

The evaluations of aid for renewables reveal a varied incentive effect. While most companies report an either full or partial incentive effect, a non-negligible number of cases also indicated the aid replaced rather than complemented private investment. The current geopolitical climate makes it obviously wise to invest in autarkic renewable energy sources to not depend too much on price volatility. This entails that several companies can, and probably will, develop financially viable energy projects, even in the absence of aid. This highlights the importance of carefully designing aid schemes to target projects that genuinely require support, while recognising that aid can still play a role in accelerating timelines or enhancing project scale.

From a proportionality perspective, the innovative practice of permitting applicants to propose their own aid intensity offers strong safeguards for ensuring proportionate support. By introducing a competitive dimension, this mechanism promotes cost-efficiency and incentivises potential beneficiaries to limit their aid requests to the minimum necessary. There is typically a negative relationship between aid intensity and project size, suggesting that larger projects benefit from economies of scale and require less public support per unit. By contrast, smaller projects, and those involving storage, tended to require higher aid levels to be viable.

With respect to appropriateness, we find that multiple aid instruments are theoretically viable and selecting the right one is of course very much context dependent. In practice, we see that a system with reimbursable expenses is generally suitable. Nonetheless, several alternatives were suggested to better address the financing constraints faced by smaller or younger firms. These include preferential loans, advance payments, and tax deductions, all of which could enhance access to capital and reduce barriers to participation.

Beyond the core findings, the evaluations also uncovered additional impacts of aid schemes. Companies report relatively frequently strategic benefits that extend beyond the specific project, such as accelerated investment timelines or freed-up capital for other initiatives. Several more structural issues were also frequently reported. Mostly infrastructure issues can hamper the development and implementation of future renewables projects, even with very generous aid schemes.

The evaluation findings emphasise the need to adopt a holistic approach in renewable energy policy that complements State aid with

regulatory reform, infrastructure investment, and streamlined administrative processes. Ensuring grid readiness and maintaining a stable and predictable policy environment can greatly enhance the effectiveness of aid measures and accelerate the deployment of renewable energy.

Future studies might focus on the interplay between aid schemes and other or non-financial barriers, such as local permitting practices or market design, as well as develop methodologies for integrating infrastructure constraints into the design of State aid schemes and the assessment of aid applications. More case-specific data and longitudinal studies would also strengthen the evidence base for policy design.

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