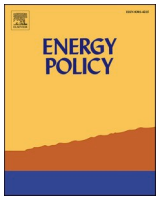
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Developing effective market-based policies to incentivise fair and efficient European electricity transmission grid expansion

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1. Introduction

The world is entering a new age of electrification, with global demand for electricity growing at 4% per year in the next 5 years (IEA, 2025b). This rapid growth, combined with the increased penetration of low-carbon sources, is straining electricity grids and necessitating capacity upgrades and improved congestion management practices (IEA, 2025a). The need to upgrade electricity grids is compounded by ageing infrastructure, volatile generation by renewables, digitalisation & cybersecurity, decentralisation of supply, and customer activation (IEA, 2025a; Biancardi and Di Castelnuovo, 2020).

The International Energy Agency estimates that global investment in grids needs to increase by 11% annually through 2030, reaching $250bn per year (IEA, 2025a, 2024). In the EU alone, Transmission System Operators (TSOs), the companies managing high voltage lines that connect generation and consumption over long distances, will need to invest €584bn in the coming decade, nearly doubling transmission lines by 2050 (Johnston et al., 2025; OECD, 2023).

The size of the investment required by TSOs triggers questions about the allocation of the costs and benefits (WEF, 2025). For instance, following announcements by European TSOs of 30-80% tariff increases in the coming 4 or 5-year tariff period, significant political concern has arisen over the impact on customer bills (Heussaff and Zachmann, 2025; ACM, 2024; CRU, 2024).

TSOs are natural monopolies, and the allocation of costs and benefits from grid investment is overseen by the National Regulatory Agencies (NRAs) that regulate TSOs and guarantee their societal value by setting the level of remuneration that TSOs can obtain as well as supervising transmission tariffs that are charged to grid users (ACER, 2024; Joskow, 2014). Regulation of grid costs' allocation, particularly whether certain stakeholders receive preferential tariffs, is also crucial in shaping fair and efficient electricity systems (CEER, 2017; Neuteleers et al., 2017). Beyond transmission tariffs, TSOs' remuneration policies also create the performance incentives that shape transmission grids, balancing a fair return to investors, an affordable grid for consumers and a robust grid for all (ACER, 2024).

Despite their critical role in ensuring a fair and efficient electricity system, TSOs' remuneration and transmission tariff policies often fall short of these goals (CEER, 2025b; ACER, 2025). For instance, traditional volume-based tariffs applied to recover fixed infrastructure costs are increasingly misaligned with the needs of a more variable and distributed electricity system (ACER, 2025). There is thus an urgent need to optimise and reform TSO remuneration and transmission tariff policies currently in place (ACER, 2025; European Commission, 2023; European Parliament, 2024a).

This paper explores **how Transmission System Operators' (TSOs') remuneration and tariffs policies can best be designed to promote fair, efficient and future-proof electricity transmission grids.** Specifically, we test current practices and recommendations from the literature against the views of expert practitioners, elicited via in-depth semi-structured interviews. While the literature contains often-complex remuneration incentive schemes and tariff signals for a wide range of desirable objectives, our analysis highlights the difficulties that can arise when remuneration and tariff policies are designed in isolation, and when TSO practitioners interpret how they should be implemented in practice. The paper is presented in four parts: i) explores the existing literature on transmission remuneration and tariffs policies and benchmarks for existing European policies; ii) lays out the methodological approach; iii) presents the results of in-depth semi-structured expert interviews; and iv) concludes on policy improvements' potential to shape a fair and efficient energy system. The scope focuses on European TSOs and excludes Distribution System Operators (DSOs), considering their economic and policy differences.

2. Literature review

Electricity market policies seek the best outcome for society by "delivering market signals for increased efficiency, higher share of

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renewable energy, security of supply, flexibility, system integration through multiple energy carriers, sustainability, decarbonisation and innovation" (European Parliament, 2024b, p.14). While keeping the electricity flowing is the "raison d'être" of TSOs, doing so efficiently is also vital since it defines the affordability and competitiveness of the grid (ACER, 2024; Joskow, 2014). Grid efficiency is characterised by both increased utilisation of the existing grid infrastructure and the development of innovative solutions to address transmission needs at a lower total cost for TSOs and society (ACER, 2021). Transmission policies in the EU have so far primarily focused on incentivising TSOs and users to achieve these grid stability and efficiency objectives, seeking to emulate a free and fair competitive market that maximises the global surplus for all market agents (ACER, 2024, 2025; European Parliament, 2024b; Leveque et al., 2003).

2.1. The recent evolution of TSO remuneration policies

Most National Regulatory Agencies (NRA) set TSOs' remuneration based on the Regulated Asset Base (RAB) of TSOs. A fair level of return is determined, which compensates for their capital (CAPEX) and operational (OPEX) expenses, as well as the risk incurred by capital investors (ACER, 2024). Remuneration policies can limit the revenues or prices TSOs can charge (price/revenues cap), their profit (return cap or cost-plus), or tie them to their performance compared to objectives or peers (performance-based or yardstick competition) (ACER, 2024). Common alternative incentive mechanisms are summarised in Table 1 below.

While the *return cap* model used to be the dominant market structure, the *revenue cap* model is currently the leading mechanism in Europe since it provides TSOs with an incentive to minimise costs and capture additional profits (CEER, 2025b; ACER, 2023; Vogelsang, 2006). While the majority of countries apply the same remuneration mechanism for both CAPEX and OPEX, some countries combine a return cap on CAPEX with a revenue cap on OPEX to counterbalance mechanisms' limitations and provide efficiency incentives (IEA, 2025a; ACER, 2023). Additional mechanisms are also being implemented to limit the CAPEX bias, such as OPEX capitalisation, shared savings mechanisms, fixed CAPEX/OPEX share (FOCS) or revenue caps based on TOTEX (i.e., Total Expenditure, which combines CAPEX & OPEX) (CEER, 2025a; ACER, 2023). Ensuring CAPEX efficiency is particularly important in light of the scale of development needed and its impact on affordability and competitiveness (WEF, 2025; CEER, 2025a; ACER, 2024). A summary of remuneration mechanisms of European TSOs can be found in Table 2 below.

Table 1
Advantages and disadvantages of common TSO remuneration mechanisms.

Remuneration mechanism	Definition	Advantages	Disadvantages
Price/Revenue cap	Remuneration based on a yearly cap that the grid operator can charge for each specific service (price cap) or on the amount that can be charged for each cluster of services (revenue cap)	Drives motivation for cost efficiency and higher return	Unsuitable for highly volatile costs Threatens service quality
Return cap/ Cost-plus regulation	Remuneration based on an allowed rate of return defined a priori on the cost incurred, starting from the determination of the total cost of service	Guarantees financial return for TSO	Fails to drive innovation and cost efficiency Creates CAPEX bias[1]
Performance-based/ yardstick competition	Remuneration, with penalties/awards, based on performance on specific metrics (e.g. quality, losses), compared with the other operators' performance in the sector or with pre-defined targets	Drives efficiency, innovation and operational excellence	Threatens service quality if the focus is on efficiency

Table 1 legend: Adapted from IEA (2025a); CEER (2025) & ACER (2023).
[1]'Capex bias' describes the propensity of the TSO to prefer CAPEX investment over OPEX increases, since remuneration is based on the total assets of the TSO.

These remuneration mechanisms have proven somewhat effective, but the design of these mechanisms remains complex as regulators have imperfect information on TSOs' improvement potential, investment needs, risks and appropriate return. The TSO also has an interest in using this information asymmetry to its advantage (ACER, 2023; Romeijnders and Mulder, 2022; Joskow, 2014). Arguably, there is therefore no single optimal remuneration policy, but rather combinations of policies that contribute to one or more strategic objectives (Vogelsang, 2006). Historically, the overriding objective was low-cost grid development, often at the expense of innovation, interconnection, user connections and service quality, compromising long-term performance and societal value (Heussaff and Zachmann, 2025; Pototschnig and Rossetto, 2024; ACER, 2024; European Commission, 2019; Poudineh et al., 2017). As a result, the EU has called for reform and evolution of remuneration schemes by establishing incentives to support future-proof grid developments and investments in more innovative and interconnection projects (European Commission, 2019, 2023). Following this steer from the EU, incentive schemes are becoming more diverse across European TSOs with the explicit aim of supporting quality, innovation and market integration, as illustrated in Table 2 (CEER, 2025b; ACER, 2023).

Despite the increasing focus of European NRAs on innovation and futureproofing, the design of TSOs remuneration incentives still faces issues (Pototschnig and Rossetto, 2024). First, too short a regulatory period can limit TSO efforts to chase incentives, while changes of RAB between periods can perpetuate a CAPEX bias (Pototschnig and Rossetto, 2024; European Commission, 2019; Joskow, 2014). Second, anticipatory investments to meet future but uncertain needs are lacking incentives, despite their potential to limit TSOs' liquidity risks and total grid costs (European Commission, 2023; ACER, 2023). In fact, anticipatory projects lack clear definition and delimitation, creating financial risks for TSOs and unnecessary costs for grid users (ACER & CEER, 2024). Third, innovative and riskier projects, such as offshore, interconnections or anticipatory investments, lack project-specific incentives (IEA, 2025a; ACER & CEER, 2024; ACER, 2023). Today, only a few regulators differentiate returns for very large, cross-boundary or offshore projects (ACER, 2023). Fourth, incentives lack focus on the output, creating misalignment between TSOs' and societal interests (Pototschnig and Rossetto, 2024). Lastly, the large number of TSO remuneration incentives in place can create network development inefficiencies and conflicting signals for TSOs (Pototschnig and Rossetto, 2024; Joskow, 2014).

2.2. Transmission tariff policies

Transmission tariff structures are the other major transmission policy area, and they are central to the affordability and competitiveness of countries' electricity supply and to the cost recovery of TSOs' investments (ACER, 2025). The EU describes transmission tariffs as the "charges applied by network operators for access to networks, including charges for connection to the networks, charges for use of networks, and, where applicable, charges for related network reinforcements" (European Parliament, 2024a). Fundamentally, tariffs define the grid cost allocation between users and the metric by which the contribution of each user is defined (CEER, 2017). While classical economic theory would suggest that consumers' contribution should equal the marginal cost that they create, in practice, TSOs face much higher average costs than marginal costs, which calls for alternative allocation mechanisms

Table 2
Overview of European TSO remuneration mechanisms and complementary remuneration incentives linked to key performance indicators of TSO.

Country	Remuneration policy		Complementary KPIs incentives											
	Return cap	Revenue cap	Add'l efficiency incentive	Security of supply	Service quality	RES integration	Balancing services	(Inter)-connection	Innovation	Financial stability	Cyber-security	DSO cooperation	GHG emissions reduction	Project specific
Belgium	CAPEX	OPEX		✓	✓			✓	✓					✓
Netherlands		CAPEX/OPEX												✓
France	CAPEX	OPEX	✓ CAPEX	✓	✓			✓	✓					✓
Germany	CAPEX	OPEX	✓ CAPEX/OPEX			✓		✓			✓			
UK		TOTEX							✓		✓		✓	
Ireland	CAPEX	OPEX		✓	✓	✓	✓	✓	✓			✓	✓	✓
Sweden		CAPEX/OPEX		✓										
Denmark		CAPEX/OPEX		✓										
Hungary		CAPEX/OPEX												
Spain	CAPEX	OPEX	✓ CAPEX/OPEX	✓		✓	✓	✓	✓	✓				
Italy		TOTEX		✓			✓	✓						✓
Portugal		TOTEX	✓ CAPEX/OPEX	✓	✓			✓						
Finland		CAPEX/OPEX	✓ CAPEX/OPEX	✓			✓		✓					
Norway		CAPEX/OPEX		✓		✓			✓					
Austria	CAPEX/OPEX			✓	✓	✓	✓	✓	✓					
Greece	CAPEX	OPEX	✓ OPEX	✓	✓	✓	✓	✓			✓			✓
Croatia	CAPEX/OPEX					✓	✓	✓			✓			
Romania		CAPEX/OPEX	✓ CAPEX/OPEX	✓	✓									
Lithuania		CAPEX/OPEX	✓ CAPEX/OPEX	✓		✓		✓	✓				✓	
Slovakia	CAPEX/OPEX			✓		✓			✓					✓
Poland	CAPEX	OPEX												
Slovenia		CAPEX/OPEX		✓	✓	✓	✓				✓			

✓ Incentive ✓ Penalty ✓ Incentive + Penalty

(Morell et al., 2021; Vogelsang, 2006; Leveque et al., 2003). In Europe, transmission tariffs vary greatly by country, by voltage (see Fig. 1) and by user (see Fig. 2).

Five main practices are used in Europe to determine cost allocation: i) *flat rate* (i.e., all consumers pay the same fee); ii) *Ramsey pricing* (i.e., charges are based on consumer demand elasticity); iii) *Dynamic tariff* (i.e., tariffs vary based on real-time cost); iv) *Transport charge* (i.e., charge is based on electricity volume consumed); v) *Capacity charge* (i.e., charge is based on max annual capacity required) (ACER, 2025; Trong and Yang, 2023). Underlying these different allocation practices are opposing approaches to fairness: equal treatment between users, the ability of users to pay, the cost caused by the users, and the preferences of users (Neuteleers et al., 2017). In practice, tariff fairness also depends on consumers' perceptions (Neuteleers et al., 2017) and tariffs are most often perceived as 'fairest' when they are based on the volume (transport charges) or the capacity (capacity charges) consumed, meaning that they are cost-reflective and non-discriminatory (Trong and Yang, 2023; Neuteleers et al., 2017).

Beyond questions of fairness, tariff practices are increasingly challenged by the rise of renewables and prosumers (i.e., consumers who also produce part of their electricity), and their impact on cost-recovery and cost-reflectivity (ACER, 2025). For instance, traditional

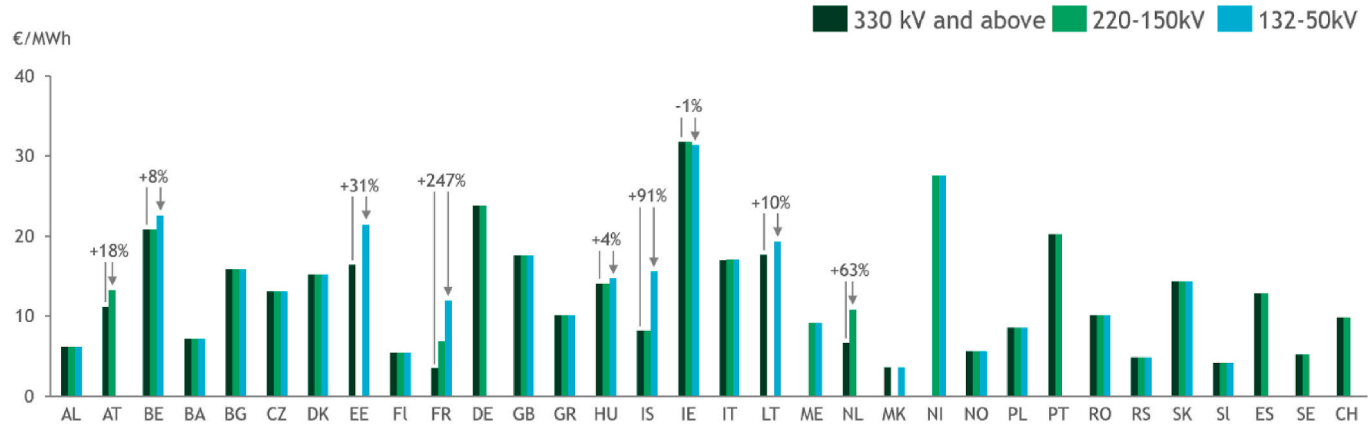


Fig. 1. Overview of European transmission tariffs for different voltage levels
Legend: created using data from ENTSOE (2022), converted to €/MWh tariffs for comparability.

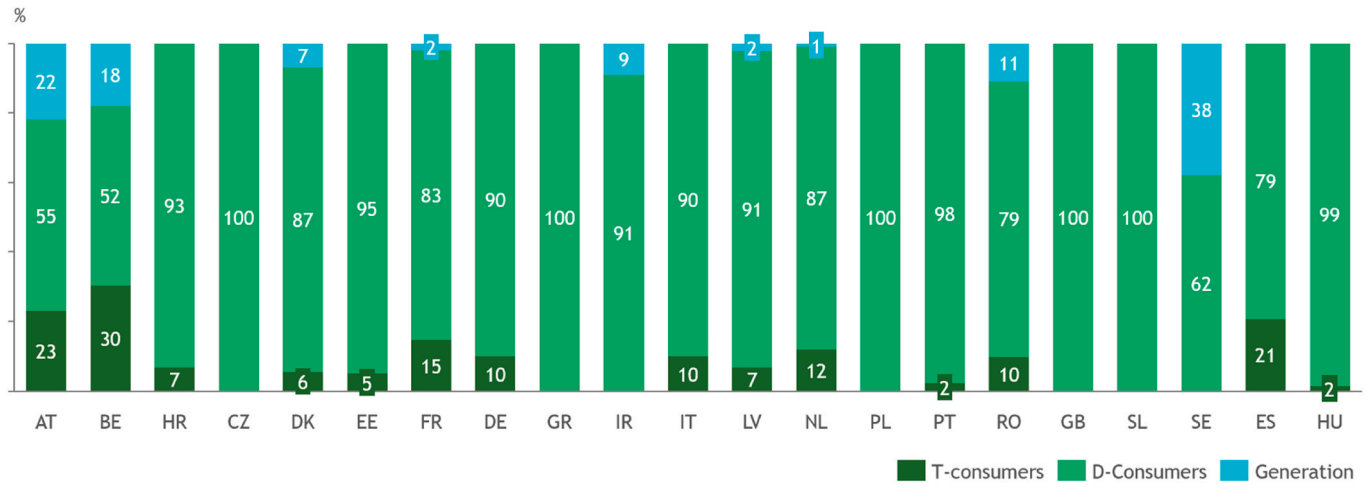


Fig. 2. Allocation of European transmission total cost between grid users
Legend: created using data from ACER (2025). T-consumers = consumers directly connected to the transmission grid, D-consumers = consumers connected to the distribution grid and charged by DSOs.

volume-based tariffs are increasingly misaligned with prosumers who, despite their production, tend to require transmission capacity at peak load, therefore not reducing the need for transmission while at the same time reducing their contribution to cost recovery (ACER, 2025; Morell et al., 2021). Anticipatory investments needed for the energy transition also create tariff fairness questions, since users need to pay for costs unrelated to their consumption (ACER, 2025).

Considering these new challenges, regulators have established guiding principles for the elaboration of new fair and efficient tariffs (see Table 3) (ACER, 2025; European Parliament, 2024a; CEER, 2017). While these institutions appear aligned on the main tariff fairness components, the European Parliament also consider broader energy system objectives for tariff policies.

Following these principles, two-thirds of European countries have adjusted their tariff methodologies in the last 5 years, adopting practices such as power-based/capacity tariffs (vs energy-based/volumetric tariffs), user differentiation, time-of-use signals, locational signals, flexible connections and the removal of unjustified discounts (ACER, 2025) (see Table 4).

The primary evolution is the adoption of capacity-based tariffs to replace volumetric tariffs (ACER, 2025). Volumetric tariffs create cost-reflectivity and cost recovery challenges since volumes consumed are increasingly more volatile (ACER, 2025; Morell et al., 2021). Capacity-based pricing thus enables more accurate cost reflectivity since additional grid investments are covered by the users who use capacity at peak times (e.g., triad demand in the UK, where capacity is based on three half-hour settlement periods of highest net system demand) (ACER, 2025; Bjarghov et al., 2022; Morell et al., 2021; Olmos and Pérez-Arriaga, 2009). Differentiating users' types and offering discounts to specific users is another tariff evolution to improve cost reflectivity and network efficiency (ACER, 2025; Gautier et al., 2021). For instance, some countries fully exempt generation from transmission, while others provide discounts to energy transition technologies (ACER, 2025).

To date, these revised tariff structures have had a mixed impact on the development of a fair and efficient energy system (ACER, 2025). For instance, exemptions for injection from generation and storage do not provide market and investment signals resulting in limited impact on system efficiency (ACER, 2025; Morell et al., 2021). On the other extreme, Tohidi et al. (2017) argue that generation should not cover the full cost of transmission as this arrangement could create inefficiencies, bias competition, and discourage investments. Avoiding creating conflicting market signals is, therefore, one of the key challenges of user tariff differentiation (ACER, 2025; Tohidi et al., 2017).

Table 3
Main guiding principles for transmission grid tariffs design.

Principles	European Parliament	ACER	CEER
Cost-reflectivity	✓	✓	✓
Non-distortionary	✓	✓	✓
Non-discriminatory	✓	✓	✓
Transparency	✓	✓	✓
Support security and market integration	✓		
Support flexibility & energy storage	✓		
Support Renewables	✓		
Promote efficient and timely investments	✓	✓	
Spread cost over time	✓		
Facilitate innovation	✓		
Predictability		✓	✓
Simplicity		✓	✓
Cost-recovery		✓	✓
Stability		✓	
Sustainability		✓	

Table 3 Legend: created using data from the European Agency for the Cooperation of Energy Regulators (ACER) (2025)., European Parliament (2024a) and the Council of European Energy Regulators (CEER) (2017).

Next to capacity-based tariffs and user differentiation, locational signals are also increasingly being considered to address grid congestion

Table 4
European Transmission tariff components and discounts or exemptions for specific user types.

Country	Transmission tariff components for consumers			Transmission tariff components for generation			Discounts & exemptions for:				
	Power-based	Energy-based	Lump sum	Power-based	Energy-based	Lump sum	Transmission-consumer	Prosumers	Distribution - consumer	Generation	Grid-level batteries
Belgium	✓	✓			✓						✓
Netherlands	✓		✓			✓		✓ 1		✓	✓ 1
France	✓	✓	✓		✓		✓	✓		✓	✓
Germany	✓	✓		Exempted			✓	✓	✓	✓	✓ 2
UK	✓	✓		✓		✓	✓			✓	✓
Ireland	✓	✓		✓						✓	✓ 2
Sweden	✓			✓	✓						
Denmark		✓			✓		✓	✓	✓	✓	
Romania		✓			✓			✓		✓	
Bulgaria		✓	✓		✓						
Hungary	✓	✓								✓	✓
Spain	✓	✓		Exempted						✓	✓
Italy	✓	✓								✓	✓
Finland		✓		✓	✓						
Slovakia				✓			✓	✓	✓	✓	✓
Slovenia	✓	✓		Exempted				✓	✓	✓	✓
Lithuania	✓	✓								✓	✓
Norway	✓	✓	✓		✓	✓	✓		✓		
Estonia		✓								✓	
Greece	✓	✓					✓		✓	✓	
Croatia	✓	✓	✓	Exempted				✓		✓	✓
Czech Republic	✓	✓						✓		✓	
Portugal	✓	✓						✓		✓	✓
Austria	✓	✓	✓		✓					✓	✓
Poland	✓	✓		Exempted			✓			✓	✓

✓ Primary tariff component ✓ Secondary tariff component ✓ Exemption ✓ Discount 1: exemption from injection 2: exemption from withdrawal

challenges and the rise of renewables (Olmos and Pérez-Arriaga, 2009). These signals improve tariff cost-reflectivity and grid utilisation by steering investments into areas with capacity (ACER, 2025; Brandstätt et al., 2011). These signals can be included directly in the tariff or in the connection charge of large users, where with deep connection charges they would pay for both their connection and the network reinforcement that they triggered (ACER, 2025; Brandstätt et al., 2011; Olmos and Pérez-Arriaga, 2009). It is sometimes argued that locational signals should target generation and industrial users since they can more easily decide on their location, whereas households have less flexibility and location-based differences could be discriminatory (Trong and Yang, 2023; Olmos and Pérez-Arriaga, 2009).

Beyond locational signals, time-based signals have also been implemented by most European NRAs, since cost causation varies in space and time (ACER, 2025; Leveque et al., 2003). Time-of-use signals in tariffs have the potential to reduce peak demand, improve energy system efficiency, and drive renewables or power-to-heat adoption at the right place and the right time (Hofmann et al., 2025; Stute and Klobasa, 2024; Bergaentzlé et al., 2019; ACER, 2025). Time-of-use signals are therefore often perceived as win-win for the electricity market, since they provide congestion management while rewarding consumers for their flexibility (Wang et al., 2023). Their design is important to avoid market distortion with energy retail prices, but rather align and compound their effect, to limit their complexity and ensure TSOs' cost recovery (ACER, 2025; Stute and Klobasa, 2024; Stikvoort et al., 2024; Wang et al., 2023; Bjarghov et al., 2022; Bergaentzlé et al., 2019; Olmos and Pérez-Arriaga, 2009). In fact, misalignment between transmission and electricity market price signals could create confusion for users, which could selectively pick the most interesting signal for them, or drop any flexibility at all (Stikvoort et al., 2024).

The most advanced time-of-use signals like dynamic pricing also face many yet-to-be-addressed adoption challenges, such as a lack of interest from households, discriminatory challenges, complex schemes and limited penetration of smart meters, which are essential for accurate tracking (ACER, 2025; Wang et al., 2023). In an ideal world the optimal signal should be granular enough to address real peaks but simple enough to facilitate their transparency for users (Wang et al., 2023; Morell et al., 2021). Moreover, adjustments may be needed for vulnerable households that are not able to adjust their demand or invest in smart energy management technologies to prevent discrimination (Wang et al., 2023; Winther and Sundet, 2023; Neuteleers et al., 2017). To address this concern, signals could be contracted voluntarily or vulnerable households could be left out of the scheme (Winther and Sundet, 2023; Neuteleers et al., 2017).

Flexible connection agreements are another time-based tariff evolution where industrial consumers receive discounts for being disconnected during peak load periods, up to 20% of the time (ACER, 2025). This scheme, however, faces the risk of postponing grid investments while threatening industry competitiveness and should therefore be considered as a temporary solution to complement time-of-use signals (ACER, 2025).

Overall, while European countries have started to implement time and location-based signals in their tariffs to exploit the flexibility and the utilisation of their grids, margins for improvements remain (ACER, 2025). Furthermore, not all countries find these signals valuable, as illustrated by the recent rejection of proposals for locational signals in the UK (DESNZ, 2025).

Beyond capacity-based tariffs, differentiation between users, location and time signals, a possible evolution would be for TSOs to take a more forward-looking view on costs (ACER, 2025). This has the potential to enable better cost reflectivity of grid use and investments than a historical view, particularly in a context of rapid grid expansion and anticipatory investments (ACER, 2025; Govaerts et al., 2023; CEER, 2017). The use of regulation to flatten the amortisation of grid investment over time (via amortisation rule changes or government loans) has also been suggested to limit tariff increases and the lack of cost reflectivity (Heussaff and Zachmann, 2025; ACER & CEER, 2024; Morell et al., 2021).

2.3. Key insights from the literature

The literature describes how TSO remuneration policies might effectively incentivise TSOs to invest in line with European energy policy ambitions via TOTEX-based remuneration schemes, output-based incentives and innovation support. It also details how tariff policies might unlock system flexibility and efficiency through a combination of capacity-based tariffs, lump sums, time & location signals and user differentiations. Yet the literature also highlights the need to consider fairness in these policy developments and identifies gaps that have arisen from recent regulatory developments. First, uncertainties remain regarding the optimal portfolio of TSOs' remuneration incentives that can be deployed without creating too much complexity (Pototschnig and Rossetto, 2024). Second, trade-offs appear between tariff signals for efficiency and fairness, with a lack of understanding of the right balance between them (Wang et al., 2023). Lastly, remuneration and tariff policies appear disconnected, creating inefficiencies. For instance, while capacity-based tariffs provide incentives to reduce peak load, they tend to be suboptimal from a total system cost perspective since they push individual customers to invest in flexibility technologies such as batteries (Askeland and Korpas, 2019).

3. Methodology and data

To bridge the gap between best practices identified in literature and how these policies are operationalised in practice, we conducted semi-structured reflective interviews with experts from TSOs, NRAs and independent specialists. The strength of this interview approach is that it makes explicit expertise, beliefs and inner decision-making processes that otherwise remain implicit within expert communities (Döringer, 2021). Semi-structured interviews also provide richer insights than surveys and quantitative analyses (Sovacool et al., 2018).

Fifteen in-depth semi-structured interviews were conducted with experts from a mix of TSOs, NRA, academia and other organisations. Considering the very niche TSO policy topic in Europe, this diverse European sample provides a good level of expert representation that is comparable to prior work in this area (see for example Dutton and Lockwood (2017) (n = 9 interviews); Haney and Pollit (2013) (n = 25 online survey respondents)).

Purposeful criterion sampling was performed in the recruitment to ensure that the experts selected had sufficient expertise on tariffs and remuneration incentives, via role (e.g., Policy officer/economist) and career length (e.g., min 2 years) (Palinkas et al., 2015). Furthermore, the study targeted key agents, who are experts and who steer and influence policy decision-making, considering their knowledge of the policy process (Döringer, 2021). A geographical exclusion criterion was also applied restricting the scope to European (including UK) NRAs and TSOs (Palinkas et al., 2015) which face a similar set of challenges, and follow (and sometimes set) EU regulatory principles. UK-EU co-operation includes the signing of a joint policy collaboration approach with the EU in 2024 (ACER, 2024; CEER, 2025; EU, 2024). This balanced group of TSO and NRA experts enabled us to capture diverse perspectives on both sides on the effectiveness of TSO remuneration incentives and tariff policies, as well as on the identification of best practices. The semi-structured interview questions focused on the design of new remuneration and tariff practices to address existing gaps, as well as the potential for coordination between the two aspects of transmission policies.

The recruitment of experts was performed iteratively, initially focusing on profile variation until reaching saturation in line with best practice (Palinkas et al., 2015). A total of 104 potential interviewees were either identified and contacted, using a predefined recruitment message, via LinkedIn or via a snowball method. After screening to ensure inclusion criteria were met, the interviews were conducted in English through the online meeting platform Teams and lasted for about an hour providing sufficient time for an in-depth of the discussion. The interviews were recorded where possible, and then summarised and coded in Excel to extract themes, patterns and relevant insights (Davies and Hughes, 2014; Braun and Clarke, 2006). Interviews were problem-centred and conducted using a pre-established list of open questions grouped by topic identified in the literature, and starting with background confirmation of the interviewees' expertise (Davies and Hughes, 2014). The question set was tested in the first interview and then shortened to focus on core questions for the remainder of the study. The final list of questions can be found in Supplementary Information.

Thematic analysis was performed, anchored in the themes identified during the literature review, to enable a detailed analysis of selected literature gaps (Braun and Clarke, 2006). Coding followed established process, starting with familiarisation and initial coding, then searching for themes and subthemes, and extracting the entire data set of transcripts into themes (Braun and Clarke, 2006). Convergences and divergences of experts' opinions were mapped and contextualised with the country and organisational side of the participants (Davies and Hughes, 2014). Finally, the themes were defined, and the insights described and synthesised (Braun and Clarke, 2006).

The list of experts interviewed can be found in Supplementary information. Anonymity was used to mitigate the social desirability bias, which can steer participants' answers to more socially acceptable answers (Sovacool et al., 2018). Their identification in this thesis solely pertains to the policy side on which they belong (i.e., TSO or NRA) to reflect the origin of some challenges and motivations discussed. In the following section the participants are therefore cited as "R_x" for experts from NRAs, "T_x" for experts from TSOs and "P_x" for experts from academia and other organisations.

While semi-structured interview methods provide useful insight there are a number of inherent limitations. First, although our analysis reached thematic saturation from the interviews conducted, it cannot be ruled out that further interviews would have identified additional themes. Second, our European focus reflects the regulatory similarity across EU and UK transmission systems but may limit the transferability of insights to other jurisdictions where different challenges may arise. Third, the interviews captured a specific moment in a rapidly evolving European policy landscape, and findings on locational signals, anticipatory investment frameworks, and TSO remits may shift as ongoing *reforms progress.*

4. Results and discussion

Here we present the key insights obtained from the interviews with European TSO and NRA policy experts. Insights are presented thematically, structured around three main policy areas: TSO remuneration incentives, transmission tariff signals, and the coordination between tariff and TSO remuneration policies.

4.1. There is no such thing as an optimal portfolio of TSO remuneration incentives

The experts unanimously considered that TSO remuneration incentives are essential policy instruments, particularly since NRAs have increasingly less visibility on the optimal solutions to deploy (P_1, R_4, T_5). Nevertheless, they also pointed out that there is no single optimal incentive portfolio across time and countries. Rather, incentive portfolios need to balance trade-offs between TSO objectives and be iteratively adjusted to address the most pressing system needs (P_1, T_2, R_3, R_4, T_5, T_7, P_8, R_9, R_12, R_13). They also identify that the gradual buildup of diverse policy objectives over the years has created complexity and uncertainty about how these incentives interact or should be prioritised (P_8). Various experts from the UK, Ireland and The Netherlands, in particular, denounced the lack of alignment on policy objectives prioritisation (R_3, R_9, T_11, R_13). For instance, an interviewee stated that: *"reliability is always the starting point and always comes first, which comes at a cost, and we should have an open discussion about*

that" (R_3), an opinion shared by another regulatory expert (R_9). Similar questions come on the cost reduction objective for TSOs: "*there should be a distinction between TSO costs and societal costs […] with increasing congestion, more costs for TSO can benefit society more*" (R_3), an opinion shared by (R_13). Beyond priority alignment, the experts emphasised the need for holistic policymaking. This need is exemplified by the Belgian energy island case, where an overfocus on innovation and growth objectives, via the development of an artificial island to connect future offshore wind, led to an uncontrolled increase in costs (R_4). This issue was also seen in Ireland, where renewables connection incentives drastically increased renewable capacity, leading to an unplanned increase in congestion and system charges (T_5). Consequently, it is argued that TSO remuneration policies could be more efficient with clearer and fewer overarching objectives that consider holistic grid and stakeholders' impacts (T_5, P_8, R_9, T_14).

Looking at how overarching policy objectives should translate into specific incentives, the experts' opinions diverge. For some, large incentive portfolios can be effectively managed with sufficient rewards and clear incentive ownership within TSOs (T_14). For other TSO experts, however, important objectives such as reliability are "*too important to be incentivised and should rather be tightly regulated, with penalties if needed*" (T_10) or that *"It is easier to incentivise cost while controlling or penalising other objectives"* (T_11). A regulatory expert also suggested a hybrid option where greater incentives should be set on dimensions where the system need is largest, while areas where there is lower improvement potential should be only slightly incentivised or penalised to ensure that minimum standards remain (R_15). This suggestion was echoed by a TSO expert: "*Incentives portfolio should balance day-to-day operations incentives, which are low-hanging fruits for TSOs, and transformational incentives*" (T_5).

Despite the lack of an optimal incentive balance, interviewees highlighted potential improvements to incentive portfolios that could mitigate some of the TSO remuneration policy challenges highlighted in the literature review. First, incentives should be set on dimensions that require the greatest reform, while a minimum standard should be kept on other key dimensions via lighter incentives, control or penalties (T_4, T_5, T_10, R_15). This approach also aligns with the objective focus suggested by Joskow (2014). Additionally, the share of these incentives in TSO revenues should be increased to drive change, rather than rewarding historical investments (R_4, P_8, T_10). Second, interviewees confirmed that incentives should be output-based and influenceable by TSOs (R_9, T_10), echoing Pototschnig and Rossetto (2024). Third, participants widely support enhanced project-based remuneration and incentives where risks differ from standard projects. One participant even argued that, in theory, every project should have its own return (R_13). However, in practice, project types with differentiated returns could be used (R_12, R_13). Anticipatory investments are particularly in need of differentiated support, considering the increase in infrastructure demand and uncertainty (T_2, R_3, T_5, T_7, T_11); an issue that has already been identified by the European Commission (2023). Still, a regulator noted that such anticipatory incentives should consider their holistic impact, balancing long-term efficiency and short-term cost for current users (R_13). Similarly, growth-specific project incentives could help TSO to better face the unprecedented CAPEX growth (T_7, R_12). One expert, however, noted that these return adjustments should only happen when *"the investors and not grid users bear this risk"* (R_4). Furthermore, the interest in project-adjusted returns appears lower for government-owned TSOs and cost-plus systems (R_3, T_6), whereas for investor-owned TSOs, aggregated TSO returns are more important than project-level differentiation (T_14). The value of a project-based return thus ultimately depends on the overall regulatory context and should be viewed as part of the aggregated TSO return.

4.2. Transmission tariff signals have value for those who can understand and respond to them

When it comes to transmission tariffs, experts generally support the development of signals and discounts for users as long as they are beneficial to the functioning of the transmission grid overall. Moreover, tariff signals should be simple enough for users to understand and respond, should be aligned with other electricity market signals, and sufficiently predictable given their potential impact on users' business cases (T_2, R_4, T_7, P_8, T_10, R_13). This finding also aligns with the literature (Stikvoort et al., 2024; Wang et al., 2023).

Regarding **user discounts**, one expert stated that they "*should be justified based on system benefit rather than pure participation*" (P_1), an opinion that was shared by other experts (R_3, R_4, T_6, P_8, T_11), and that aligns with tariff design principles of cost-reflectivity, non-distortionary and non-discriminatory (ACER, 2025; European Parliament, 2024b). It also means that discounts should remain technology-neutral to avoid any market imbalance and discrimination (R_9, T_11, R_12). For instance, offering discounts to batteries based on the flexibility benefits they provide is a fair differentiation (P_1, R_3, R_4, T_6, P_8, R_12, R_13, T_14). Additionally, participants noted that discounts for industrial consumers are more a support for industry competitiveness than a grid development mechanism (R_4, T_7, T_10, R_15). Nevertheless, such discounts could be justified from a cost recovery perspective by ensuring that industrial demand matches forecasts and contributes to transport tariffs, despite the fairness challenge it creates (R_4, T_7, P_8). Other forms of government support to industries could thus be favoured to avoid interfering with transmission signals (T_10, T_11, R_13). Experts also noted that evaluating the right degree of discount is complex, notably because they should not reduce tariff signals (P_8, T_10, T_14).

Regarding the use of **tariff signals**, the experts note that time-based signals are generally more effective than locational signals due to their higher impact on congestion and the lower complexity over longer periods of time, since congestion areas vary with network developments (P_1, T_5, T_6, R_13). Locational signals can also trigger cost-reflectivity issues since users' tariffs would also depend on neighbours' consumption (T_11). Moreover, TSOs would be able to influence and discriminate in favour of the industrial competitiveness of entire regions by prioritising grid investments (R_3, T_7, T_11). Lastly, locational signals might not even be needed, considering the permitting and delay challenges that new grid development creates for grid users, which naturally incentivise investment in areas with spare capacity (R_4, T_5). These challenges come in addition to the discrimination issue impacting households that are unable to move, which was already identified in the literature (Trong and Yang, 2023). Nevertheless, some experts believe that locational signals could provide long-term and stable development signals complementary to short-term and volatile time-of-use signals (T_10, R_13). This signal combination could also mean time-based signals that vary based on the local congestion status (T_6, R_15). To address fairness concerns, stronger signals could be implemented pre-investment via, for example, deep connection charges, potentially complemented with weaker signals for already established users who can't move (P_1, T_2, R_13). Overall, the use of locational signals appears thus more controversial and limited than stated in the literature and is rather seen as secondary to time-of-use signals.

Regarding **time-of-use** signals, the experts generally support their importance and inclusion in grid tariffs, in line with the literature (ACER, 2025; Hofmann et al., 2025; Stute and Klobasa, 2024). However, experts' views diverge on the strictness of their application to users. For instance, some participants support the idea that "*signals are great for those who have flexibility, but it can feel like a tax/penalty for those who cannot adjust*" (T_2) and that "*price signals should correspond to the elasticity of the users*" (R_3), a sentiment echoed by other experts (R_9, T_11, R_15) and the literature (Wang et al., 2023). Other experts, primarily from the TSO side, challenged this view by saying that every user should be charged according to their consumption to ensure cost-reflectivity

(P_1, T_7, T_11). Therefore, time-based signals need to balance two key fairness perspectives: cost reflectivity/causation and non-discrimination/equity (P_10). The experts identified multiple solutions to resolve this trade-off, such as voluntary participation in signals via contracts, stronger signals for more flexible users or bill support for poor households (T_2, R_9, T_10, T_11, R_13, R_15), which aligns with Winther and Sundet (2023) proposal to make signals voluntary or selective. Interviewees also mentioned that time-based signals should be tailored to users' ability to understand these signals, therefore providing more complex signals to generation or large industrials compared to households (R_3, T_14, R_15). The question remains, however, about what the minimum signal provided to all users should be (R_13, R_15). Moreover, the DSO/TSO split reduces transmission tariff signals' impact since they are often pooled and billed by the DSO, meaning that consumers' flexibility doesn't necessarily result in a direct bill reduction (T_6, T_14). On that front, one expert pointed to the potential role of energy suppliers to play in managing signal complexity for households, through smart appliances or batteries, therefore keeping simple bills for households while creating demand flexibility (R_15).

More fundamentally, some participants question the total value and flexibility that can be generated with market-driven signals (T_6, T_7, P_8, R_9). For instance, time-based signals could simply shift peak load rather than addressing it (T_7). Household habits would also require strong price signals to effectively drive change, which would create discrimination (T_10). There is also a lot of uncertainty regarding the impact of signals on cost recovery, which adds to the complexity (P_8, R_9). This value also depends on the status of the network, as developing grids can benefit more from such flexibility (P_8, T_11).

To conclude, these experts expressed a preference towards more complex and user-tailored time-based signals with a restricted adoption of locational signals (T_10, T_11, T_14, R_15). Whilst the literature discussion is centred on debating the best sort of time-of-use signals, the experts pointed towards adjusting the complexity of signals (frequency of price changes, number of pricing components, …) based on users and their preferences and highlight a role to play for DSO and energy retailers in unlocking households' flexibility.

4.3. Further alignment between TSO remuneration and transmission tariff policies could unlock value in congestion management, innovation and anticipatory investment

The experts agreed that both tariff and TSO remuneration policies aim for the same objective: an efficient and fair development of the grid. However, they noted that these are distinct tools with specific purposes and influence different types of decisions, therefore limiting the overall coordination potential. For instance, network signals do not help to identify which grid solutions to employ to address demand needs, such as between building interconnections or reinforcing national lines (P_1, T_11). Nevertheless, interviewees confirmed that there is potential for further policy alignment, particularly for congestion management, innovation and anticipatory investments. This policy complementarity has so far been neglected by the literature, despite its potential for more efficient grid developments.

4.4. Renewables and congestion management investment require both remuneration and transmission tariff signals and incentives for efficient grid development

The majority of experts asserted that congestion management and renewables roll-out, such as batteries, PV or smart grids, could be efficiently guided and supported by coordinated tariff signals and TSO remuneration incentives (T_2, R_3, R_4, T_5, T_6, T_7, P_8, R_9). For instance, prosumers' tariffs and TSO incentives could incentivise solar panels or batteries development either at household- or industrial-scale, depending on what is most efficient for system (T_6, T_7), in line with the suggestion of Gautier et al. (2021) and Askeland and Korpas (2019). For instance, locational- and time-based tariff signals, complemented with TSO incentives on grid utilisation and congestion management, could support the development of batteries or solar on old generation sites or directly on-site industrial plants, thereby improving grid utilisation and reducing congestion (R_4, T_14). More broadly, this would mean developing behind-the-meter tariffs to ensure that the right elements are built in the right place (R_13).

The experts went on to argue that implicit demand management via market signals should be used "*as much as possible*" to limit the need for explicit demand response, such as batteries, and that TSOs should be incentivised to leverage this implicit demand management (R_3, T_14). On this front, the development of flexibility sharing pools that incentivise both grid users and TSOs to build congestion management capacity could be a powerful policy alignment mechanism (P_8, T_11, T_14). Similarly, an expert pointed out that we should rely on the balancing service market and remove the barriers to entry for all users (R_13). TSOs can also be incentivised to develop flexible contract agreements, improving the utilisation of the grid and reducing tariffs for users (R_15). Lastly, one participant added that TSOs typically negotiate congestion management tariffs based on their congestion remuneration as a maximum ceiling, while it should be based on the societal benefit that this congestion management creates (R_3).

4.5. Broadening the remit of TSOs together with greater private sector participation in innovation could spark further efficiency and grid futureproofing

The risks involved and the lack of NRA's understanding of which innovations to prioritise result in limited innovation investment by TSOs (R_4, T_5, T_11, R_12). To address this challenge, experts suggested that policies should jointly increase targeted TSO innovation incentives, improve innovation cost-recovery via transmission tariff policy changes and increase private players' participation in innovation to derisk investment and stimulate innovation (T_2, R_3, T_5, T_6, T_7, R_9). Such policies could take the form of innovation benefit-sharing schemes and participative pilot projects (R_3). NRAs could also create free technology zones where private innovations can be tested with discounted tariffs (R_15).

Other experts also noted the potential of enlarging the remit of TSOs' activities to support the development and orchestration of smart grids, via investment incentives and dedicated market tariff signals through smart metering and participation discounts (T_5, T_6, P_8, T_10, T_11, R_12, R_13, R_15). While such development is believed to increase grid efficiency, other TSO experts suggested nuance is required: "*It is not efficient for the TSO as it would need to build up the transmission infrastructure as a backup anyway. […] TSOs need to act as insurance since they are the ones responsible for the supply reliability*" (T_7) and "*there is a lot of societal value in grid development that should not be neglected*" (T_11). It also remains an implementation challenge, particularly when it comes to the coordination between DSO and TSO (P_8, R_9, T_10, R_13, T_14). On this front, one expert added that the split between TSO and DSO is a legacy, and a single larger operator could orchestrate the increasingly complex balancing across different voltage levels (R_13).

4.6. Anticipatory investments would benefit from clearer guidelines on project identification & cost recovery

Regarding anticipatory investments, multiple experts have pointed out that the "*problem has become [more] prominent because of the magnitude, cost and volume of the investments, but the problem has always been there*" (P_1), echoed by others (T_2, R_3, P_8). The experts also pointed out that *"electrification is a clear trend that makes the risk of overdimensioning much lower now"* (R_3) and that if there are supply constraints and no market cooling perspectives, "we should always choose bigger when we can" (R_3, T_7, R_9). Participants also observed that the risk and cost of overbuilding in this context is not as high as the shadow

cost of not connecting users (T_7, R_13). Furthermore, grid lines have a much longer lifetime than generation and storage technologies, which bear uncertainty on which will emerge as winning. There is thus potential for NRAs to coordinate TSOs' remuneration incentives for anticipatory investments and tariff signals or discounts to incentivise users to use the future transmission lines (T_7, R_9, R_13, R_15). Nevertheless, some experts cautioned against excessive anticipatory investment, noting that excessively high tariffs could deter users, reduce industrial competitiveness and hinder TSOs' cost recovery (R_4, T_7, P_8). The intergenerational justice aspect is also an area of disagreement among experts. For some: "*future generations will benefit more from these infrastructures and should therefore pay more*" (P_9), while for others: "*current users will likely continue to benefit from these infrastructures in the future*" (T_10). To address these concerns, NRAs should provide TSO remuneration incentives on grid capacity utilisation and design tariff policies to ensure gradual cost recovery, potentially using government lending to flatten the amortisation (P_8, T_11, R_13).

5. Conclusions and policy implications

TSO remuneration and transmission tariff policies are undergoing significant change, driven by policy-makers' desire to better support electrification and the efficient rollout of renewables at the same time as limiting the burden on consumers. Over the last decade, they have evolved towards TOTEX- and incentive-based remuneration schemes for TSOs, as well as capacity- and signal-based tariffs for users. While these reforms undoubtedly confer improvements, efficiency and fairness challenges remain. Challenges include regulators setting conflicting policies and objectives, a lack of support for investments that anticipate future needs, a lack of innovation, discrimination against users who are unable to respond to market signals and a lack of cost reflectivity for users who pay for investments from which they will not benefit.

Despite addressing the same underlying objective of fair and efficient grid development, we find that TSO remuneration incentives and transmission tariff policies, NRAs, are most often studied and designed in isolation. The experts we interviewed, in contrast, emphasised that a small number of large, clearly targeted incentives is more effective than a broad portfolio of generic, overlapping ones.

We identify four key areas where joint tariff and TSO remuneration policy making would likely material benefits: i) *congestion management*, ii) *investment in generation and storage*, iii) *innovation*, and iv) *anticipatory investment*. For congestion management, NRAs could seek complementarity between their TSO incentives for the development of demand response, such as batteries, and their tariff signals to support users' demand flexibility. This bilateral support could be operationalised via a single balancing market, where both users and TSOs can be rewarded. Similarly, energy generation and battery investments could be supported through TSO incentives for capacity development, while tariff signals would steer this capacity development towards areas where transmission capacity is available or where local storage is needed. For innovation, the development of coordinated policies by NRAs could take the form of benefit-sharing mechanisms where the private sector and TSOs jointly fund, develop and share the benefits of innovations. For some experts, the development of smart and decentralised grids is another grid efficiency lever which could be orchestrated by NRAs through complementary TSO remuneration incentives and user transmission tariffs. Lastly, project-specific TSO remuneration incentives could be paired with tariff signals that encourage users to connect to and use anticipatory infrastructure. This pairing addresses both the risk borne by investors and the cost reflectivity concerns faced by current users.

Our analysis also highlights the trade-off between efficiency and fairness faced by NRAs in developing policies. While transmission tariff signals are central to promoting more efficient grid use and improving the cost reflectivity of tariffs, they can also discriminate against users unable to respond to these signals. Most interviewees believed that tariff signals should be adapted to users' "*capacity to understand and act*". In practice, this means generators, large industrials, and opt-in users would thus face more complex signals than the default signals applied to households. While much of the literature emphasises *"which signal is best,"* this research underscores instead that the key question is *"which signal is appropriate for which user,"* given heterogeneous capabilities and constraints of different users.

Faced with this trade-off between efficiency and fairness, the development of tariff signal 'archetypes' could provide a practical way to enhance granularity allowing different user groups to be targeted while avoiding the complexity of personalised signals. These archetypes would need to be designed by NRAs to provide tariff signals for different user profiles, such as dynamic pricing for industrials and day/night tariffs for households. Likewise, offering tariff discounts to users is considered fair as long as their participation enhances grid efficiency, such as reduced congestion or increased utilisation.

In practice, we suggest aligning TSO remuneration incentives with the system's most pressing needs, such as congestion management, connection backlogs, or integration of renewables, while maintaining minimum performance standards on other dimensions through light incentives or penalties. This focus is seen as key to addressing system needs, since generic and diverse portfolios of TSO remuneration incentives are seen as conflicting and suboptimal.

5.1. Recommendations for policymakers

This research has several implications for TSO remuneration and transmission tariff policies set by National Regulatory Agencies.

First, governments and NRAs should clearly and explicitly state their main policy objectives, and these should be in line with the system's most pressing needs. While objectives can evolve and be reviewed regularly, this focus is essential for internal consistency across policy instruments and for predictable expectations among market participants.

To support the realisation of key objectives, NRAs should seek to simplify their TSO remuneration incentives schemes to fewer but larger incentives, while non-priority performance dimensions would remain influenced by NRAs via light-touch incentives or penalties in case of poor performance. TSO remuneration policies and transmission tariff policies should be jointly designed by NRAs, sending signals that stimulate users to connect and use the grid in line with the policy objective in place. To prevent undue discrimination and unfairness, NRAs should implement different levels of signal complexity based on users' profiles, with the option to always opt for more complex signals for users willing and able to respond. NRAs should also facilitate tariff pass-through from TSOs to DSOs and establish governance arrangements that enable retailers to integrate system signals into retail offerings. These signal archetypes should be reviewed frequently to ensure their effectiveness and gradually increased in complexity over time. This approach creates additional flexibility while giving users sufficient time to adapt and avoiding discrimination among users.

5.2. Recommendations for future research

We believe three avenues for future research stand out. First, the identification of user-specific tariff 'archetypes' or signals remains largely unexplored and would benefit from both quantitative modelling and user-side empirical work. Second, the coordination potential between remuneration and tariff policies deserves detailed mechanism design work, ideally including quantification of efficiency gains relative to siloed policy approaches. Third, the question of whether the current TSO/DSO split optimally serves the coordination requirements of decentralised, high-renewables, grids merits dedicated empirical investigation. Quantitative validation of the policy recommendations advanced here, through grid modelling, regulatory impact assessment, or natural experiments arising from ongoing reforms would also be a

valuable complement to the qualitative insights generated by this study.

CRediT authorship contribution statement

Sam Vandezande: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Richard Green:** Supervision, Writing – review & editing. **Raphael Slade:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

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Data availability

Data will be made available on request.

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