ENSURE-Background paper

HOW CAN REGULATION FOSTER INNOVATION IN THE ELECTRICITY GRID?

Findings from case studies in Great Britain and Italy

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AUTHORS

Maximilian Bauerdorf
Researcher

Prof. Dr. Dierk Bauknecht
Gruppenleiter Energiesystemanalyse & Regulierung / Senior Researcher

Moritz Vogel
Senior Researcher

This paper is based on the Master Thesis conducted by Maximilian Bauerdorf at the Albert-Ludwigs-University of Freiburg in 2023.

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Öko-Institut e.V. / Oeko-Institut e.V.

info@oeko.de www.oeko.de

Geschäftsstelle Freiburg / Freiburg Head Office Postfach / P.O. Box 17 71
79017 Freiburg. Deutschland / Germany
Tel.: +49 761 45295-0

Büro Darmstadt / Darmstadt Office Rheinstraße 95
64295 Darmstadt.
Deutschland / Germany Tel.: +49 6151 8191-0

Büro Berlin / Berlin Office Borkumstraße 2
13189 Berlin. Deutschland / Germany Tel.: +49 30 405085-0

Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

EXECUTIVE SUMMARY

Integrating renewable energy sources (RES) into the electricity grid is crucial for decarbonization. However, increasing renewable energy integration challenges the stability and reliability of lower voltage networks managed by distribution system operators (DSOs). Simply expanding networks alone is not sufficient; DSOs need to innovate for successful RES integration. Current regulatory frameworks fall short in promoting such innovations. Therefore, national regulatory agencies (NRAs) should actively foster DSOinnovation through economic and non-economic mechanisms. To compile experiences of economic and non-economic regulatory mechanisms and their ability to foster DSO innovation, case studies in Great Britain and Italy were conducted: regulatory frameworks were analyzed, and experts from DSOs, NRAs, and academia were interviewed.

We must consider that DSOs are primarily companies that are concerned with maximizing their profit. Thus, economic mechanisms are particularly attractive in incentivizing DSOs to innovate. Economic mechanisms either provide funds for research, development, and demonstration activities (RD&D),or reward innovative behavior through higher revenues. Enabling DSOs to invest in RD&D provides an opportunity for them to profit from more innovative solutions, which are required to solve grid challenges. Cost pass-through mechanisms that allow the recovery of RD&D costs were identified as essential for DSO innovations. British stakeholders highlighted that mechanisms such as the Network Innovation Allowance (NIA) and the Strategic Innovation Fund (SIF), are highly effective in fostering innovation. These mechanisms provide DSOs with dedicated funding for RD&D, that is exempt from the efficiency pressures of the revenue cap. To ensure that funding is used for promising RD&D activities, reporting and monitoring mechanisms were identified as necessary.
Beyond that, DSOs need to be able to generate extra profits through innovative practices. Settingadditional revenue allowances that are linked to predefined output-goals, has been identified as a promising approach for encouraging DSOs to innovate. The opportunity to earn additional revenues addresses the core economic interests of DSOs in maximizing their profits, thus incentivizing them to innovate for additional profit.

Insights from the interview show that economic incentives are only one side of the coin. Practical experience suggests, that non-economic mechanisms are necessary to guide DSOs in their innovative behavior and to enable their innovative abilities through cooperation and knowledge sharing. In Italy and Great Britain, non-economic instruments strongly influence the direction of DSO RD&D, as the challenges the firms need to address are predefined through regulatory innovation trials RITs) and regulatorysandboxes. As opposed to waiting for the DSO to innovate, NRAs might have to address the DSO directly. However, such mechanisms were criticized for their lack of funding and limited duration.

The interview participants also emphasized the importance of institutional factors in fostering DSOinnovation. In particular, they identifiedthe innovation culture and the right personnel within a DSO as being a central factor for a firm's ability to innovate.

Getting the regulatory framework right is challenging and requires resources and sufficiently qualified personnel. Monitoring RD&D costs passed through, setting output-goals to raise the revenue caps, as well as coordinating RITs, requires a thorough understanding of the DSOs tasks and knowledge about the complex challenges posed by the integration of RES. This means NRAs will need additional competent staff, which will result in higher costs. To finance this, the use of public funds must be considered.

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1 INTRODUCTION AND OVERVIEW

In order to mitigate the effects of climate change and to reach the targets of the Paris Agreement to limit the temperature increase to 1.5°C it is a global imperative to decarbonize the electricity sector through integration of renewable energy sources (RES) (Intergovernmental Panel on Climate Change 2022). RES are mainly being connected to lower voltage distribution networks which are owned and managed by distribution system operators (DSOs) (Koutsoukis et al. 2021). The integration of RES into the regulated natural monopoly of distribution networks challenges the grid's stability and reliability (Brunekreeft et al. 2020). To properly integrate RES into the electricity networks, relying on available technology, like expanding the networks, is not sufficient, it is necessary for DSOs to innovate and to find new approaches to grid operation (Jamasb et al. 2020). Since the era of liberalization, electricity network regulation has had trouble in facilitating innovation, and current investment levels through network companies are inadequate in addressing the tasks ahead (Jamasb et al. 2020). The International Renewable Energy Agency (2019) and scientists such as Poudineh et al. (2017) stress the importance of regulation in incentivizing DSOs to innovate.

Regulation of electricity networks can be roughly distinguished into cost-based and price-based regulation. Cost-based regulation sets prices based on the total costs a company incurs, repaying the DSO the costs it incurred to deliver its services and granting it a rate of return on its capital (Laffont and Tirole 1993). Price-based regulation does not directly link the tariffs a customer has to pay to the DSO's actual costs but replicates the incentivizing factors found in competitive markets that are missing in cost- based regulation; the concept is therefore also referred to as incentive regulation (Bauknecht 2011). As the revenue (price) cap is set ex-ante, DSOs have an incentive to lower costs and to become more efficient as extra profits made can be kept, but not necessarily to innovate (Rious and Rossetto 2018b; Bauknecht 2011).

Innovation in this context refers to research, development and demonstration (RD&D) stages in companies that result in process and product innovations, following Tidd et al. (2005). Process innovations can refer to automation processes in electricity distribution to better manage RES integration (Kreusel et al. 2021). Product innovations include electricity storage innovations, such as large-scale batteries, helping to shift electricity loads on the grid (International Renewable Energy Agency 2019).

Regulatory mechanisms to foster innovation can be economic and non-economic (Jamasb and Pollitt 2015). Economic mechanisms include cost- and price-based approaches (Laffont and Tirole 1993) or, correspondingly, input- and output-based mechanisms (Bauknecht 2011). Non-economic mechanisms include regulatory sandboxes and regulatory innovation trials (Bauknecht et al. 2021).

Input-based mechanisms give the DSO cost security for innovation-related expenditure. Mechanisms are the following:

- *RD&D cost pass-through*:
  Via a budget reserved for RD&D, the DSO can pass-through innovation related costs to its customers, excluding the costs from efficiency measures.

- *RD&D capitalization*:
  By allowing the DSO to add innovation related capital expenditures to its regulatory asset base, the DSO can earn an extra return. RD&D related costs are treated as capital expenditure (CAPEX).

Output-based mechanisms motivate the DSO to innovate and incentivize the DSO to excel in its performance as only successful innovations pay off.

Mechanisms are the following:

- *Additional revenue allowances:*
  By setting output-goals for the DSO to reach and by connecting their fulfilment to an increase or a decrease of the revenue caps, the DSO is incentivized to successfully innovate.

- *Extending the regulatory period:*
  An extension of the regulatory period allows the DSO to profit longer from successful innovations.

Non-economic mechanisms address the complexity of the energy transition and go beyond the economic regulatory formulas, understanding regulation as a two-way communication between the NRA and the DSO (Bauknecht et al. 2019; Bauknecht et al. 2021).

- *Regulatory sandboxes:*
  The regulator temporarily derogates current regulation to enable the DSO to test technological (product) innovations.

- *Regulatory innovation trials:*
  The regulator tests new regulatory alternatives. For this it allows spatially and temporarily limited regulatory alternatives in a real-world setting, starting from a regulatory challenge, allowing to include a broad set of perspectives aiming to create new regulatory knowledge.

2 CASE STUDIES

To gather experiences with economic and non-economic mechanisms, case studies were conducted in Great Britain and Italy. These two countries were selected due to their long experience with regulatory mechanisms that foster innovation (Bovera and Lo Schiavo 2022; Rious and Rossetto 2018b). The study covered the period from the beginning of the respective regulatory cycles up to December 31, 2023.

The research process involved two major steps. First, desk research was conducted to analyze the current regulatory frameworks in Great Britain and Italy to identify mechanisms that can potentially foster innovation. Second, interviews (n=10) were conducted with key stakeholders from the energy sector, including experts from DSOs, regulatory agencies, and research institutions from the respective countries to gather experiences with the mechanisms found. The interviews, lasting between 0:34h to 1:05h, were conducted between September and October 2023. The distribution of the interview partners varied based on their availability. The distribution of experts interviewed is depicted in table 1-1. Interview partners were anonymized.

Table 1-1: Number of experts interviewed after country and stakeholder group

Stakeholder group interviewed/ Country	Great Britain	Italy
Distribution System Operators (DSO)	2	2
National Regulatory Authority (NRA)	1	2
Researchers	2	1

Source: Öko-Institut

Next, the case study results for Great Britain and Italy will be presented. Initially, a brief overview of each case study country will be provided. This will be followed by the presentation of each country's economic and non-economic mechanisms; subsequently, experiences with these mechanisms will be discussed. Additionally, experiences with institutional factors will be presented.

2.1 Case Study Great Britain

The electricity regulator for Great Britain (GB) is the Office of Gas and Electricity Markets (Ofgem).[1] The current regulatory period is running from April 1st, 2023 until March 31st, 2028 (Ofgem 2022).The distribution network in GB has a length of around 800.000 km, it is owned and managed by six stock listed DSOs (see CEER 2023).

GB can be seen as a pioneer country in the realm of innovation and regulation (Rious & Rossetto 2018). Having liberalized its networks early on and having introduced price-based regulation in the 1990s, GB was the first country to introduce special mechanisms to foster innovation among DSOs in 2004 (Lockwood 2016; Rious and Rossetto 2018b). Ofgem expects DSO innovation to reduce overall prices and to create extra value for its customers through new products or services (Ofgem, 2020). GB has both economic and non-economic regulatory mechanisms in place to foster DSO innovation. Economic network regulation in GB is output-based, including input-based elements.

First, mechanisms in place will be laid out, then respective experiences with them will be presented.

[1] Northern Ireland has another NRA which was not subject to this study.

[2] https://smarter.energynetworks.org/

2.1.1 Economic mechanisms and experiences

Input-based mechanisms in GB

In GB, two mechanisms allow the DSO to pass RD&D costs through to grid users. These are the Network Innovation Allowance (NIA) and the Strategic Innovation Fund (SIF). With the NIA being a research budget for each DSO and the SIF being a broader innovation program that comprises more funding.

The NIA entitles every DSO to receive a certain budget which is exclusively reserved for RD&D related projects (in between £7.5m to £18m). It must be spent during the five years of the price control without prior application on a use it or lose it basis. The exact amount depends on an ex-ante evaluation by Ofgem of how and what the DSO wants to spend the allowance on. NIA is financed through network tariffs (Ofgem 2023b).

To qualify for a NIA project, it must be ensured that projects financed foster the energy transition and create benefits for consumers. Ofgem requires DSOs to spend the allowance on RD&D that comprises the use of new equipment and/or practices and wants DSOs to generate learning effects. DSOs must explain and prove to Ofgem how their processes and products are innovative and how results can be made accessible to other DSOs. Therefore, the use of the allowance must be documented, and, upon request, the precise usage of the allowance must be explained to Ofgem. DSOs are required to cooperate with each other as well as with transmission system operators (TSOs); partnerships with non-network partners are also emphasized.
Learning results and dissemination of project data from projects funded under the NIA must be sharedon the ENA Smarter Networks Portal[2]. Project progress information published must be detailed enough to a degree, that other DSOs can replicate the knowledge generated. DSOs and TSOs must jointly organize a conference in which they share knowledge and learning experiences.

Another cost pass-through mechanism is the SIF. For DSOs to obtain funding under the SIF, they must apply for a funding pot with overall £450m budget and must compete against other innovation projects and against TSOs. Innovation funded under the SIF must be in line with Ofgem's innovation vision in which Ofgem derives innovation challenges must be addressed (Ofgem 2021). Ninety percent of project costs are covered through the SIF, and the funding comes from network charges. NIA and SIF are mutually exclusive (Ofgem 2022a; 2023c).
All projects that apply for SIF funding are evaluated by an expert panel. Projects funded must address the innovation challenge, have a robust methodology, benefit consumers, and must include diverse stakeholders. To ensure projects deliver successful outcomes, application for funding is divided into three consecutive phases (Ofgem 2023c):

- In the discovery phase companies apply for RD&D funding by submitting applications for innovative solutions. Applications must include detailed methodologies, potential customer benefits, and a financing plan. They must include an innovation justification, present the possible impact of the project, and a plan on how the project can be moved into business as usual. The goal of this phase is to *"find and fund ambitious, innovative projects with the potential to accelerate the transition to net zero"* (Ofgem 2023d). The duration of this phase is a maximum of two months; the budget is limited to £150.000 per project.

- The subsequent alpha phase is dedicated to refining and evaluating various solutions developed in the discovery phase, setting the stage for any subsequent large-scale demonstration of projects. The most critical assumptions are tested in this phase, ensuring a robust foundation for future development. The duration of this phase is a maximum of six months; the budget is limited to £500k per project.

- During the beta phase the aim is to implement and assess projects on a large-scale after they successfully passed the discovery and alpha phase. The length of this phase depends on the project but is usually in between 6 and 72 months; the project budget starts at £500k.

Knowledge transfer and subsequent dissemination of the knowledge is of central relevance. SIF receivers must organize and hold an annual conference, which can be the same as for the NIA.

Beyond the SIF and the NIA, GB applies the so called slow and fast money approach to determine the DSO's revenue caps, taking capital expenditure (CAPEX) and operational expenditure (OPEX) together. This approach, also referred to as fixed-OPEX-CAPEX-share (FOCS) (Bebenburg et al. 2023), allows the addition of a share of TOTEX, the slow money, to the regulatory asset base and to be capitalized. It represents the third input-based regulatory approach applied in GB that fosters innovation.
This approach addresses the Averch-Johnson effect (Gold-Plating) (Averch 2018), as a fixed share of TOTEX is capitalized. In this way, DSOs apply a technology based on its suitability to deal with a challenge and not based on its cost characteristics. As innovative solutions often are OPEX-based, this paves the way for them.

Experiences with input-based mechanisms

Generally, stakeholders stated that SIF and NIA do foster innovation. An interviewee from Ofgem stated that NIA is so useful as it fosters DSO innovation that not necessarily results in efficiency savings, which otherwise would not be possible under the revenue cap. A British DSO interviewee stated that NIA was beneficial, enabling them to spend money on innovation they would normally not do due to a focus on minimal spending and output delivery The NRA representative shared this opinion. Positive opinions about the SIF further came from another British DSO interviewee who said that the application process for the SIF has improved in comparison to its predecessor (the so-called Low Carbon Network Fund), now being less administratively burdensome.
One DSO interviewee said that the coercive requirement to cooperate with other DSOs under the SIF is fostering innovation. On the obligation to cooperate with non-network partners, another DSO interviewee said that it made them leave their silos, which fostered innovative ideas through the input of others, including non-network firms.

Beyond the benefits that are provided by NIA and SIF, stakeholders also pointed out challenges and possible improvements of both mechanisms. A DSO interviewee mentioned that the amount of funding for both cost pass-through mechanisms was not enough and that the funding had been reduced over the years. The lack of clarity as to whether project funding will be granted under the SIF was said by the DSO interviewee to be the reason why DSOs would not apply for it in the first place. The same interviewee described it as critical that the SIF is so strict about the timescales in which innovation must be delivered, which in its opinion is contradictory when cooperating with external partners such as universities, who are working in much longer time scales. The same interviewee called for more available funding for innovation for DSOs in order to be able to master the challenges by the integration of RES.

Another, non-regulatory approach mentioned by a DSO interviewee, able to foster DSO's innovation, was public funding. It allows the passing through of RD&D costs, with the difference that costs will not be financed through network tariffs but via public funds.

Interviewees were not explicitly mentioning RD&D capitalization as part of the TOTEX approach to be relevant in fostering innovation.

Output-based mechanisms

Ofgem sets output delivery incentives (ODI) to incentivize RES integration and to improve service quality. Depending on whether a set output delivery target has been achieved or not, the ODI can adjust the DSO's revenue cap upwards or downwards. There are three broad output groups that Ofgem has set within this regulatory period that DSOs must consider (Ofgem 2022b):

1. Meeting the needs of consumers and network users,
2. maintaining a safe and resilient network,
3. delivering an environmentally sustainable network.

For example, Ofgem published a position paper (Ofgem 2019), requiring DSOs to elaborate strategies to address RES integration via more efficient use of existing networks. For this, an ODI was set up (Ofgem 2022a). Depending on an ex-post stakeholder survey, an evaluation through a performance panel of independent experts and the measurement against performance metrics, DSOs face rewards or penalties ranging from +0.32% to -0.16% on their return on regulatory equity in the first year, with adjustments ranging from +0.4% to -0.2% in subsequent years (Ofgem 2022a).

Another output-based mechanism that is applied in GB is the Business Plan Incentive (BPI). Through the BPI DSOs can be ex-ante rewarded for innovative projects in their business plans that surpass Ofgem's expectations, offering up to +2% of their revenue allowance for plans that deliver exceptional innovative ideas (Ofgem 2022b).

For example the DSO National Grid Electricity Distribution received an additional £4.6m (Ofgem 2022a) for offering "*a bespoke smart energy action plan every two years*" (ibid., p.67) to 1.2 million customers. In case of not reaching that goal over the course of the price control, the BPI has a claw back mechanism integrated, which allows this funding to be reclaimed (ibid.).

Within the current regulatory framework stakeholder engagement plays a crucial role during the DSO's preparation of business plans. Two groups, the Customer Engagement Group (CEG) and the Challenge Group (CG) are both challenging the DSO's business plans to foster efficiency and innovation. Both groups contain stakeholders who are impacted by the DSO's activity, as well as energy sector experts and consumer advocates; CEGs are formed by the DSOs, while the CG is created through Ofgem. The process allows both Ofgem and the stakeholders to directly influence the DSO to innovate and to steer the DSOs' direction of innovations.

As a third and final output-based mechanism, an increased duration (eight years) of the regulatory period was applied in the last regulatory period. This allowed DSOs to longer reap the benefits of successful innovations. However, in a decision in 2018, Ofgem reduced the length of its regulatory period from eight to five years with the change of the period in 2023 (Ofgem 2022a). Ofgem explained that although a longer duration should allow DSOs to reap the benefits of successful innovation over a longer time period, this limits Ofgem's ability to reset certain cost allowances and output goals (Ofgem 2018a).

Experiences with output-based mechanisms

Stakeholder generally stated that additional revenue allowances have a positive effect on innovative activities of DSOs. A DSO and the Ofgem interviewee highlighted the effectiveness of the incentive/penalty scheme of the Output Delivery Incentive (ODI) in promoting innovation within DSOs. The interviewees commended how setting targets that need to be reached encourages companies to innovate by mimicking competitive market behaviors.
The emphasis was set on the importance of comparable benchmarks across companies to foster innovation in achieving or surpassing these targets. This way, network operators are given a clear goal and the flexibility to innovate in how they meet these goals. Both sources agreed that output-based regulation through additional revenue allowances offers the essential space for DSOs to innovate.

A DSO interviewee emphasized the effectiveness of the stakeholder engagement process behind BPI in fostering the DSO to innovate, as it allows them to identify customers' needs and subsequently to adapt the DSOs goals to be more innovative, referring for example to enhanced connection performance. An interviewed researcher stated that the stakeholder engagement process was excellently working, improving the DSOs business plans, prioritizing the needs of stakeholders over shareholders, and fostering innovation.

The experts interviewed also pointed out challenges and room for improvement with additional revenue allowances. Critical voices came from an interviewed researcher on the evaluation of outcomes and challenges in the measurement of outputs. The researcher said it could be hard to measure if an output was met and emphasized the importance of well working indicators on the fulfilment of outputs.

Possible trade-offs regarding output-based regulation, mentioned by a DSO interviewee, occur where information asymmetries exist in favor of the DSO, such as where the DSO can deliver the goal to a much lower cost than previously expected through the NRA, exploiting the asymmetry to its favor.

A DSO interviewee called for an extension of the regulatory period, arguing that more time was necessary to innovate, especially when partnering with external actors. The source argued that more time under an extended regulatory period would allow the DSO to keep more profits and to benefit longer from innovation. This contrasts with the reduction of the regulatory period realized by Ofgem, as mentioned above.

Interviewees from research, DSOs, and the NRA all emphasized the importance of price based incentive regulation's ability to foster innovation by making the DSO strive for efficiency gains. The expert interviewed from the NRA said that innovation is driven through efficiency savings. This was further elaborated by the Ofgem representative: "Efficiency targets are a really important element as they tap into the business mindset of a network because ultimately, they are companies that have to deliver shareholder value." The interviewee from the research side supported the argument saying that innovation is best incentivized if it allows network firms to earn money. Also, one interviewee from a DSO said that efficiency incentives are central in motivating them to innovate.

2.1.2 Non-economic mechanisms and experiences

Regulatory sandboxes

Innovation Link, a unit within Ofgem, offers "a dedicated service to support businesses looking to offer innovative products and services to the energy sector" (Ofgem 2016). Their offer to innovators, which can be not only but also DSOs, comprises two approaches: Fast Frank Feedback (FFF) and the Sandbox (Brearley 2023). Both offers do not comprise funding.

Through FFF the Innovation Link offers DSOs preliminary feedback on regulatory impacts on proposed innovations, assessing novelty and consumer benefits (Ofgem 2018b). The sandbox aims to assist innovators, focusing on consumer protection and innovation value (Ofgem 2020). Innovation Link describes the sandbox as an answer to a constantly changing energy landscape, trying to allow for a removal of regulatory barriers, enabling new approaches in the sector by allowing experiments (Ofgem 2020). Sandboxes are available to all energy market participants, not only to DSOs/TSOs, addressing innovators at all levels (Ofgem 2020).

The Innovation Link provides sandboxes for two types of use cases: *trials* and *entering the market*. These are defined as follows:

- *Trials* refer to projects in an early innovation phase, in which a DSO wants to test a new service or product under real life conditions for which the regulatory rules are not clear. A trial can refer to a demonstration or a pilot project. To give clarity to innovators, Ofgem supports DSOs with advice and guidance, explaining how existing regulations affect their planned innovation. Ofgem also offers comfort to innovators through appeasement in case of concern about the violation of rules during a trial. Also, short time derogations from existing regulation are possible within trials.

- The use case *Entering the market* refers to the deployment of innovation (Ofgem 2020). In this stage, an innovator who has already developed a service or product, but who is unsure if the proposed innovation is legally practical, gets support and consultation from Innovation Link which confirms or denies the products or services' permissibility. Alternatively, if a DSO has detected a specific rule that is hindering its service or product, the sandbox can help in finding ways to relieve this rule by offering a time-limited derogation. The time-limited derogation offers the opportunity for DSOs to work under a removed regulatory hurdle temporarily. Once a derogation is granted, the DSO must report and monitor the process. Ex-post, information on the derogations must be published.

Innovation Link's work is very much characterized by its focus on consultative processes for DSOs, aiming to explain to DSOs how existing regulation can affect them. Derogations from current rules are possible, but they are not the primary focus. Knowledge production is a central aspect of the British sandboxes.

Experiences with regulatory sandboxes

Although regulatory sandboxes show great potential to foster innovation, they face different challenges the way they are currently applied in GB. This was reflected by the interviewed stakeholders.
An NRA interviewee saw the flexibility regulatory sandboxes provide as a powerful mechanism to encourage the facilitation of innovation due to their flexibility. Even though optimistic about this instrument, the NRA expert interviewed stated that only one DSO had ever asked for a sandbox once, which made the interviewee doubt to what extent DSOs have the ability to think out of the box. Indeed, only one sandbox had been granted for a DSO, for UK Power Networks on the 30th of June 2021[3]. The same interviewee said that derogations outside of Innovation Link were granted, but they were not related to innovation projects.[4]
A DSO interviewee criticized that a central problem is that there is no funding provided for sandboxes by Innovation Link, which makes it less attractive to use this mechanism. An interviewee from the research side stated to see it critical for DSOs to engage in regulatory sandboxes, describing it as burdensome as they must invest time and resources. The same interviewee addressed the fact that the innovation outcomes are very unclear for the DSO, making it further unattractive to participate and take a risk.

The NRA interviewee explained that a huge shortcoming of regulatory sandboxes is, that derogations are limited in time, making it less attractive for DSOs to engage and invest resources. Even though the NRA interviewee stressed the fact that a permanent repeal of rules is not excluded and is in theory possible.

A lack of scientific proof for the effectiveness of regulatory sandboxes is another point of critique from the scientific interviewee, who was skeptical about the mechanisms ability to foster innovation. The same interviewee said not to be aware of any robust measurement on how sandboxes could foster innovation on the grid and that the existing literature is very descriptive.
Another interviewee from the research side said that regulatory sandboxes focus only on technological innovations and failed to address the need for changing people's behavior and evolving trust between consumers and DSOs, which is far more important in light of the energy transition.

New sandbox approach in GB

As an outlook, the NRA representative gave an insight into the developments at Ofgem, being aware of the shortcomings of the current approach. The NRA interviewee said that Ofgem will define dedicated problems for the innovators – especially DSOs – to solve, giving them more clarity on where they should focus any innovative approaches by providing a clear problem set. This way, Ofgem directly approaches DSOs and does not wait any longer for them to come up with innovative ideas. This idea has materialized in the form of Ofgem's proposal for the Future Regulation Sandbox (Ofgem 2023a).

[3] See here: https://www.ofgem.gov.uk/energy-policy-and-regulation/policy-and-regulatory-programmes/innovation-link.

[4] Further derogations, not as part of innovation link and not with the central aim to foster innovation, can be found here: https://www.ofgem.gov.uk/master-publications-library?keyword=derogation&industry_sector=1610&sort=publication_date (last accessed: 08.08.2024).

2.1.3 Experiences with institutional factors

Beyond regulatory mechanisms, stakeholders also stated that other factors are important and can foster or hinder innovation.

The innovation culture within DSOs was seen by the regulatory interviewee and the DSO interviewees as a central aspect in fostering innovation. Mehralian et al. (2024) conducted a literature study on innovation culture and found that innovation culture fosters creativity, tolerates risk, and encourages knowledge sharing with colleagues. An encouraging environment motivates employees to transform this knowledge into innovative products. Following an interview partner from a DSO, innovation culture can be created by infusing network operators with practitioners who have collected experience in non-network industries and therefore provide new insights.

Engaging in partnerships with universities and non-network partners for long-term research and with suppliers is viewed as beneficial for advancing innovation, with universities preferred for their pure research motivation. As mentioned above, it was stated by a DSO that universities work in a longer time frame and thus time frames for innovation of DSOs therefore need to be rethought.
In this light, a DSO and a regulatory expert both proposed regulatory periods with different durations for different purposes, as innovation needs its own timescale. Ofgem's expert stated, that innovation and reaching net zero are long-term goals that need longer regulatory periods, whereas short term efficiency improvements are better done in a shorter time.

Also, soft influencing through regulatory position papers and the establishment of a vision through the regulator were described as encouraging innovation among DSOs by the Ofgem interviewee, leveraging peer pressure and motivating DSOs to avoid becoming industry laggards.
However, competition among network operators should not become too excessive as it might potentially hinder innovation. Ofgem's expert described innovation as a team sport, which requires cooperation, especially within decarbonization where all firms face the same challenges, suggesting that the competitive aspect of price controls might not always support innovation efforts.

2.2 Case Study Italy

The Italian electricity regulator is called Autorità di Regolazione per Energia Reti e Ambiente (ARERA). The regulatory period analyzed was the second half of their eight year long period, which covers the time span of 1.01.2020 until 31.12.2023. The Italian distribution network has a length of 1.276.000 km, and it is mainly privately owned (CEER 2023). In Italy, although there are altogether 123 DSOs, a single DSO serves 85.3% of all consumers, and together with nine other companies, the top ten DSOs serve electricity to 98.5% of all customers (ARERA 2023). Italy can be seen as a pioneer country in the application of regulatory mechanisms that foster innovation, having introduced output-based mechanisms as early as 2000 and input-based mechanisms as early as 2008 (Cambini et al. 2014; Bovera and Lo Schiavo 2022). Italy has economic and non-economic mechanisms in place to foster DSOs' innovation. Italian economic network regulation is output-based.

First, mechanisms to foster innovation will be described, then respective experiences with them will be presented.

2.2.1 Economic mechanisms and experiences

Within the investigated regulatory period, mechanisms, divided into input- and output-based mechanisms were the following.

Input-based mechanisms

There were no dedicated input-based mechanisms directly focusing on RD&D costs, neither a RD&D cost pass-through nor RD&D capitalization mechanism. However, according to an Italian DSO, the presence of these mechanisms would be helpful, as they ensure an easy recovery of costs related to innovation. In this regard, the interviewee from research said that it could be helpful to have an input-based mechanism which allows for remunerating efforts made towards basic research without putting pressure on the DSO to have successful outcomes, as is the case with output-based mechanisms.

Output-based mechanisms

Output-based mechanisms, as described by Besseghini (2023) are designed to alleviate congestion and reduce constraints on the electrical grid. These mechanisms include specific outputs, such as service quality metrics, including the frequency of electricity outages, as outlined by ARERA (2020).

DSOs are evaluated based on these metrics, with their performance directly influencing whether they must pay penalties or receive rewards. For example, title 2, articles 128 - 132 (ARERA, 2020) specify output-based incentives, specifically addressing DSOs operating in certain high voltage to medium voltage transformation sections.
The requirements for voltage control on medium voltage distribution networks specify, that medium voltage control must run at a certain complexity level which involves using under-load variators to keep the distribution networks stable. Priority is given to transformation sections with significant power flow reversal.

DSOs are incentivized to incorporate under-load tap changers into their systems through a financial reward of 250€ for each mega volt ampere (MVA) of capacity handled by their transformers (ARERA 2020). This financial incentive not only encourages DSOs to install or upgrade transformers but also motivates them to explore new technologies and more efficient processes for additional mega volt amperes to be passed through their transformers. DSOs can recoup their RD&D costs for improved transformers through increased revenue achieved by meeting specified output targets. This in turn isonly possible once the innovation output is productive, making successful innovations even more interesting for DSOs.

Experiences with output-based mechanisms

Experts interviewed from ARERA, and the DSOs were all positive when talking about output-based regulation. One ARERA interviewee explained that output-based regulation has a very long history, first introduced in 2000, being the first regulatory stimulus to foster innovation in Italy. Outputs set were first addressing the quality of supply, which, following the ARERA expert, strongly improved due to network innovation. The same interviewee said that output-based regulation is central in motivating the DSO to be more innovative.

A DSO expert interviewed stated that on the one hand, reaching outputs can be challenging, but the interviewee was sure that the potential financial incentive of fulfilling output goals, the DSO is motivated to innovate. Similarly, another DSO interviewee explained, that the price and penalty scheme introduced via output-based regulation motivated them as a DSO to innovate as it allowed to obtain an increased revenue cap.

Although outputs have a positive impact on DSO innovation, output goals should be measurable and consistent, as a DSO interviewee stated that it can be challenging to quantify the output and to verify if the desired output has been reached. One DSO expert gave the example that traditional outputs such as the number of interruptions are easy to measure, whereas more innovative outputs set, such as an increase in demand-response services in the operation of the electricity grid, are more challenging to measure for the DSO. The DSO expert interviewed emphasized the fact that outputs used in incentive regulation must be very clear for the DSO to understand to ensure goal fulfilment, saying that too quick changes in outputs can result in uncertainty. The expert from the regulatory agency argued in a similar way, saying that DSOs should be clearly informed about what outputs are relevant for them to know what to manage.

A DSO expert said that outputs should be monitored and adapted to react to external situations such as the rise of energy prices in 2022. The regulatory expert interviewed said that monitoring helps ensure quality of service on the grid, which then ensures the constant adaptation of goals. The same expert said that it is relevant to enforce penalty payments to the DSOs and that penalties must be strictly enforced, as DSOs always try to talk their way out of it.
The interviewed researcher stated that in order to set output goals, there must be competent staff employed at the NRA who are able to push the DSO out of its comfort zone and who are able to understand the complexity of the energy transition, including RES integration. The interviewee from research stated that a prerequisite for finding and employing the right staff is that the NRAs are financially equipped to pay them a competitive salary.

Nonetheless, the interviewed researcher also stated, that the pace of innovation by DSOs, which can be traced to output-based regulation, is not in line with the pace of the transformation at the distribution network level. Connected to this, the researcher interviewed said it can be a problem to identify and evaluate the right output goals to be set.

2.2.2 Non-economic mechanisms and experiences

Within the investigated regulatory period, different mechanisms could be found that can be divided into regulatory sandboxes (derogations) and regulatory innovation trials.

Regulatory sandboxes

One non-economic regulatory mechanism identified has clear characteristics of a regulatory sandbox as it describes a time-limited testing of new technical solutions towards the enhancement of service quality based on a regulatory derogation.

Areas of low service quality in the Italian electricity grid are a topic of huge concern to the regulator as, exemplarily described in article 27 (ARERA 2020), which addresses the problem of a high number of electricity outages and resulting low service quality. To reduce the number of outages, regulatory experiments in the form of derogations are possible under article 27a, allowing for higher service levels and giving space for innovation. For DSOs to be eligible for a regulatory experiment, they must provide an application in which they explain their plans and what kind of derogations they require to reach their goals which is assessed by ARERA. Experiments must end at the same time as the regulatory period. Depending on monitoring and the assessment of results, large-scale extensions of derogations are possible. All DSOs with more than 15.000 consumers are eligible (ARERA 2020).

Regulatory experiments should encourage better service quality in areas where interruptions were measured (ARERA 2020). Through derogations, the DSO can pursue an alternative path to an objective pre-defined by ARERA and can operate outside the usual regulatory requirements. Derogations refer to temporary suspensions of the reward and penalty system under output-based regulation for the time of the experiment. An alternative reward and penalty system will be put in place for the time of the experiment, which is set up by the DSO itself but checked for fulfillment by ARERA. A cap on total awards earned through a derogative measure ensures that regulatory experiments do not lead to an unjust advantage compared to operations under standard conditions.

To be eligible for a derogation, DSOs must identify the exact regulatory obstacle that is blocking innovation and deliver convincing evidence that only via a derogation they can be innovative and improve. DSOs taking part in experiments must install a reporting system with suitable indicators to regularly transmit the effects of the derogations to the NRA. In order to be approved for a derogation, DSOs must present a quality improvement target which at minimum reaches the improvement target set by ARERA. DSOs must present innovative technological solutions to the NRA that show potential to improve service quality. DSOs must define a spatially limited area for their experiment and must refer to a comparable area which can be used as a control group to ensure replicability and scalability of the experiment's results.

Experiences with regulatory sandboxes

An interviewee from ARERA said, that regulatory sandboxes do foster technological innovation. Experts from DSOs interviewed stated that sandboxes are a good way to incentivize them to innovate, with one DSO expert further elaborating that the regulatory sandbox protects the DSO from not achieving an agreed output-goal as it protects the DSO in giving a "duty free zone", emphasizing that it fosters innovation.

Regulatory Innovation Trials

The second non-economic regulatory approach in Italy is pilot regulation, which can be classified as regulatory innovation trial. Such pilot regulation in Italy is described as *"an ex-ante regulatory framework defining a transitional regime to cope with a novel issue impacting the power system"* (Wang et al. 2021, p. 50).

For example, in part III of the Italian regulatory framework for DSOs (ARERA 2020) a regulatory innovation trial was described. It addresses the renewal of distribution networks, specifically the development of networks in urban areas and the regulatory challenge to make the DSO and the apartment building management cooperate to identify the number of risers to be modernized and upgraded. Every DSO with more than 100.000 end customers must to take part. The trial ran from 1.1.2020-30.6.2023, limited to risers that were built before 1985.

The precise regulatory trial to be tested was aimed at testing the efficiency and effectiveness of the inclusion of stakeholders - apartment owners - in addressing a specific regulatory issue – cooperation of DSO and apartment owner in the modernization of risers - and to acquire knowledge and information that could later be used to improve

the regulatory framework to make DSOs commit more and better in light of future challenges (ARERA 2020). DSOs had to report to ARERA. Results of the trial have not been published to date.

Another example of pilot regulation is resolution 352/2021/R/EEL, which was set up to experiment with regulatory options for the provision of ancillary flexibility services through DSOs (ARERA 2021). Based on pilots conducted by DSOs, the future regulation on flexibility services will be adapted.

Experiences with Regulatory Innovation Trials

A DSO expert interviewed praised the collaboration with ARERA, referring to the pilot project on ancillary flexibility services, highlighting the pilot regulation's success. Another DSO expert interviewed emphasized the knowledge and experience exchange during the regulatory trials with other DSOs and with ARERA, describing it as beneficial in fostering innovation, allowing for tailored new regulation to the DSO's needs and resource availability. The same expert interviewed said that the approach is potentially available to everyone, making the possibility to influence regulation available for everyone.

The DSO interviewee described it as very positive that ARERA gave the opportunity to experiment with regulation, referring to pilots with flexibility services saying it helps *"to create an exchange [...] between your needs as DSOs and the availability of the resources, how you will do this, how much you will pay [...] something that you propose as operators"*. The DSO interviewee said that regulatory innovation trials allow DSOs to influence the regulatory frameworks according to their experience, which can then be potentially adopted as standard regulations applicable to all operators. Pilot regulation was perceived as very positive by both Italian DSO experts interviewed due to its cooperative nature between DSO and regulator, allowing for adaptation of regulation to the DSO's reality.
A potential enhancement for regulatory trials was described by one DSO expert who said that it would be good to get an even better consensus ex ante with all involved project partners, as this would allow to have clearer processes and a better distribution of tasks, allowing for even more innovation.

Experiences with regulatory sandboxes and regulatory innovation trials (not to differentiate in between)

Regarding scalability and replicability of a regulatory experiment's results, an expert from the regulatory agency interviewed mentioned that the knowledge transfer from a big DSO to smaller ones is not problematic, but from smaller to bigger DSOs it poses a challenge as smaller DSOs have less influence. For the regulator it is simply harder to detect innovation from small DSOs. Connecting to this, a DSO expert interviewed said that it was especially important that regulatory experiments are scalable and replicable so they can be extended to the next administrative level. The same expert said that one step towards better replicability and scalability could be done through the sharing of the generated knowledge. An expert interviewed from the research side said, that for experiments to be replicable and scalable, experiments should not be too specific. Also, to be sure about causalities and variables influencing each other, the interviewee recommended not to test too many innovations at once. The expert attested to regulatory experiments the ability to foster innovation in Italian DSOs. Additionally, from the DSO side it was noted that the certainty of having costs recovered would be good considering higher risks caused by regulatory experiments.

The expert interviewed from research emphasized that it was a good approach to make DSOs work on the implementation of a pre-given problem set, defined by the regulator, contrasting this to the (old) regulatory sandbox in GB where DSOs experiment on a narrow and specific case, approaching the regulator with a concept.
An expert interviewed from research also stated that it is good to give DSOs an outlook that what theyexperiment with would be leading to change, emphasizing that the regulator must show commitment and willingness to implement change.

In any case, to make a regulatory experiment work well and to get representative results, the DSO expertinterviewed stated the importance of including all the relevant stakeholders who must be given a voice

2.2.3 Experiences with institutional factors

In Italy, stakeholders stated that cooperation between DSOs, NRAs, and other relevant stakeholders is important to enable innovations by DSOs. Especially an effective collaboration between NRAs and DSOs was described as crucial by a DSO interview partner, who underlined the need for regulators to have a realistic understanding of network operations and the DSOs tasks and challenges. Beyond that, a DSO expert described partnerships with universities and non-network partners as beneficial as they allow for the introduction new ideas and the fostering of innovation within DSOs by incorporating new, disruptive perspectives into existing processes.
Also, European entities were deemed important: A DSO expert described the EU DSO entity as pivotal in promoting DSO innovation through collaborative efforts among DSOs on topics like flexibility markets, while an interviewee from ARERA saw potential in this approach but remained cautious due to its early stage and dependency on the European Commission's support.

Not only was cooperation between DSOs and other stakeholders deemed important but also company culture within DSOs was named to be very important for fostering innovation by DSO interviewees. This included on the one hand an organizational attitude that emphasizes innovation, but also a workforce, which is focused on innovation. In this regard, the necessity of suitable employees within DSOs was emphasized.
The argument was supported by an expert from academia who said that competent and skilled staff in the regulatory agencies are essential for promoting DSO innovation, capable of constantly designing new schemes that challenge DSOs and adequately evaluating company performance amid increasing complexity due to the energy transition.
The expert from research interviewed proposed public funding as a potential future method to support DSO innovation, especially when cost-based mechanisms are used. This would be a non-regulatory approach as the funding is not coming from network fees.

Experts interviewed from research and from ARERA mentioned that stricter unbundling rules might foster DSO's innovation. The expert from ARERA highlighted the competitive advantage integrated DSOs have over non-integrated ones due to potential data sharing, despite regulatory oversight. The interviewee from research stressed the growing relevance of reassessing unbundling rules in the face of emerging business models that blur traditional energy service boundaries, suggesting a review to ensure DSOs focus on efficient energy distribution without influence from affiliated generators or suppliers. This could lead to greater innovation incentives for fully unbundled DSOs in exploring alternative solutions.

3 RESULTS

Overall, fostering innovation through regulation appears to be most promising through economic mechanisms. The RD&D cost pass-through and additional revenue allowances linked to output goals were effective. Within non-economic mechanisms, RITs were described as fostering DSO innovation. Setting output goals and setting up RITs is challenging as; it requires a sound understanding of the DSOs' tasks and complex challenges that are posed by the integration of RES to the grid. This places significant demands on the NRAs' work, as understanding and designing complex regulatory mechanisms is costly and time intensive.

Cost pass-through mechanisms, such as the Network Innovation Allowance or the Strategic Innovation Fund, were also described as suitable to incentivize DSOs to innovate as, they allow DSOs to have separate funding to be spent on RD&D. Furthermore, they are exempted from the efficiency pressure under the revenue cap.

Reporting and monitoring mechanisms should be implemented to ensure funding is spent on RD&D related projects. To increase the likelihood of successful innovations, obligatory cooperation and knowledge exchange between DSOs appears to be promising mechanisms. To ensure these mechanisms are successful, the timeframes to invest in innovative solutions may need to be extended beyond the regulatory period. Beyond that, DSOs need to be able to generate profits through innovative behavior. Setting additional revenue allowances linked to pre-defined output-goals has been identified as being particularly effective in incentivizing DSOs to innovate. It appeals to the core economic interests of DSOs which is to maximize their profits, viewing innovation as a means to profits. The challenge for the DSO to find a way to successfully tackle a pre-set challenge was described as the core motive in making a DSO innovate.

Experiences with regulatory sandboxes have been mixed, yielding notable challenges as well as some promising outcomes. The participation in sandboxes was described as an economic risk if no extra funding is provided. Furthermore, issues were raised with the method itself. The time-bound characteristic of sandboxes was criticized as well as their technical focus and the lack of empirical evidence for their effectiveness in fostering innovation. One positive aspect highlighted, was that derogations from regulation allow for short term relief from efficiency pressure under the revenue cap. The British NRA has developed a targeted, active approach, guiding DSOs to solve predetermined challenges, as self-generated DSO innovations have previously fallen short.
Regulatory innovation trials (non-economic mechanisms) were described as bridging the NRA and the DSOs' needs through continuous knowledge and experience exchange. The possibility for DSOs to propose a new regulatory approach was identified as an incentive for them to innovate.

Getting the regulatory framework right is a challenge and requires resources and sufficiently qualified personnel. Setting output-goals to raise the revenue caps as well as coordinating RITs requires a thorough understanding of the DSOs' tasks, and knowledge about the complex challenges posed by the integration of RES. This means NRAs and DSOs will need additional competent staff, which will result in higher costs. To finance this, using non-regulatory funding in the form of public money, must be considered.

According to the stakeholders, institutional factors also play a role in enabling innovations through DSOs. The British and Italian experts interviewed stated that a DSO's corporate culture and its approach towards innovation are particularly important. An introduction of managers who bring fresh perspectives from non-network industries, able to provide competition-oriented insights into DSOs, was reported to foster innovation. In this context, targeted cooperation with universities and suppliers was also identified as fostering innovation, as it supports knowledge and experience exchange. To foster such cooperation and knowledge exchange in among DSOs and across Europe, the EU DSO entity is likely to play an important role.

4 CONCLUSION

DSOs are heavily influenced by the regulatory environment which has focused on efficiency gains since the liberalization of the energy sector. DSOs today are facing challenges such as RES integration, which is not properly accounted for in current incentive regulations. DSOs need a new regulatory environment that enables them to cope with the challenges of renewable integration through innovative new approaches. The case studies exemplified that NRAs can utilize economic and non-economic regulatory mechanisms to successfully enable DSOs to engage in innovative problem solving.

Overall, NRAs should treat DSOs first and foremost as what they are: companies with agoal of maximizing their profit. Economic mechanisms are particularly attractive and effective in incentivizing DSOs to innovate. These mechanisms enable DSOs to spend money on RD&D activities and make it possible to earn profits from the application of innovative solutions. Prime examples of these mechanisms can be found in Great Britain. There, cost pass-through mechanisms enable DSOs to spend money on RD&D and additional output goals which lead to financial rewards for innovative behavior.

Non-economic instruments such as regulatory sandboxes and regulatory innovation trials are important to guide DSOs in their innovative behavior and to enable their innovative abilities through cooperation and knowledge sharing. However, they need to be designed in the right way to really be attractive for DSOs and to motivate DSOs to take part. Without sufficient funding and time pressure, they can be perceived as economically risky. Regulators should carefully consider the implementation of regulatory sandboxes. Regulatory innovation trials seem more promising in this regard, as they help bridge the NRA and the DSOs' needs through continuous knowledge and experience exchange. In order to foster knowledge exchange among DSOs and across Europe, the EU DSO entity should be leveraged. Extensive experiences with non-economic regulatory mechanisms exist in Great Britain and Italy.

As the examples show, input-based and output-based mechanisms can be combined and flanked by non- economic mechanisms. The current challenges caused by decarbonization demand the application of many innovative mechanisms in order to integrate RES in an effective and efficient way. This also means that more experts must be employed at the NRAs who are able to understand the DSO's complex challenges, set output goals, orchestrate RITs and coordinate knowledge and experience exchange. To meet the anticipated increase in costs for personnel, new ways of funding must be considered.s that more experts must be employed at the NRAs who are able to understand the DSO's complex challenges, set output goals, orchestrate RITs and coordinate knowledge and experience exchange. To meet the anticipated increase in costs for personnel, new ways of funding must be considered.

BIBLIOGRAPHY

ARERA (2020): Delibera 646/2015/R/eel, Testo integrato della regolazione output-based dei servizi di distribuzione e misura dell'energia elettrica periodo di regolazione 2016-2023 in vigore dal 1° gennaio 2020. Allegato A, TIQE aggiornato. Online available at https://www.arera.it/fileadmin/allegati/docs/15/646-15alla_tiqe.pdf.

ARERA (2021): Deliberazione 352/2021/R/EEL, Progretti pilota per l'approvvigionamento di servizi ancillari locali. Online available at https://www.arera.it/fileadmin/allegati/docs/21/352-21.pdf.

ARERA (2023): Summary of the annual report to the european union agency for the cooperation of energy regulators and the european commission on the regulatory activities and fulfilment of duties of the regulatory authority for energy networks and environment. Online available at https://www.arera.it/fileadmin/EN/publications/acer_and_ec/AR_2023_-_Summary_EN.pdf.

Averch, H. A. (2018): Averch-Johnson Effect. In: *The New Palgrave Dictionary of Economics*, pp. 618–624.

Bauknecht, D. (2011): Incentive Regulation and Network Innovations. In: *EUI Working Paper RSCAS* 2. Online available at https://cadmus.eui.eu/handle/1814/15481.

Bauknecht, D.; Bischoff, T.,S.; Bizer, K.; Führ, M.; Gailhofer, P.; Heyen, D. A.; Proeger, T.; Leyen, K. von der (2019): Exploring the pathways: Regulatory experiments for sustainable development – An interdisciplinary approach. In: *ifh Working Paper* 22, pp. 1–16. Online available at https://www.econstor.eu/bitstream/10419/208382/1/1683885708.pdf.

Bauknecht, D.; Heyen, D. A.; Gailhofer, P.; Bizer, K.; Proeger, T. (2021): How to design and evaluate a Regulatory Experiment?, A Guide for Public Administrations, Oeko-Institut e.V; Georg-August- University Goettingen; University of Applied Sciences Darmstadt.

Bebenburg, C. von; Brunekreeft, G.; Burger, A. (2023): How to deal with a CAPEX-bias: fixed-OPEX- CAPEX-share (FOCS). In: *Z Energiewirtsch* 47 (1), pp. 54–63. DOI: 10.1007/s12398-023-0906-4.

Besseghini, S. (2023): Annual Report on Regulatory Activities and the State of Services, PRESENTATION BY THE CHAIRMAN. Online available at https://www.arera.it/fileadmin/EN/publications/annual_report/ra23_eng.pdf.

Bovera, F. and Lo Schiavo, L. (2022): From energy communities to sector coupling:a taxonomy for regulatory experimentation in the age of the European Green Deal. In: *Energy Policy* 171 (13), pp. 1– 16. DOI: 10.1016/j.enpol.2022.113299.

Brearley, M. (2023): Ofgem annual report and accounts 2022 to 2023, HTML, Reports, plans and updates. Chief Executive's Foreword. Online available at https://www.ofgem.gov.uk/publications/ofgem-annual-report-and-accounts-2022-2023-html.

Brunekreeft, G.; Kusznir, J.; Meyer, R.; Sawabe, M.; Hattori, T. (2020): Incentive regulation of electricity networks under large penetration of distributed energy resources – selected issues. In: *Bremen Energy Working Papers.* Online available at https://ideas.repec.org/p/bei/00bewp/0033.html.

Cambini, C.; Croce, A.; Fumagalli, E. (2014): Output-based incentive regulation in electricity distribution: Evidence from Italy. In: *Energy Economics* 45, pp. 205–216. DOI: 10.1016/j.eneco.2014.07.002.

CEER (2023): Report on Regulatory Frameworks for European Energy Networks 2022, Incentive Regulation and Benchmarking Work Stream. C22-IRB-61-03. Council of European Energy Regulators. Online available at https://www.ceer.eu/documents/104400/-/-/2a8f3739-f371-b84f-639e- 697903e54acb.

Intergovernmental Panel on Climate Change (2022): IPCC PRESS RELEASE, The evidence is clear: the time for action is now. We can halve emissions by 2030. (2022/15/PR). Online available at https://www.ipcc.ch/site/assets/uploads/2022/04/IPCC_AR6_WGIII_PressRelease_English.pdf.

International Renewable Energy Agency (2019): Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables., International Renewable Energy Agency. Online available at //media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_Landscape_2019_report.pdf?rev=754a9a1985434152ba4eaa5ef80b7225.

Jamasb, T. and Pollitt, M. G. (2015): Why and how to subsidise energy R+D: Lessons from the collapse and recovery of electricity innovation in the UK. In: *Energy Policy* 83, pp. 197–205. DOI: 10.1016/j.enpol.2015.01.041.

Jamasb, T.; Llorca, M.; Meeus, L.; Schittekatte, T. (2020): Energy Network Innovation for Green Transition: Economic Issues and Regulatory Options, Working paper. Copenhagen Business School [wp]. (Working Paper No. 15-2020; No. 18-2020CSEI). Department of Economics. Copenhagen Business School.

Koutsoukis, N. C.; Georgilakis, P. S.; Korres, G. N.; Hatziargyriou, N. D. (2021): Distribution Systems. In: Springer Handbook of Power Systems. Unter Mitarbeit von K. O. Papailiou: Springer, Singapore, pp. 1093–1129. Online available at https://link.springer.com/chapter/10.1007/978-981-32-9938-2_15.

Kreusel, J.; Moser, A.; Pletzer, T. (2021): Positionspaper zum Regulierungsrahmen für Netze in der Transformationssituation der Energiewende, ENSURE Position: Netzregulierung. (German source). Online available at https://www.kopernikus-projekte.de/lw_resource/datapool/systemfiles/elements/files/D604704AB47C0700E0537E695E86792F/live/document/2111_ENSURE_Position_Netzregulierung.pdf.

Laffont, J.-J. and Tirole, J. (1993): A theory of incentives in procurement and regulation 1. print. Cambridge, Massachusetts: MIT Press.

Lockwood, M. (2016): Creating protective space for innovation in electricity distribution networks in Great Britain: The politics of institutional change. In: *Environmental Innovation and Societal Transitions* 18, pp. 111–127. DOI: 10.1016/j.eist.2015.05.007.

Meeus, L.; Glachant, J.-M. (ed.) (2018): Electricity network regulation in the EU, The challenges ahead for transmission and distribution (Loyola de Palacio series on European energy policy). Cheltenham, UK, Northampton, MA, USA: Edward Elgar Publishing.

Mehralian, G.; Farzaneh, M.; Yousefi, N.; Haloub, R. (2024): Driving new product development performance: Intellectual captial antecedents and the moderating role of innovation culture. In: *Journal of Innovation & Knowledge* 9 (3).

Ofgem (2016): Ofgem launches Innovation Link, Press Release. Online available at https://www.ofgem.gov.uk/publications/ofgem-launches-innovation-link.

Ofgem (2018a): RIIO-2 Framework Decision, Our approach to setting price controls for GB gas and electricity networks. Ofgem. London. Online available at https://www.ofgem.gov.uk/sites/default/files/docs/2018/07/riio- 2_july_decision_document_final_300718.pdf.

Ofgem (2018b): What fast, frank feedback can and cannot offer. Online available at https://www.ofgem.gov.uk/sites/default/files/docs/2018/10/fast_frank_feedback_can_and_cant.p df.

Ofgem (2019): Position paper on Distribution System Operation: our approach and regulatory priorities. Online available athttps://www.ofgem.gov.uk/sites/default/files/docs/2019/08/position_paper_on_distribution_ system_operation.pdf.

Ofgem (2020): Energy Regulation Sandbox: Guidance for Innovators, Guidance, Office of Gas and Electricity Markets. Online available at https://www.ofgem.gov.uk/publications/energy-regulation- sandbox-guidance-innovators.

Ofgem (2021): Ofgem Innovation Vision 2021 – 2025. Online available at https://www.ofgem.gov.uk/sites/default/files/docs/2021/05/innovation_vision_2021- 2025_final_ 24may2021.pdf.

Ofgem (2022a): RIIO-ED2 Final Determinations Core Methodology Document, Decision. Online available at https://www.ofgem.gov.uk/sites/default/files/2022-11/RIIO-ED2%20Final%20Determinations%20Core%20Methodology.pdf.

Ofgem (2022b): RIIO-ED2 Final Determinations Overview document, Decision. Online available at https://www.ofgem.gov.uk/sites/default/files/2022-11/RIIO-ED2%20Final%20Determinations%20Overview%20document.pdf.

Ofgem (2023a): Proposal to introduce the Future Regulation Sandbox, Call for input. Online available at https://www.ofgem.gov.uk/sites/default/files/2023-10/Proposal%20to%20introduce%20the%20Future%20Regulation%20Sandbox%20Cfl%20final.pdf.

Ofgem (2023b): RIIO-2 NIA Governance Document: Version 3. Online available at https://smarter.energynetworks.org/media/ynrfamyk/riio-2-nia-governance-document-v3-clean- 1.pdf.

Ofgem (2023c): SIF Governance Document [version 2.1]. Online available at https://www.ofgem.gov.uk/sites/default/files/2023-02/SIF%20Governance%20Document%20v2.1%20final%20clean.pdf

Ofgem (2023d): Strategic Innovation Fund Round 2 Discovery projects approved for funding, Ofgem. Online available at https://www.ofgem.gov.uk/decision/strategic-innovation-fund-round-2- discovery-projects-approved-funding.

Rious, V. and Rossetto, N. (2018a): Continental incentive regulation. In: Meeus, L. and Glachant, J.-M. (ed.): Electricity network regulation in the EU. The challenges ahead for transmission and distribution. Cheltenham, UK, Northampton, MA, USA: Edward Elgar Publishing (Loyola de Palacio series on European energy policy), pp. 28–54. Online available at https://www.elgaronline.com/display/edcoll/9781786436085/9781786436085.00012.xml.

Rious, V. and Rossetto, N. (2018b): The British reference model. In: Meeus, L. and Glachant, J.-M. (ed.): Electricity network regulation in the EU. The challenges ahead for transmission and distribution. Cheltenham, UK, Northampton, MA, USA: Edward Elgar Publishing (Loyola de Palacio series on European energy policy).

Tidd, J.; Bessant, J. R.; Pavitt, K. (2005): Managing innovation, Integrating technological, market and organizational change Third edition. Hoboken, NJ: John Wiley & Sons, Ltd.

Wang, A.; Magnien, G.; Gianinoni, I.; Benett, L.; Ievin, R. (2021): Innovative Regulatory Approaches with Focus on Experimental Sandboxes 2.0, Casebook. Austria, Belgium, Canada, Denmark, France, Israel, Italy, Norway, Sweden and the United Kingdom; ISGAN Annex 2. An, A. (ed.). Online available at https://www.iea-isgan.org/wp-content/uploads/2021/10/Regulatory-Sandbox-2.0_For- Publication.pdf.

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Authors

Maximilian Bauerdorf,
Dierk Bauknecht,
Moritz Vogel

Publisher

Öko-Institut e.V. / Oeko-Institut e.V.
info@oeko.de www.oeko.de

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