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Performance-based regulation: Aligning incentives with clean energy outcomes

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Introduction

For many years, Europe has been in the process of moving to an integrated, liberalised and competitive electricity system to ensure that European consumers have access to affordable and secure energy. In more recent times, concerns over climate change have also made decarbonisation imperative, with the goal now firmly set to develop an electricity system that is clean as well as cost efficient. As a key part of this transition, Europe has embarked on a process of fundamentally changing its electricity networks. The need to accommodate increasing amounts of variable renewable energy resources — due mainly to decentralised generation such as wind and solar, the growth in prosumerism and increases in demand caused by electrification of the heat and transport sectors — is posing major challenges to grid operation and development that will only intensify in the years ahead. Addressing these challenges and ensuring that the energy transition can progress at the lowest cost will require network operation based on innovation and the advances in technology that are opening up new opportunities and driving down costs.

Network operators, particularly distribution system operators (DSOs), will play a pivotal role in exploiting these opportunities and facilitating a cost-effective clean energy transition. However, in order for them to do so, power sector regulation will need to change. In addition to promoting the traditional goals of ensuring security and quality of supply, regulation will need to embrace the challenges ahead and support innovation necessary to deliver the energy transition at minimum cost to consumers. Using performance-based regulation (PBR) to link the remuneration of network companies to outcomes consistent with the clean energy transition is an effective method for incentivising network companies to become active agents of this change.

Each EU Member State now has a single independent National Regulatory Authority (NRA) providing regulatory oversight of network operators, and in accordance with European legislative packages, their institutional design, powers and responsibilities have been progressively harmonised. However, due to differing national preferences and circumstances, Europe still exhibits a diverse range of regulatory approaches for electricity networks. Some focus uniquely on electricity, others oversee both the electricity and gas sectors, with yet others also having other utility sectors such as telecommunications and railways under their purview. The Third Energy Package[1] adopted in 2009 requires Member States to ensure that NRAs maintain their independence vis-à-vis industry and political interests by having appointed board members and operating under separate budgets that they use autonomously. The role of individual NRAs is also influenced by the economic resources made available to them, as some regulatory approaches are more complicated and resource intensive than others.

The new European legislation on the internal market for electricity recognises the role of performance-based network regulation in the new Electricity Regulation agreed in 2018: NRAs "may introduce performance targets in order to incentivise distribution system operators to raise efficiencies, including through energy efficiency, flexibility and the development of smart grids and intelligent metering systems, in their networks."[2] This regulation is well aligned with the recommendation of the Council of European Energy Regulators, which encourages Member States to consider output-based (i.e., performance-based) incentives in their national regulation and allow the DSOs to find optimal solutions to meet consumer expectations. Fostering flexible regulation to support least-cost decarbonisation features prominently in the council's 2019–2021 strategy.[3]

This paper reviews the current status of network regulation in Europe, the regulatory models currently employed and how they may need to change in light of changing technology and climate goals. In particular, the authors consider the role of performance-based regulation in providing the necessary regulatory framework to support the delivery of outcomes consistent with the clean energy transition as well as more traditional measures such as security and quality of supply.[4]

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[1] European Commission. *Market legislation* [Webpage]. Retrieved from https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation

[2] Article 16(8) of the Electricity Regulation adopted in 2018. Publication in the Official Journal pending as of the date of this publication.

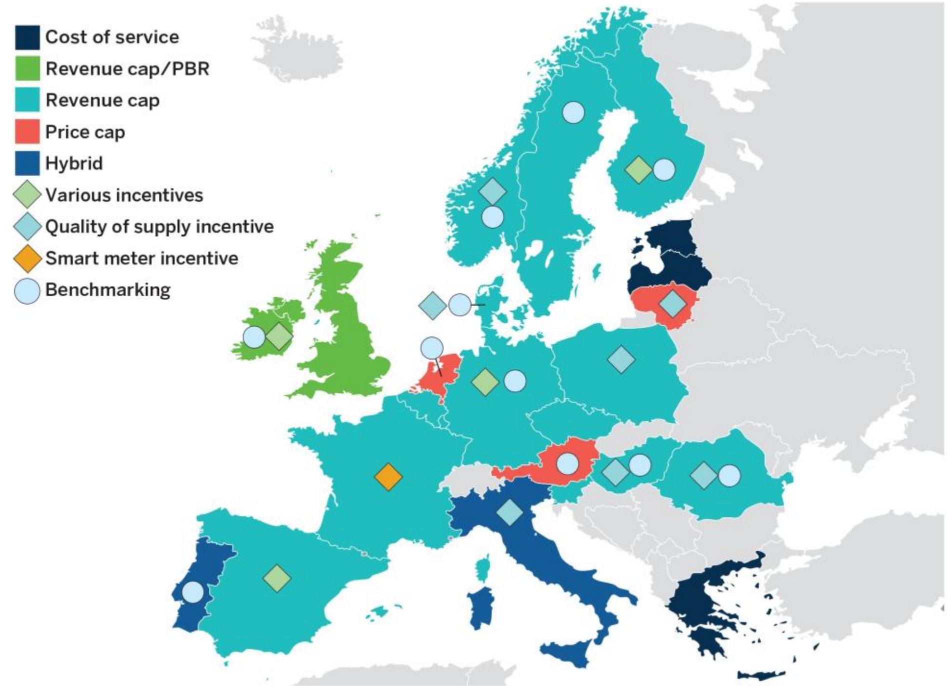
[3] Council of European Energy Regulators. (2018). *Incentives schemes for regulating distribution system operators, including for innovation: A CEER conclusions paper*. Brussels, Belgium: Author. Retrieved from https://www.ceer.eu/documents/104400/-/-/1128ea3e-cadc-ed43-dcf7-6dd40f9e446b); and Council of European Energy Regulators. (2019). *CEER's 3D strategy (2019-2021) digitalisation, decarbonisation, dynamic regulation: CEER's 3D strategy to foster European energy markets and empower consumers*. Brussels, Belgium: Author. Retrieved from https://www.ceer.eu/documents/104400/-/-/483aa2de-7785-f5bb-87fb-4b0398fcfe0b)

[4] The authors would like to acknowledge and express their appreciation to Nicolò Rossetto and Jean-Michel Glachant of the Florence School of Regulation for providing helpful insights into an earlier draft of this paper. Responsibility for the information and the views set out in this paper lies entirely with the authors.

Network regulation in Europe

As shown in Figure 1, a recent survey conducted by the Council of European Energy Regulators captured the diverse range of practices for regulating distribution service companies across Europe.[5]

Figure 1. Regulatory models for distribution system operators in Europe



Source: Council of European Energy Regulators. (2018). *Incentive schemes for regulating distribution system operators, including for innovation.*

As illustrated in Figure 1, European network regulatory models can be broadly categorised as cost-of-service or incentive regulation.[6] In reality, all models influence DSO behaviour in one way or another; in other words, all regulation is incentive regulation to some extent.

Cost-of-service or *cost-plus* regulation is arguably the oldest form of regulation and is often referred to as traditional regulation. As the name suggests, the model is based on the principle that prices are set so as to give the DSO a reasonable opportunity to recover the costs *actually* incurred in operating the network, including a fair return on capital invested. It gives it an incentive to invest, since prices are set, in part, on the basis of total investment and return on that investment. Cost-plus regulation consequently incentivises the network company to overinvest in capital expenditures.

Incentive-based regulation refers to any deviation from cost-of-service regulation that is intended to reward (or punish) specified behaviours and outcomes of the DSO. There are many variations of incentive regulation, and sometimes the vocabulary used to describe it can be

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[5] Council of European Energy Regulators. (2019). *Summary of the CEER report on regulatory frameworks for European energy networks*. Brussels, Belgium: Author. Retrieved from https://www.ceer.eu/documents/104400/6509669/C18-IRB-38-03b+Regulatory+Frameworks+Report_Summary.pdf/73e6ada0-1b78-4efd-dea6-bc820fe24d91

[6] For a discussion on incentive regulation, see Rious, V. and Rosetto, N. (2018). Continental incentive regulation. In L. Meeus and J. M. Glachant. (Eds), *Electricity network regulation in the EU* (pp. 28-51). Cheltenham, UK, and Northampton, MA: Edward Elgar Publishing. Retrieved from https://www.e-elgar.com/shop/eep/preview/book/isbn/9781786436092/

confusing. But, as a general matter, it can be broken down into these two general forms: revenue-cap and price-cap regulation. Price-cap regulation is a variation on cost-of-service regulation in which DSOs are given a limited amount of discretion to adjust their prices for productivity, inflation and other specified factors, according to regulatorily approved formulas. Being a price-based regulation, the DSO retains an incentive to deliver, which is not the case if cost and revenues are decoupled. With revenue-cap regulation, regulated utilities are motivated to reduce costs if the regulation decouples those costs from the revenues the DSO is able to earn.[7] The regulator will assume an operational efficiency gain when setting a revenue cap, and the DSO can increase its profits by achieving greater efficiency than this baseline over the price control period. The cost savings associated with increased efficiency are passed to customers in the next price control period in the form of a reduction in allowed revenue, with the regulator assuming additional efficiency gains in the new price control period.

Performance-based incentives or *performance-based regulation (PBR)* is yet another overlay on the method regulators use to calculate base prices and determine revenues (such as cost-of-service, price-cap or revenue-cap regulation). Its objective is to shift the utility's focus from inputs, such as capital expenditures for network upgrades and maintenance, to outputs, such as improved reliability, deployment of distributed energy resources (DERs), increased energy efficiency, environmental protection, customer satisfaction and protecting vulnerable consumers. By rewarding utilities with increased revenues for specified performance or, conversely, by punishing them with reduced revenues for failure to perform, PBR aims to encourage utilities to deliver on important goals of national public policy in order to maximize their profits. Regulated entities have the freedom and flexibility to decide how to deliver the defined outputs. The power system is undergoing a rapid transformation, and although some trends are clearly identifiable — new technologies, supply decentralisation, demand-side participation, electrification of new sectors and digitalisation that allows for the availability of large volumes of data and real-time control — many technology and price developments are not yet foreseeable, especially not by the regulator. PBRs, being agnostic about the way network companies deliver the outputs and, at the same time, linking revenue to their attainment, create competition for the best solutions and hence room for innovation.

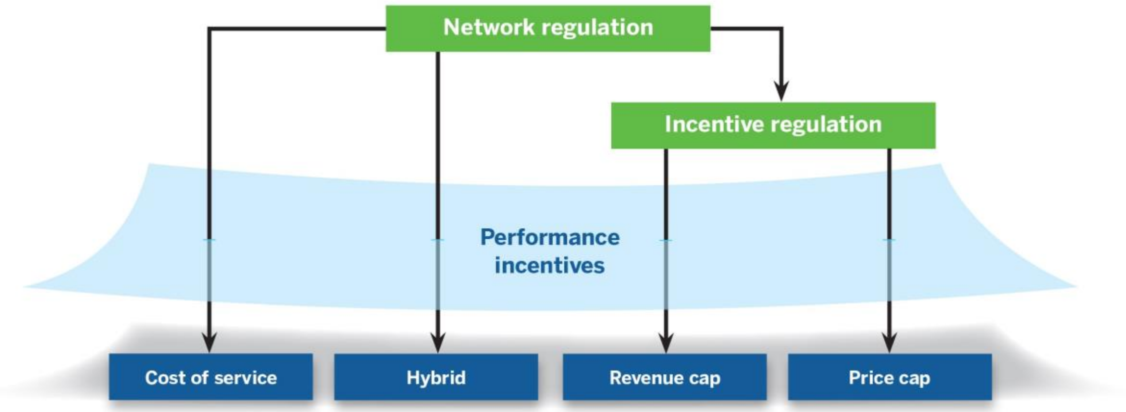
Benchmarking or *yardstick regulation* is a subset of performance-based regulation. Instead of linking revenue adjustments to the achievement of specified goals, allowed revenues are adjusted based on an index of the costs and performance of comparable utilities, for example, those in the top percentile. The utility can make additional profit by raising its performance above the target set by the regulator. In this way, the average performance of the utility community is increased over time. Yardstick regulation is hardly ever used as an exclusive tool to set the revenue of the firm but is typically restricted to certain cost items (e.g., operating expenses) or to defining the targets in PBRs. Benchmarking is favoured by Member States such as Germany, the Netherlands and Denmark, which have large numbers of network operators.

The typology of regulatory methods illustrated in Figure 2 includes a hybrid scheme that employs a cost-of-service model on capital expenditures (CAPEX) and, at the same time, a cap on operating expenditures (OPEX) that provides incentives to improve operational efficiency. Regulation can prescribe different models for different subsets of expenses; however, this combination is frequently employed in Europe. Incentive regulation schemes in Europe that are predominantly revenue-cap schemes often have some performance-based incentive elements

[7] Decoupling is the term used in the United States to describe a revenue cap that breaks the link between sales volume and revenues.

(most frequently quality of service), and sometimes the allowed revenue is linked to the performance of peers (benchmarking or yardstick competition layer) (see Figure 1). We label as PBRs — in a somewhat arbitrary manner — those regulatory regimes where output incentives are integrated more consistently and not only in an ad hoc manner. The revenue-cap model is a suitable framework for including systematic performance incentives. The revenue cap could include reasonable assumptions about efficient investment and achievable reductions in operational costs. Operational efficiencies might, for example, be achieved by setting a target level for the costs of resolving congestion, which the utility achieves though more efficient redispatch or increased network availability.

Figure 2. Interaction of performance incentives with taxonomy of utility regulation methods



As indicated above, PBR is an incentive-based framework that focuses on outputs rather than inputs. Regulation, as a general matter, is intended to impose discipline on DSOs, with regard to efficiency, customer service and similar aspects, that a competitive market would otherwise stimulate. PBR is a means for doing so and, importantly, for achieving outcomes that markets and traditional regulation would not, on their own, achieve. This regulatory method attempts to align network operator's interests with those of customers and society at large, offering the prospects of higher returns if companies deliver services at a price and quality consistent with what society and customers want.

A fundamental requirement of PBR is, therefore, to define outcomes that reflect public policy goals. One of the consequences of PBR is a need for the regulated utility, as well as the NRA, to engage with customers in order to understand what the customer really needs. From an NRA perspective, engagement is necessary to ensure that utilities identify the relevant service areas and set appropriate performance standards. From a network company's perspective, engagement is necessary to build a business plan that has the support of consumers because customer satisfaction is likely to be an important measure of success.

Finally, outputs need to be measurable, so that network companies can be held to account for delivery, and credible, with appropriate rewards and penalties for overdelivery or underdelivery. Outputs will include traditional needs and services, such as reliability and quality of supply, conditions for connection, customer satisfaction, safety and similar aspects, but can also include requirements to consult more widely in developing business plans and achieve stakeholder support for specific investments. For example, are proposed network developments supported by the customers who are expected to pay for them? Looking forward, PBR objectives should in future include outputs specifically related to the energy transition, with a focus on enabling prosumerism (consumers who both produce and consume energy), demand flexibility and energy efficiency.

Aligning incentives with public policy goals

Compared to other regulatory models, PBR provides a more direct mechanism to align the regulatory incentives imposed on regulated companies with public policy goals. Effective PBR schemes identify desired objectives and set reasonable performance metrics around them.[8]

Set clear goals

The important first steps in creating a PBR mechanism are to articulate and prioritise guiding goals and to identify what is important to stakeholders and consumers in the context of these goals. Regulators must then understand how well or how poorly conventional regulation meets those goals in a business-as-usual scenario.[9] An example could be a goal to limit increases in network tariffs by delaying the need to build new or expand existing transmission and distribution infrastructure. One way to achieve this is by increasing the utilisation of existing assets through innovation. It is important to note that the PBR goals should be long term to avoid changing direction too frequently. They should address what the regulator, network company and stakeholders want the energy generation and delivery systems to provide to consumers in five, 10 and 20 years. An important outcome of the United Kingdom's RIIO network regulation model[10] (Revenue = Incentives + Innovation + Outputs) was that DSOs and transmission system operators (TSOs) had to engage with consumers to understand their needs and gain acceptance for their business plan. Clear goals that are long term in nature, spanning a 15- to 20-year horizon or longer, can provide the overarching guiding principles for a PBR framework.

Provide directional incentives

These guiding goals are honed by more specific *directional incentives*. Directional incentives specify measurable performance criteria that allow for a clear assessment of whether the goal has been achieved or not. One measure might be, for example, the average time to connect new renewable energy installations. Once the regulator determines whether the goal has been attained, a positive or negative incentive is applied. Directional incentives linked to the public policy goal above could be focused on limiting growth in the transmission and distribution systems (e.g., limiting the growth of the distribution system circuit peaks to less than 2%

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[8] Littell, D., Kadoch, C., Baker, P., Bharvirkar, R., Dupuy, M., Hausauer, B., . . . Logan, J. (2018). *Next-generation performance-based regulation: Volume 2 (Primer — Essential elements of design and implementation)*. Lakewood, CO, and Montpelier, VT: National Renewable Energy Laboratory and Regulatory Assistance Project. Retrieved from https://www.raponline.org/knowledge-center/next-generation-performance-based-regulation-volume-2-primer-essential-elements-of-design-and-implementation/

[9] Littell, D., Kadoch, C., Baker, P., Bharvirkar, R., Dupuy, M., Hausauer, B., . . . Logan, J. (2017). *Next-generation performance-based regulation: Emphasizing utility performance to unleash power sector innovation*. Lakewood, CO, and Montpelier, VT: National Renewable Energy Laboratory and Regulatory Assistance Project. Retrieved from https://www.raponline.org/knowledge-center/next-generation-performance-based-regulation-emphasizing-utility-performance-unleash-power-sector-innovation/

[10] Ofgem. *Network regulation — the 'RIIO' model* [Webpage]. London, England: Office of Gas and Electricity Markets. Retrieved from https://www.ofgem.gov.uk/network-regulation-riio-model

annually on any one circuit) and in encouraging energy efficiency, demand response and location-specific distributed generation.

Identify clear and measurable metrics

Performance criteria are defined by various standard power system *metrics* (capacity, generated or consumed electricity, avoided CO_2) or consumer impact indicators (satisfaction, reliability, security of supply and similar ratings) to which the actual monetary incentive is linked. Metrics are the medium through which measurable performance criteria are applied. Performance metrics can be thought of as a set of specific quantifiable outputs of work that represent aspects of service that are critical to successful outcomes (e.g., quality of supply measured through the System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI)). Individual accomplishments related to each metric are scored relative to a reward scale to determine an incentive level. The reward and penalty levels are often capped, and the target level of the metrics is not a single value but a range (with a target deadband). By default, PBR compensation is symmetric with regard to performance outcomes. However, when, for example, a new performance goal is introduced, it might be more appropriate to have rewards only, whereas penalty-only schemes are better suited once acceptable levels have been achieved. Metrics can then be used individually or in combination to create a basis for an incentive reward.

Metrics work well if they can use a standard definition or, lacking that, are precisely defined. Having relevant data to evaluate how close the utility is to achieving its goals is critical to determining the effectiveness of the directional or operational incentive. The availability of information applicable to the goals and metrics is necessary for awarding incentives or assessing penalties.

This means that high-level goals cascade down into directional incentives, measurable performance criteria and, finally, metrics as illustrated in Figure 3.

Figure 3. Performance-based regulation pyramid: From goals to metrics

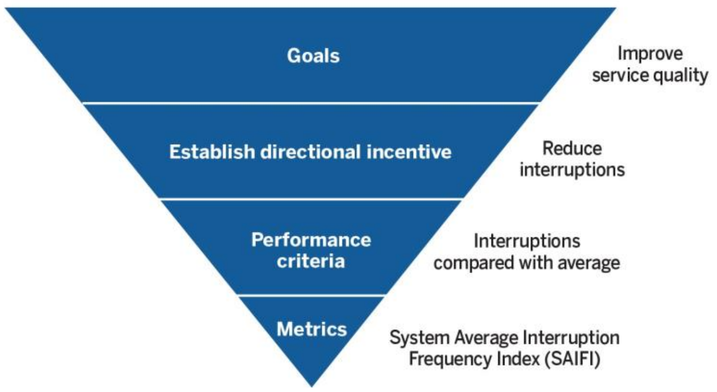

Table 1 consolidates a number of relevant policy goals and real-world examples as well as ideas for the corresponding performance criteria and metrics. It is important to realise that a given metric might be more suitable in one country and less adoptable in others.

Table 1. Policy goals, real-world examples, performance criteria and metrics

Guiding goals	Directional incentives	Measurable performance criteria	Metrics
Quality of supply/ reliability	Reduce number of supply interruptions/deviations outside statutory or operational limits	Number of supply interruptions/ deviations compared to average target	SAIFI - System Average Interruption Frequency Index SAIDI - System Average Interruption Duration Index Number of deviations
Deployment of distributed energy resources (DER)	Speed up connections of DER	Improved response time for interconnection requests	Average number of days from application to connection Failed applications
	Introduce appropriate locational signals for DER siting	Avoided network upgrade cost due to better siting	Kilometres and capacity of avoided lines
		Introduction of locational tariffs	Yes/no
	Greater DER penetration		Number of DER units, total installed DER capacity (kW-MW), DER generation (kWh-MWh)
	Faster smart meter deployment*	Number of meters put into operation	Cost per meter, deployment time and metering performance
	Faster smart grid deployment		Rated power (MW) of distributed generation connected to each medium-voltage /high-voltage primary substation providing real-time data Transformation capacity (MVA) of each primary station with improved voltage control Savings in investment
	Data transparency	Regulated access to consumer and system condition data	Number of complaints
Temporal optimisation of network use	Introduction of time-of-use network tariffs		Percentage of consumers switched to time-of-use tariffs
System efficiency	General cost efficiency	Improved net volume efficiency	Efficiency index (actual cost of a DSO compared to an average DSO)
		Improved load factor	Average/maximum utilisation
	Network loss reduction		Percentage of physical losses compared to energy delivered
Service quality		Consumer satisfaction	Number of complaints

*Where metering is under the DSO's mandate.

Policy areas ripe for PBR

Implementing non-wire solutions

PBR can be an important mechanism to enlarge the portfolio of solutions for serving an increasing and more volatile load. Rather than upgrading the existing network, non-wire solutions (NWSs) often provide a more cost-effective option. A non-wires solution is "an electricity grid investment or project that uses nontraditional transmission and distribution (T&D) solutions, such as distributed generation (DG), energy storage, energy efficiency (EE), demand response (DR), and grid software and controls, to defer or replace the need for specific equipment upgrades, such as T&D lines or transformers, by reducing load at a substation or circuit level."[11]

The traditional compensation model of earning a rate of return on capital assets is a major barrier for the spread of NWSs. DSOs need to be motivated by new revenue streams and incentives to engage in exploring these opportunities. The explicit inclusion of NWSs in network planning, investment and operation can be achieved through introducing rules (as part of PBR or stand-alone) requiring or incentivising the network companies to assess demand-side alternatives to traditional infrastructure and ensuring proper regulatory oversight of proposed investments. The principle mechanisms used in different jurisdictions include:

Rate-of-return incentive: Utilities are allowed to earn a rate of return on their avoided capital expenditures in order to make the financial incentives for non-wire measures comparable to investment in traditional network assets (TOTEX approach).

Mandatory cost-benefit test considering energy efficiency and other alternatives: Network companies can be required to explicitly consider non-wire solutions alongside supply-side options (e.g., network upgrades) in a cost-benefit analysis. In the European discourse, this is increasingly described as "Efficiency First" in network planning.

Shared net benefit incentives: The utility can earn a portion of the savings from NWAs. This is an incentive already used in several U.S. states.

So far, European Member States have only limited experience with non-wires solutions, with the UK's RIIO framework being the leading example.

NWSs in RIIO

In the past, regulation of electricity, gas and heat networks in the UK was driven by a "predict-and-provide mentality."[12] In recognition of this, Great Britain's Office of Gas and Electricity Markets (Ofgem) changed the old RPI-X framework, which calculated retail price inflation minus expected efficiency improvements. One of RIIO's objectives is to encourage network companies to "play a full role in delivering a low carbon economy and wider environmental objectives."[13] RIIO fundamentally changed the previous price formula in that it recognises operational costs in a similar fashion to capital costs. This approach has been coined TOTEX and is intended to result in a shift in network companies' focus from capital investment to outcomes.

Demand-side management, including demand response and energy efficiency, can also receive support under the program's innovation funds (see textbox "RIIO on innovation" on page 11); however, in reality, UK network companies are not yet delivering demand-side solutions at scale, and it is unlikely to happen without further incentives and regulations. Thankfully, the regulator took a serious look at the role network companies can (and should) play in delivering

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[11] Navigant Research. (2017, 23 February). *Non-wires alternatives, non-traditional transmission and distribution solutions: Market drivers and barriers, business models, and global market forecasts*. Retrieved from https://www.navigantresearch.com/reports/non-wires-alternatives

[12] Strbac cited in House of Commons Energy and Climate Change Committee. (2010). *The future of Britain's electricity networks: Second report of session 2009-10*. Volume I, HC194-1. London, England: Author. Retrieved from https://publications.parliament.uk/pa/cm200910/cmselect/cmenergy/194/194.pdf

[13] Ofgem (2013, 4 March). *Price controls explained* [Fact sheet]. London, England: Author. Retrieved from https://www.ofgem.gov.uk/publications-and-updates/factsheet-price-controls-explained

end-use energy efficiency. At a high level, Ofgem committed itself to creating a level playing field for demand-side and supply-side resources. This marks an important step in the right direction.[14]

Using PBR to trigger innovation

Transitioning to a clean power system involving the connection of increasing numbers of distributed resources, combined with the decarbonisation of the heat and transport sectors, has the potential to significantly increase network investment requirements and costs under a business-as-usual scenario. Without intervention, it is estimated that the combined electrification of heat and transport could cause the peak electricity demand of a developed economy to grow as much as 1 GW per year post 2030.[15]

Rapidly increasing network costs, therefore, have the potential to undermine the energy transition. It is essential that the utilisation of existing assets is maximised and the need for additional assets is minimised through both operational and technical innovation.

Innovation in electricity networks is a particularly challenging because of the long life of network assets and regulation's traditional focus on cost efficiency. Adopting regulatory models that embrace innovation as well as cost efficiency is, therefore, a fundamental requirement for driving increases in system efficiency. Efficiency can be increased through improvements in the utilisation of existing assets and by encouraging network operators to adopt the new working practices and new technologies necessary to minimise investment requirements in the light of the challenges that will surface in the years ahead.

Advances in technology and communications are providing many opportunities for reducing or deferring the need for investment through increasing system efficiency. This is particularly true of the distribution networks, which have traditionally been designed as unidirectional, radial, tapered networks operated on a "fit-and-forget" basis with little automation or even supervisory and monitoring facilities at the medium- and lower-voltage levels. Opportunities include the use of demand-side measures to ease congestion, the use of on-load tap changers to ameliorate voltage excursions (voltage constraints often prevent the use of available thermal capacity on radial networks), more extensive supervision and automatic switching to maximise usable thermal capability, circuit monitors that allow advantage to be taken of prevailing weather conditions, fault-level limiters to allow more interconnection and the like.

Network operators can be encouraged to embrace these opportunities through innovation initiatives such as the ones in RIIO and also by assuming an increase in operational efficiency through innovation when setting allowed revenues. In other words, the revenues network operators can recover would be reduced by an amount that reflects reasonably expected cost savings brought about by innovation. An additional incentive to increase system efficiency through innovation would be to set asset utilisation targets, where additional allowed revenues would be awarded for increases in asset utilisation beyond the target.

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[14] Rosenow, J. (2018, September 6). Replacing copper with negawatts — how the UKs RIIO-2 could revolutionise network regulation. *Energy Post*. Retrieved from http://energypost.eu/replacing-copper-with-negawatts-how-the-uks-riio-2-could-revolutionise-network-regulation/

[15] Energy Networks Association. (2017). *Electricity network innovation strategy*. London, England: Author. Retrieved from http://www.energynetworks.org/assets/files/electricity/futures/network_innovation/electricity_network_innovation_strategy/Electricity%20Network%20Innovation%20Strategy%20v3.0.pdf

RIIO on innovation

There are specific RIIO innovation schemes that encourage DSOs to try new solutions. The Network Innovation Competition provides up to 90 million pounds of funding per year to a small number of large-scale innovation and demonstration projects. The majority of proposals and approved projects focus on more efficient management of the supply infrastructure.[16]

Another avenue for supporting demand-side management is the Network Innovation Allowance, which aims to fund small-scale innovation projects. Its value is 0.5% to 1% of network companies' allowed revenues, based on the thoroughness of their innovation plans. There are some demand-side management projects that have received support under this mechanism,[17] but similar to the Network Innovation Competition, the projects are dominated by supply-side projects. Finally, the Innovation Roll-out Mechanism enables companies to apply for additional funding to roll out a proven innovation that meets defined criteria, including where it cannot fund the rollout itself.

Sweden: System efficiency

The revenue-cap regulation employed in Sweden since 2012 uses two performance criteria for pursuing the goal of efficient grid utilisation: network losses and average load factor. The approach does not prescribe ways to achieve these goals; DSOs are free to use any available management or technological innovation. The metric used for revenue adjustment is the percentage of losses in total energy distributed in the grid. Improvement in the loss ratio is shared equally between the DSO and the network users (in the form of a lower revenue cap).

The metric used to incentivise DSOs to optimise their grid utilisation is the load factor. The higher the load factor, the more evenly load is spread across the hours in the distribution network, which can potentially result in deferred network investment. The cost reduction is shared between the DSO and the network users according to the achieved load factor. DSOs can improve their revenue cap by passing on the incentive to their consumers in the form of dynamic electricity tariffs, which offer consumers lower prices in exchange for reducing their electricity demand in hours when the network is congested.

Integrating more distributed energy resources

Distributed energy resources are key to future power systems. Distributed generation (mainly solar photovoltaic (PV)), new sources of demand (electric vehicles, heat pumps), storage and changes in consumers' consumption behaviour (energy efficiency and demand response) will alter the terrain of network operators. DSOs need to be able to integrate new sources of demand and new types of generation while minimising the cost of their service and maintaining quality standards. They must also use these same distributed resources to maintain network security or

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[16] See, for example, Ofgem. (2019). *Network Innovation Competition — Funding direction for National Grid Electricity System Operator*. London, England: Office of Gas and Electricity Markets. Retrieved from https://www.ofgem.gov.uk/publications-and-updates/network-innovation-competition-funding-direction-national-grid-electricity-system-operator; and Ofgem. (2016). *Network Innovation Competition 2018 funding decisions*. London, England: Office of Gas and Electricity Markets. Retrieved from https://www.ofgem.gov.uk/publications-and-updates/network-innovation-competition-2018-funding-decisions

[17] Energy Networks Association. *ENA 'smarter networks' portal* [Webpage]. London, England: Author. Retrieved from http://www.smarternetworks.org/

run the risk of considerably increasing the cost of secure operation. What can DSOs do to keep the grid running at minimum cost? In the long run, they can reduce network investment needs with non-wires solutions: either by DER procurement (see U.S. examples[18]) or by offering locational network tariffs that would help optimise the siting of new generation and demand. In addition to the spatial aspects, time-of-use network tariffs motivate consumers to shift their consumption away from congested periods — this reduces peak demand and, in turn, the size of the location-specific network section. Hence, innovative tariffs can provide long-term signals for investment and short-term signals for network use in a way that helps to keep investment requirements under control. The revenue incentive can be linked to a requirement to offer such tariff options, similar to energy tariffs.

DSOs provide connection of consumers and producers to the network: they can either foster or hinder easy and quick access for new users.[19] The performance of network companies can either be assessed by estimating their contribution to the baseline (how much new DER would have been connected otherwise) or by surveying those who applied for network connection.

Efficient DER integration requires smart meters that provide essential information to the DSO for grid management. This is important, as the load profiles historically used for energy resource planning show only the traditional, predictable load. This, however, fails to account for consumers' behind-the-meter resources. Metering data is also essential for third-party energy service providers such as demand response aggregators. The deployment rate and cost of smart meters can be incentivised through network regulation (see example from France), as can making metering data available to the consumer and third-party providers (with consumer consent).

Finally, the "smartening" of grids (i.e., incorporating technology into the physical grid to collect real-time information on its state) is another way to make better use of the existing network that facilitates the integration of new users without (or with fewer) new wires (see example from Italy).

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[18] Littell, D., Kadoch, C., Baker, P., Bharvirkar, R., Dupuy, M., Hausauer, B., . . . Logan, J. (2018). *Next-generation performance-based regulation: Volume 3, Innovative examples from around the world*. Lakewood, CO, and Montpelier, VT: National Renewable Energy Laboratory and Regulatory Assistance Project. Retrieved from https://www.raponline.org/wp-content/uploads/2018/05/rap_next_generation_performance_based_regulation_volume3_april_2018.pdf

[19] Sometimes the network companies have the right to reject connection applications without substantial justification, and they are reluctant to approve it due to the tariff scheme that reduces their revenue, for example, behind-the-meter solar PV with annual net metering and a volumetric network tariff.

Italy: DER

The rapid expansion of intermittent and distributed generation in Italy — due to the very generous renewable support scheme for PV until 2013 — has changed the power system considerably. The renewable energy resources installed mainly in the South resulted in congestion and reverse power flows: when energy flows from the medium-voltage power grid (distribution) to the high-voltage grid (transmission), this is an indicator of a critical distribution grid condition. To facilitate network modernisation and promote innovation for increasing the grid's capacity to host distributed energy resources, the Italian regulatory authority for energy, networks and environment, ARERA, added an input-based element to the DSO regulation in 2006 for real-life demonstration pilots in critical network areas (reverse power flows for more than 1% of year).[20] Network companies could apply for a 2% extra weighted average cost of capital for 12 years based on a transparent set of criteria. Projects were selected on the basis of the unit cost of additional DG hosting capacity, coupled with the projects' replicability, feasibility, size and innovative character. The regulation was eliminated in 2015. It is seen as a transitional regulation that developed metrics for a future output-based incentive regime from 2020.

Smart meter deployment in France

Based on the positive cost-benefit analysis of large-scale smart meter rollout, the French regulator launched a special regulatory framework for incentivising smart meter rollout in 2014. The Linky project[21] aimed at a rollout to 90% of consumers on the low-voltage grid by the end of 2021. The bonus payment for the DSO (300 basis point on smart meter and IT assets) is based on three performance criteria: investment cost, timely deployment and service performance.

The metric associated with timely deployment is the number of meters that are installed and able to communicate compared to the deployment forecast. Service performance is measured by way of successful or failed meter readings, the availability of the internet portal and response time for remote service requests. Failure to meet the predefined performance results in penalties.

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[20] Lo Schiavo, L. (2018, 5 May). *Incentive regulation of smart distribution systems: From input-based demonstration to output-based deployment* [Presentation]. ARERA (Autorità di Regolazione per Energia Reti e Ambiente): Italian Regulatory Authority for Electricity Gas and Water. Retrieved from https://erranet.org/wp-content/uploads/2017/12/3_LoSchiavo_Incentive-Regulation-of-Smart-Distribution-Systems.pdf

[21] Enedis. *Linky, the communicating meter* [Webpage]. L'Electricite en Reseau: electricity distribution network for continental France. Retrieved from https://www.enedis.fr/linky-communicating-meter

Conclusions and policy recommendations

Performance-based regulation provides the opportunity to place customers at the heart of DSO planning for a decarbonised and sustainable future. By focusing on outputs that customers value most and ensuring that these are delivered in the most cost-effective fashion, the interests of consumers will be protected in the energy transition. Linking the revenue of network companies to certain well-established performance metrics, most notably SAIDI/SAIFI, is already a widespread practice in Europe, while some countries have extended the scope of metrics to pursue system efficiency or renewable deployment goals. However, other countries, notably the UK, have adopted a more extensive performance-based approach by introducing a range of outcomes, defining quantitative metrics and setting specific targets and introducing financial incentives and penalties for each. The UK also adopts a TOTEX approach to remove the capital bias that exists in traditional regulatory approaches and provides funding for innovation through shared learning. After extending the scope of its performance incentives in 2016, Italy is currently engaged in stakeholder consultations to secure an efficient new output-based regulatory paradigm from 2020.

The outputs to be incentivised though PBR regulation should be those most valued by network users as well as outputs promoting public policy goals, such as a cost-effective energy transition. Network customers will place the most value on excellent customer service, for example, speed and efficiency in dealing with complaints or issues, rapid connection, high levels of network reliability and quality of supply and increased resilience. Regulators can measure these outputs relatively easily and set targets that reflect best practices.

PBR can help realise current energy policy goals and achieve the energy transition by focusing utility attention on outputs such as RES capacity connections, increased network utilisation and the introduction of cost-reflective network tariffs.

In defining outputs and associated targets, it is important to ensure performance over the long term. This may be achieved by defining long-term goals and setting directional incentives that require, for example, year-on-year improvements in performance. Arrangements to allow expenditures designed to improve performance in subsequent price control periods, rather than in the current period, will also encourage a long-term view.

The surge of new and continuously evolving technical and market opportunities available to DSOs, coupled with network capacity investments for the secure and cost-efficient provision of grid services to all potential users, is likely to aggravate the informational asymmetry between the network companies and the regulator. Under these circumstances, output-based regulation that is agnostic towards the means of achieving the desired policy goals is more appropriate than regulators predefining inputs into it.

Previous experience with PBRs in Europe and in the United States offers some basic design principles that are worth considering when developing a PBR mechanism:[22]

Transparency and inclusivity at each step — A process of developing a new regulatory framework should be inclusive and transparent to ensure that the framework ultimately delivers what users really want. Network users and other stakeholders need to be able to

[22] Littell, D., et al., 2017.

express their preferences and feel assured that their views have been given due consideration. RIIO, for example, even provides an additional revenue allowance for credible stakeholder involvement both for the TSO and the DSOs.

DSOs and TSOs should be able to demonstrate how their business planning processes ensure that all alternatives to traditional investment in assets are considered in an objective fashion. A TOTEX approach should be considered to ensure that utilities have no commercial preference for traditional investment over operational alternatives such as demand response or energy efficiency measures. As innovation will be crucial to achieving a cost-effective energy transition, regulation should encourage utilities to embrace new technologies, digitalisation and similar developments.

Align performance benefits and rewards — When rewards and penalties are applied in close temporal proximity to utility performance, the relationship of incentive to performance is easier to assess. For instance, the application of revenue reductions immediately after a season of poor service quality provides a more tangible link of revenue to performance than one that is delayed.

Keep performance targets and metrics flexible — Performance incentives, for example, may increase reliability to the point that further increases are no longer justified. In this case, achieved improvements in performance should be assumed to be "business as usual," and incentives may need to become asymmetric, that is, penalties for reducing performance but reduced or no rewards for further increases in performance. At certain intervals, the parameters need to be assessed and recalibrated to reach the desired outcomes if the environment has changed — let alone if policy goals are changing. Note, however, that there is a trade-off between the stability and the flexibility of the regulatory regime.

Learn from experience — Modifying PBR to address operational observations is a good management practice. Even with the most careful consideration of possible impacts of performance incentives, there may be unexpected consequences. Penalties, for example, can result in excessive risk aversion by the network company and, as such, hinder the application of more risky innovative solutions. Experience gained in pilot regulations — such as the one in Italy aimed at smart grid pilots that awarded input-based rewards — can be transformed into an output-based reward mechanism.

Simple designs are good — To minimise the risk of gaming, create clear and well-defined incentives and metrics. Data collection and analysis in support of these incentives and metrics that are difficult to audit or review should be avoided, as limited access of regulators and consumers to utility data creates a risk of data manipulation.[23] Third-party experts should be used to collect, analyse and verify data when practical. In addition, simple designs make the scheme easier to understand and thus increase the likelihood that consumers, environmental advocates and policymakers themselves will support the PBR.

Incrementality can reduce regulatory risk — The size of the incentive should be matched to the desired impact in a full-fledged PBR. Outputs that provide relatively minimal societal benefit should receive correspondingly minimal incentives, while those that significantly advance the public good should be rewarded proportionately. However, gradually scaling up the size of the incentive revenue, contingent upon meeting the predefined goals, might be a good method for

[23] Littell, D., et al., 2017.

incremental increases, particularly as new PBR metrics are introduced and evaluated. Some jurisdictions may find it useful to institute a tracking metric first, which is a performance metric without any related financial incentives.

Evaluation and verification — Evaluation and verification of the outputs is an essential element of a successful PBR program. All regulation should be continuously evaluated and improved, and PBR programs are no different. It is all the more imperative to incorporate continual evaluation and verification when programs are new.

Appendix
Examples of performance-based regulation in Europe

United Kingdom

After several revisions of its price cap regime (RPI-X, which calculated retail price inflation minus expected efficiency improvements), the UK introduced a new price cap regulation that implements the first across-the-board performance incentives in Europe. As such, it is a key point of departure when discussing performance-based regulations (PBRs). The primary emphasis of the previous regime on operational efficiency resulted in distribution system operators (DSOs) becoming averse to risk and innovation. As a result, they were judged unfit to efficiently serve consumers in the changing energy landscape.[24] Although the RIIO (Revenue = Incentives + Innovation + Outputs) scheme retained a strong cost efficiency driver similar to RPI-X, it linked a considerable share of allowed revenue to the performance of DSOs on various outputs that reflect regulatory priorities. Key features of RIIO described in the following are illustrated in Figure 4.[25]

The base revenue, the major part of the allowed revenue, is set based on a forecast of all efficient costs, including both capital expenditures (CAPEX) and operating expenditures (OPEX). The total expenditure (TOTEX) approach makes the DSO indifferent to the type of solutions applied to increase efficiency. It encourages them to deliver outputs and not simply invest in the network.

The five-year cost control period was extended to eight years to lengthen the investment horizon and provide stronger incentives for revenue retainment. The regulator has now changed this back to five years for the next phase of RIIO but allows network companies to make the case for longer periods to garner allowances for certain activities.[26] DSOs are incentivized to outperform their TOTEX allowance. The closer the DSO forecasts provided in their price control business plans are to the regulators' view of efficient cost, the higher the share the DSO is permitted to keep in case of any underspending.

There are specific RIIO innovation schemes that encourage DSOs to try new solutions. The Network Innovation Allowance (NIA) is designed to fund smaller-scale research, development and demonstration projects and the Network Innovation Competition (NIC) provides funding to a small number of large-scale innovation projects.

In contrast to RPI-X, which included some performance incentive elements in an ad hoc manner, RIIO applies a suite of such incentives from the outset of the regulatory period to improve six outputs that are deemed relevant by the regulator: customer satisfaction, safety,

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[24] Mandel, B. (2014). *A primer on utility regulation in the United Kingdom: Origins, aims, and mechanics of the RIIO model*. New York, NY: Guarini Center. Retrieved from http://guarinicenter.org/wp-content/uploads/2015/01/RIIO-Issue-Brief.pdf

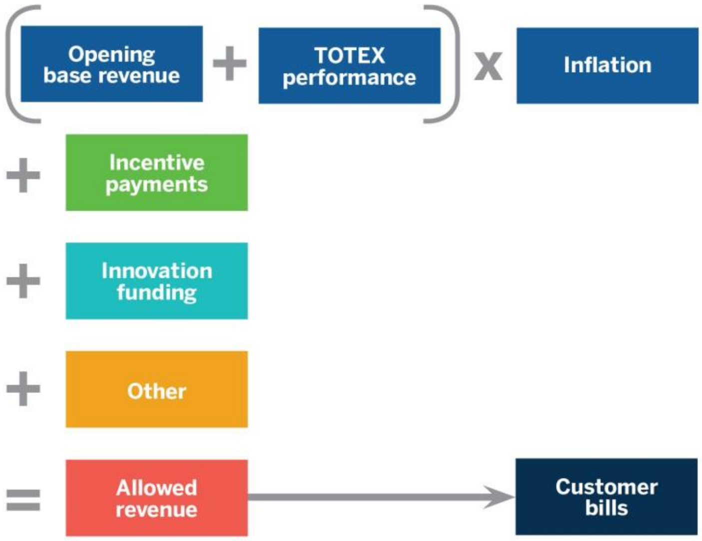
[25] Ofgem. (2017). *RIIO-ED1 annual report 2016-17*. London, England: Office of Gas and Electricity Markets. Retrieved from https://www.ofgem.gov.uk/system/files/docs/2017/12/riio-ed1_annual_report_2016-17.pdf

[26] Ofgem. (2018). *RIIO-2 framework decision*. London, England: Office of Gas and Electricity Markets. Retrieved from https://www.ofgem.gov.uk/publications-and-updates/riio-2-framework-decision

reliability, conditions for connection, environmental impact and social obligations. Performance brings either financial rewards or penalties.

Financial incentives are complemented by reputational incentives by making public the performance of the individual DSO. Utility benchmarking and scorecards identify utilities that excel and those that lag. In addition, Ofgem publishes annual reports on the performance of all network companies, including tables that compare performance output areas.

Figure 4. RIIO process for calculating allowed revenue



Source: Ofgem. (2017). *RIIO-ED1, annual report 2016-2017.*

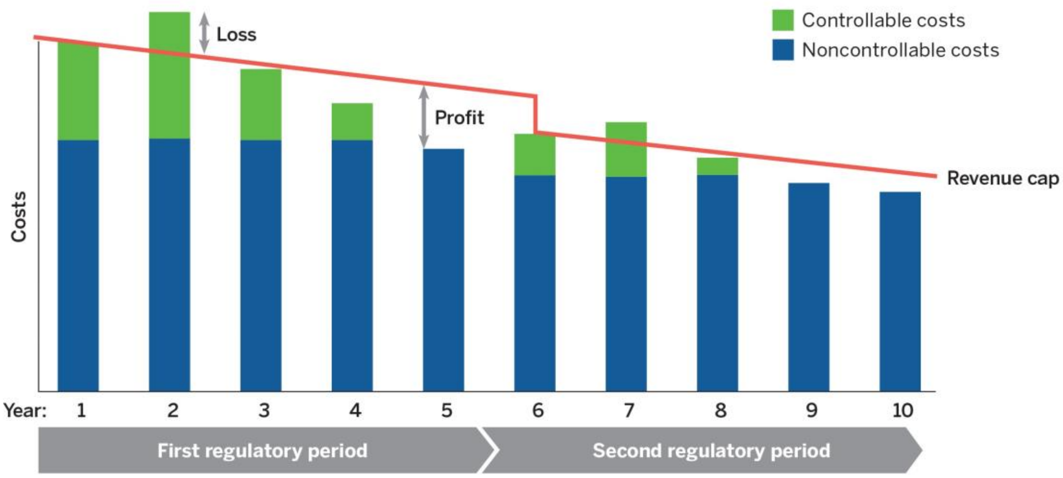
Germany

As a first step of power market liberalisation, Germany implemented a cost-plus regulation for electricity and gas network operators in 2005 to limit windfall profits. In 2009, this was replaced with an incentive regulation scheme that set the authorised revenue in the form of a revenue cap, as shown in Figure 5.[27] The predefined annual revenue is reduced gradually over the duration of the five-year regulatory period and is determined for each individual network company. Noncontrollable costs are passed through to consumers. All other costs, including both capital and operational costs, are subject to national efficiency benchmarking.[28] The benchmarks are divided into separate categories for electricity and gas, as well as for DSOs and transmission system operators (TSOs).

[27] Bundesnetzagentur (2015). *The mechanism* [Webpage]. German Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway. Retrieved from https://www.bundesnetzagentur.de/EN/Areas/Energy/Companies/GeneralInformationOnEnergyRegulation/IncentiveRegulation/Mechanism/IncebtReg_Mechanism-node.html

[28] Müller, C. (2017). Introduction to incentive regulation [Unpublished presentation]. German Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur).

Figure 5. Revenue cap mechanism in Germany



The effect of incentive-based regulation: Revenue caps and costs, and hence also the charges for network users, decrease in the long term.

Source: Bundesnetzagentur. (2015). *The mechanism.*

Benchmarking determines each network operator's relative cost efficiency compared to its peers based on statistical methods. The calculation takes into consideration, however, the different characteristics of the operator that have an impact on its costs, such as the number of metering points, the length of underground and overhead lines, annual peak load and the area served. This benchmarking only applies to larger electricity DSOs — those with over 30,000 power customers or 15,000 gas customers. Smaller ones were subject to an efficiency level of 87.5% for the first regulatory period. From the second period onward, the efficiency level is the weighted average of all efficiency levels determined in the national efficiency benchmarking for gas and electricity DSOs, respectively. Within the second period, the level was 96% for power DSOs.

Only 190 of the 880 public distribution power networks are regulated by the federal regulator, the German Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur). The 700 power distribution network operators regulated by states are much smaller on average. (The figures are not public, but a very high number fall under the rules for small distribution network operators with a standard factor for efficiency).

Consumers criticise the system, arguing that the efficiency value has a limited impact on network revenues and that it applies more to cost-efficient investments and less to the network operator's operational efficiency.[29] A public consultation on this system of competitive efficiency is currently ongoing, but major changes are not expected.

As a general rule, the regulated revenue is not adjusted within the regulatory period, but if a DSO's supply obligations change significantly, such as the need for network expansion or restructuring, it can be undertaken in the course of the regulatory period. The DSO is not required to wait until the next cost assessment. Quality of supply is safeguarded with a bonus

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[29] Bundesverband Neue Energiewirtschaft. (2016, 28 January). Netzengelte: Belastung für Energiekunden verringern, Transparenz herstellen [Network fees: Lower burden for consumers, maintain transparency] [Presentation]. Association of Energy Market Innovators. Retrieved from https://www.bne-online.de/fileadmin/bne/Dokumente/20160128_Pressegespr%C3%A4ch_bne_vzbv_Lichtblick_final.pdf; and Bundesverband Neue Energiewirtschaft. (2018, 16 August). *bne-Stellungnahme zur Konsultation zur Auswahl der Vergleichsparameter zum Effizienzvergleich* [Association of Energy Market Innovator's response to consultation to choose parameters for comparing efficiency levels]. Retrieved from https://www.bne-online.de/fileadmin/bne/Dokumente/Stellungnahmen/2018/20180816_bne_Stellungnahme_zur_Konsultation_zur_Auswahl_der_Vergleichsparameter.pdf

and penalty system. Companies at above-average quality levels receive an amount in addition to the cap, while those with comparatively poor quality levels will face a reduction in revenue. The performance criteria used to assess quality are network reliability and network performance.

France

The French regulator, Commission de Régulation de l'Énergie, decided on a special regulatory framework for incentivising smart meter rollout in 2014.[30] The decision was based on the results of the Linky pilot project run by ERDF (Électricité Réseau Distribution France, now Enedis), the single largest distribution operator in France, and the resulting cost-benefit analysis of large-scale smart meter rollout as required by the Electricity Directive of 2009 (Directive 2009/72/EC).[31] The aim of the Linky project was to deploy 35 million smart meters by the end of 2021 for consumers on the low-voltage network (≤36 kVA), representing a rollout rate of 90%. The regulator would cover the cost of meters (around 5 billion euros in total, spread over 20 years, i.e., the full period during which the benefits are expected to be realised), in exchange for the DSO bearing the risks for service quality and implementation (both in terms of cost overruns and deadlines). This special regulatory framework gives the DSO incentives to:

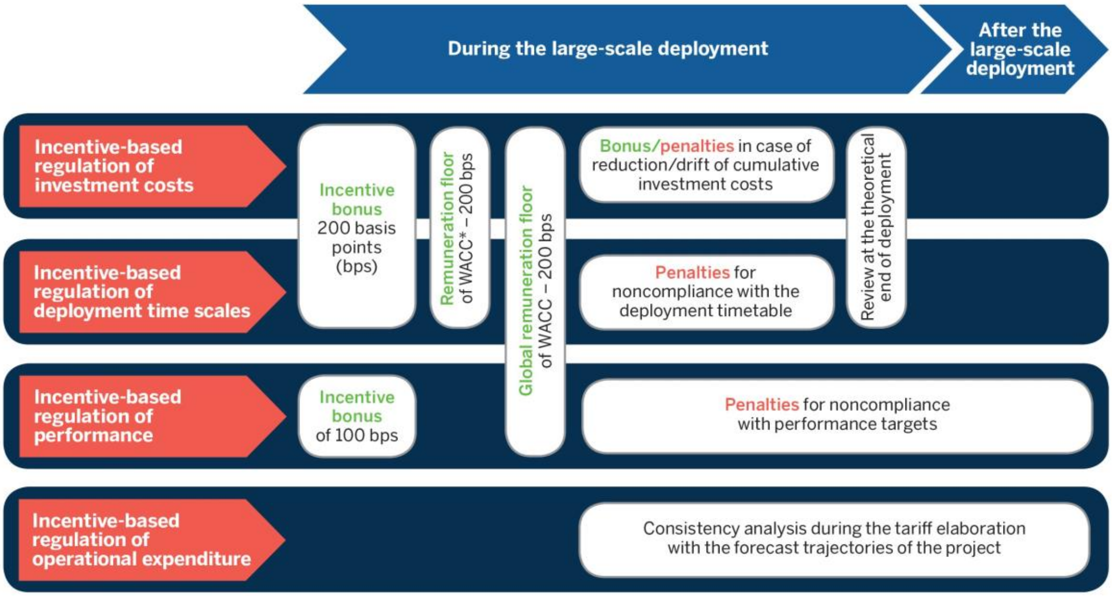
- control investment costs.
- comply with the deployment timetable.
- guarantee the performance level expected from the Linky metering system.

The cost and speed of deployment are straightforward measures for a successful rollout, but system performance is also essential for realising the benefits that can be derived from technical intervention, estimated at 1 billion euros (2014 figure at current value), and meter reading, estimated at 0.7 billion euros (2014 figure at current value). These benefits are directly proportional to the performance level of the metering system. Figure 6 shows the incentive system in more detail.

[30] Information in this section, including the graphic, is from CRE (2014, 17 July). *Decision determining the incentive-based regulatory framework for ERDF's smart metering system for low voltages (LV) ≤ 36 kVA* [English translation]. Paris, France: Commission de Régulation de l'Énergie (French energy regulatory commission). Retrieved from http://www.cre.fr/en/documents/deliberations/decision/smart-metering-system

[31] European Parliament and Council of the European Union. (2009, August 14). Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC. Official Journal of the European Union. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0072&from=en

Figure 6. Incentive-based regulation system for Linky project



*weighted average cost of capital

Source: Commission de Régulation de l'Énergie. (2014).

The incentive is a bonus of 300 basis points (bps) on assets (smart meters and related IT system): 200 bps are allocated to a joint goal concerning investment costs and deployment timescales, with another 100 bps for service performance (e.g., successful or failed meter reading, availability of internet portal, response time to remote service requests). Failure to meet the predefined performance results in penalties. The cost-related penalty is rather strict: from the first euro of additional cost, the 200-bps bonus is lost for this additional cost, and no remuneration whatsoever (not even base rate) will be applied to any further costs exceeding 105% of the preset cost level.

The deployment incentive is based on the number of meters that are installed and able to communicate compared to the forecast deployment timetable. Monitoring takes place regularly throughout deployment. The penalty is a per-unit charge (5.4 euros in 2017 increasing to 16.2 euros in 2021), multiplied by the number of meters not installed or not communicating compared to the deployment target.

The amount of penalties on investment costs and compliance with the deployment timetable, and on all three elements combined as well, is capped at 400 bps of remuneration (base rate minus 200 bps).

The incentives are set on the basis of the following evaluation scheme:

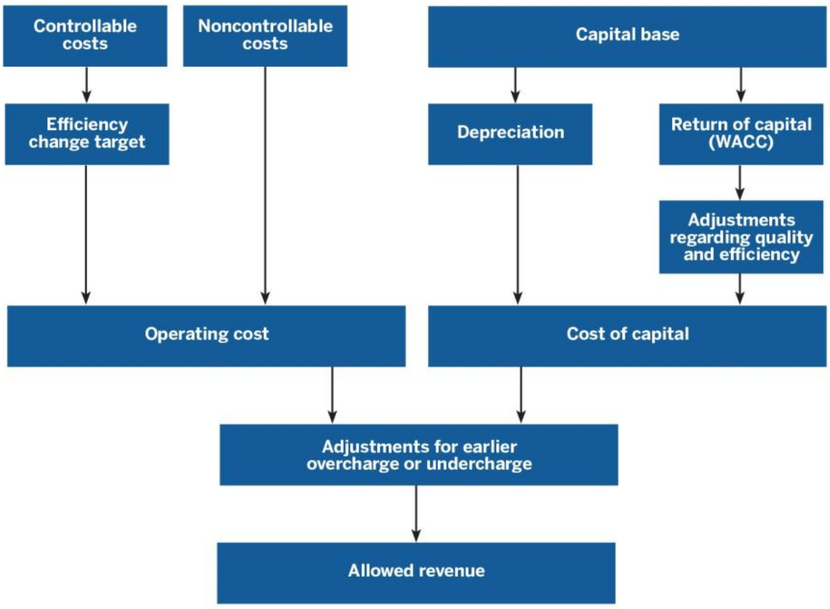
- An annual review of investment costs, with financial incentives if costs drift or reduce.
- A biennial review of compliance with the forecast deployment timetable, with penalties for late deployment.
- A final settlement of the cost and time-scale incentives at the planned end of large-scale deployment (2021) to induce Enedis to make up any delays or cost variances during the large-scale deployment phase.
- An annual review of the system's performance based on quality of service delivered from the start of the deployment phase throughout the lifetime of the project; penalties are payable if the predefined outputs are not achieved.

The regulator will specifically monitor how the DSO's operating expenses are affected by the Linky project. During each tariff year, the regulator will ensure that the trajectory of operating charges presented by Enedis is consistent with the projections for cost reductions related to meter reading, carrying out technical work and reducing line losses, and to operating the metering system.

Sweden

In response to the Energy Efficiency Directive,[32] which requires Member States to ensure that DSOs improve efficiency in network design and operation (Article 15), Sweden has introduced a new incentive for efficient grid utilisation, in addition to the existing one on continuity of supply. Sweden has applied a revenue cap regulation since 2012. DSOs must report to the regulator their costs, capital investment and current performance related to quality of supply and network utilisation. The regulator, in turn, defines the parameters needed to set the revenue cap: the efficiency factor, the depreciation, the return on capital and the two performance indices. The adjustment of the revenue cap is limited to 5%. Figure 7 illustrates the calculation method for allowed revenues.[33]

Figure 7. Components of Swedish revenue cap regulation



Source: Swedish Energy Markets Inspectorate. *Incentive scheme for efficient utilization of electricity network in Sweden.*

The two indicators used for measuring the efficiency of grid utilisation in the 2016–2019 regulatory period are (a) network losses and (b) the cost of feeding the grid and average load factor. The regulation does not prescribe the ways to achieve these goals; it is left to the discretion of the DSOs (and, by default, the technology market). As network losses increase

32 European Parliament and Council of the European Union. (2012). Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32012L0027

33 Wigenborg, G., Werther Öhling, L., Wallnerström, C. J., Grahn, E., Alvehag, K., Ström L., and Johansson, T. *Incentive scheme for efficient utilization of electricity network in Sweden*. Eskilstuna, Sweden: Swedish Energy Markets Inspectorate. Retrieved from https://www.ei.se/Documents/Publikationer/rapporter_och_pm/Rapporter%202016/Incentive_%20scheme_for_efficient_utilization.pdf

costs and, consequently, tariffs as well, an incentive to reduce them is beneficial for the users. The indicator used is the proportion of losses in relation to total energy distributed in the grid. An increase or reduction in the actual percentage, compared to the DSO's historical level of network losses, triggers and adjustment of the revenue cap. The individual baseline takes into account the differences between the structures of DSOs. The benefits are shared equally between the DSO and the network users, in the form of a lower revenue cap.

The metric used to incentivise DSOs to optimise their grid utilisation is the load factor, that is, the ratio of average and peak load measured at each interconnection point where the DSO's network connects to the higher-voltage grid. The higher the load factor, the more evenly load is spread across the hours in the distribution network. Considering that the networks are designed to serve peak load, flattening the load curve means more efficient use of the grid and, potentially, deferring investment in network infrastructure.

The cost reduction is shared between the DSO and the network users according to the achieved load factor. In the extreme case that the load factor is one (average load equals peak load), the whole amount is allotted to the DSO. DSOs can improve their revenue cap by passing on the incentive to their consumers to shave peak demand by introducing dynamic tariffs. These tariffs vary according to grid conditions and encourage consumers to reduce electricity consumption during times when the network is congested.

The DSOs and their customers will need to cooperate to change how and when consumers' use electricity so that cost savings can be shared between them. The National Regulatory Authority is monitoring the performance of DSOs with the aim of developing further ways to incentivise efficient utilisation of the power grid.

Italy

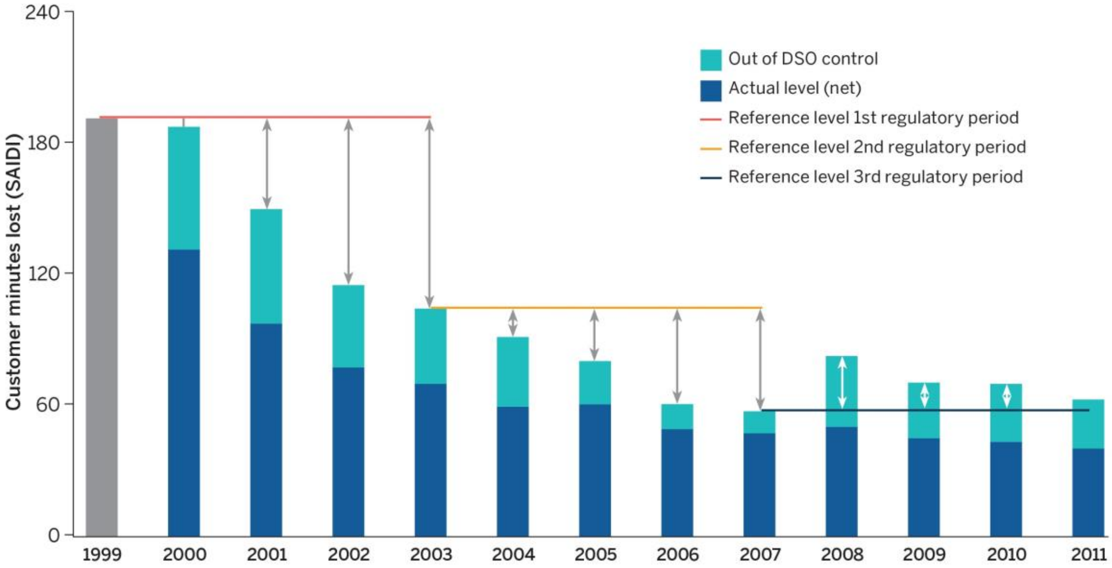
Quality of service regulation has a long history in Italy. The original price cap regime designed in 2000 has evolved into a hybrid regulation with an incentive-based scheme for operating expenditures and a cost-of-service scheme for tariff components covering capital expenditures. An output-based quality incentive was introduced from the outset for DSOs with regard to the duration and frequency of interruptions. It was extended to the TSO starting in 2004 in the form of rewards or penalties based on overperformance or underperformance in terms of energy not supplied. Targets for energy not supplied were set at the beginning of each regulatory period.

As of 2000, the metric used in the regulation was the System Average Interruption Frequency Index (SAIFI), net of exceptional events. As of 2008, the measures were SAIFI and the Momentary Average Interruption Frequency Index, net of exceptional events, for the medium-voltage and low-voltage systems. Data was collected on a per-district basis for the more than 300 districts to avoid any distortion that would be caused by averaging the figures from better- or worse-performing districts. The value of lost load was defined based on a market survey. As illustrated in Figure 8,[34] targets were set for each year of the four-year regulatory period, and tariffs were adjusted by the reward or penalty at the end of each year. The regulatory regime

[34] Lo Schiavo, L. (2016). Towards output-based regulation: A regulatory perspective based on KPIs for fostering innovation [Presentation]. ARERA (Autorità di Regolazione per Energia Reti e Ambiente): Italian Regulatory Authority for Electricity Gas and Water. Retrieved from http://hobbydocbox.com/Radio/74525812-Towards-output-based-regulation-a-regulatory-perspective-based-on-kpis-for-fostering-innovation.html

was very successful in increasing continuity of supply in general and closing the performance gap across DSOs.

Figure 8. Incentive regulation of continuity of supply, Italy, 1999-2011



Source: Lo Schiavo, L. (2016). *Towards output-based regulation: A regulatory perspective based on KPIs for fostering innovation.*

In the meantime, however, the rapid expansion of intermittent renewable energy resources and distributed generation has changed the power system considerably.[35] Renewables capacities installed mainly in the South resulted in congestion and reverse power flows: when energy flows from the medium-voltage (MV) distribution network to the high-voltage (HV) transmission network; this is an indicator of a critical distribution grid condition. Network operators identified critical areas on the basis of transformer capacity, minimum load and the generation connection request.[36]

To facilitate the connection of new renewable units and minimise the need for new network investment, the regulator (ARERA) added an input-based element to the regulation in 2006 for real-life demonstration pilots in critical network areas. These were defined as areas with reverse power flows for more than 1% of the year. Network companies could apply for a 2% extra weighted average cost of capital for 12 years based on a transparent set of criteria. Projects were selected on the basis of the unit cost of additional hosting capacity for distributed generation, coupled with the projects' replicability, feasibility, size and innovative character. As they are financed from public sources, the technological solution could not be patented, and nonproprietary communication protocols were required to minimise interface costs for network users.

With its decision 654/2015, ARERA defined a transition process to balance the objective of increased stability with the need to reform the regulatory paradigm. Based on the conviction that the hybrid approach creates a risk that companies adopt capitalisation policies to maximise their revenues, the regulator decided to introduce a TOTEX-based approach from 2020. This

[35] Wind and solar photovoltaics (PV) comprise 24.5% of the total installed capacity in 2016 compared to 1.3% in 2004. Wind and PV production made up 13.7% of the total production in 2016 versus 0.6% in 2004. Distributed generation accounted for 21% of the total installed capacity in 2015 compared with 4.6% in 2004; while production from distributed generation was 18.1% of the total produced in 2015 compared with 4.7% in 2004. Lo Schiavo, 2018.

[36] Lo Schiavo, 2018.

approach is combined with incentive menus and output-based incentive schemes to reveal to network companies the value of new investments in outputs and services for network users.[37]

Based on the results of pilot programmes related to smart distribution system functionalities and their calculated benefits, the regulator introduced two output metrics for smart grid rollout in 2016: ability to monitor power flows and the state of connected distributed energy resources, and voltage control on the medium-voltage network (only where reverse power flows occur more than 1% of year).[38] Having real-time data on networks, coupled with the exchange of data between DSOs and the TSO, facilitates better forecasting and emergency response, translating to lower reserve needs. The first proposed metric for this output is described as the rated power of distributed generation from renewables associated with transformers with improved voltage control, paired with a bonus of 20 euros/MW per annum.

Improved voltage control yields higher distributed generation hosting capacity and hence deferred distribution investment. The second proposed metric is "transformation capacity (MVA) of each high-voltage and medium-voltage primary station with improved voltage control" with a bonus of 250 euros for each megawatt of transformer capacity (with improved voltage control).

Currently, the regulator is engaged in stakeholder consultations to establish an efficient new regulatory paradigm that will be accepted by network operators.

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[37] Oxera Consulting LLP. (2016). *Agenda: Electricity network regulation in Italy moves towards a new paradigm* [Webpage]. Retrieved from https://www.oxera.com/agenda/electricity-network-regulation-in-italy-moves-towards-a-new-paradigm/

[38] Lo Schiavo, 2018.

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Littell, D., Kadoch, C., Baker, P., Bharvirkar, R., Dupuy, M., Hausauer, B., Linvill, C., Migden-Ostrander, J., Rosenow, J., Wang. X., Zinaman, O., and Logan, J. (2017)

Next-Generation Performance-Based Regulation: Volume 1 (Introduction—Global Lessons for Success)

https://www.raponline.org/knowledge-center/next-generation-performance-based-regulation-volume-1-introduction-global-lessons-for-success/

Littell, D., Kadoch, C., Bharvirkar, R., Dupuy, M., Hausauer, B., Linvill, C., Migden-Ostrander, J., Rosenow, J., Wang. X., Zinaman, O., and Logan, J. (2018)

Next-Generation Performance-Based Regulation: Volume 2 (Primer—Essential Elements of Design and Implementation)

https://www.raponline.org/knowledge-center/next-generation-performance-based-regulation-volume-2-primer-essential-elements-of-design-and-implementation/

Littell, D., Kadoch, C., Bharvirkar, R., Dupuy, M., Hausauer, B., Linvill, C., Migden-Ostrander, J., Rosenow, J., Wang. X., Zinaman, O., and Logan, J. (2018)

Next-Generation Performance-Based Regulation: Volume 3 (Innovative Examples from Around the World)

https://www.raponline.org/knowledge-center/next-generation-performance-based-regulation-volume-3-innovative-examples-from-around-the-world/

Littell, D., Kadoch, C., Bharvirkar, R., Dupuy, M., Hausauer, B., Linvill, C., Migden-Ostrander, J., Rosenow, J., Wang. X., Zinaman, O., and Logan, J. (2018)

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