C›ONSTRUCTOR
UNIVERSITY

Improving regulatory incentives for electricity grid reinforcement

Study for Autoriteit Consument en Markt (ACM), The Hague

Prof. Gert Brunekreeft[1]

Constructor University Bremen

gbrunekreeft@constructor.university

16. June 2023

---

[1] The author is grateful for useful discussion and comments by ACM. The views expressed in this report are the sole responsibility of the author and do not necessarily comply to the views of ACM.

Contents

1 Executive summary

Regulation theory and practice are making next steps. In many countries, regulation of electricity networks experiences a shift in focus away from efficiency-oriented regulation towards investment-oriented regulation. This is not because efficiency-oriented regulation is not working. It does work: it sets incentives to improve efficiency. But the goals have changed; in particular, the energy transition requires adjustment and expansion of the electricity networks. To this end, efficiency-oriented regulation is not very well-equipped and the search now is for a more investment-oriented regulation. At the same time, efficiency remains an important constraint. We are thus looking for something that could be coined efficient investment-oriented regulation.

Another development is output-oriented regulation (OOR), which supplements the base regulation with revenue elements that reflect the achievement of specifically determined regulatory output targets or performances. Output-oriented regulation can incentivize activities that require cost increases and/or upfront expenditures and can capture external effects. External means that costs and/or benefits are (partly) incurred by third parties and not by the decision-maker. In contrast, internal means that costs and benefits of an action are primarily incurred by the decision-maker. Regulation typically aims at internal effects; additional OOR-elements aim to include external effects.

This study for ACM follows these developments. The main research question in this study is: How can regulation better incentivise grid operators to invest in grid reinforcement effectively? We note that grid reinforcement will often be grid expansion, but it can also entail making better use of existing network capacity.

It should be stressed that the regulatory incentives discussed in this study are merely a small part in a wider discussion on grid reinforcement. There are limits to what incentives in the regulation can do. A larger part of the problem of grid reinforcement lies in planning and permitting. These problems cannot be solved by monetary incentives in the regulation and should be addressed elsewhere.

The study presents and evaluates a wide range of possible regulatory options for incentives for grid reinforcement. It primarily aims to present and evaluate the pros and cons of various options and discuss the trade-offs between the main policy goals. Policy recommendations may follow naturally, but are not the primary aim of the study. Rather, it aims to give substantiated input for further discussion.

This study does not contain a problem analysis of the investment incentives in the current regulatory regime in the Netherlands. Presuming that investment incentives need to be strengthened, the aim of the study is to discuss possible ways how this could be done. Analysis of possible problems is done elsewhere.

The suggestions and the analysis are made for a general regulatory context and do not necessarily match the current regulatory regime in the Netherlands. Having said that, we note that the regulation in the Netherlands is always present in the background.

The study takes an academic perspective. Yet, it is not the intention to provide a comprehensive literature review, nor to provide a comprehensive overview of international regulatory experience.

The regulatory approaches aiming for grid-reinforcement are each evaluated using five criteria:

- Effectiveness: does it reach the goal of grid reinforcement?
- Efficiency: is output produced with optimal use of time, effort and resources?
- Affordability: do system costs increase or decrease and what does this imply for the network user?
- Implementation: is implementation (for firms and the regulator) manageable or is it complex and challenging?
- Sustainability: does it contribute to a sustainable environment?

The reader may note that these criteria include the three main goals of the energy policy triangle: supply security, affordability and sustainability.

In the report, first four regulatory base models are discussed:

Base regulation model Variation 1A: Investment budgets

- **Forward looking investment (expenses) budget**
- **Additional ad hoc investment measures**
- **TOTEX-based sharing factors around the budget**

Base regulation model Variation 1B: CAPEX true-up (TSO)

- **Annual CAPEX true-up and OPEX under time-lagged revenue cap**
- **Project-based forward-looking budgets for qualifying projects**
- **Benchmarking for efficiency**

Base regulation model Variation 2A: CAPEX-true-up (DSO)

- **Annual CAPEX true-up and OPEX under time-lagged revenue cap**
- **Project-based forward-looking budgets for qualifying projects**
- **Benchmarking for efficiency**

Base regulation model Variation 2B: Price/revenue-cap

- **Price/revenue-cap (aka tariff regulation) with volume driver, including RES-expansion mechanism**

Figure 1: Overview of the four base regulation models

The first two base models (variations 1A and 1B) aim primarily at the TSO-regulation, and the latter two (variations 2A and 2B) aim at DSO-regulation. In the Netherlands, the current TSO-regulation contains elements of both the base model Investment budgets and the base model CAPEX true-up (TSO). Moving towards either variation would thus be a shift in focus, rather than a structural change; a change to model 1A, however, would be a very significant shift though. The current DSO-regulation in the Netherlands is a price-cap model. Thus the base model Price/revenue-cap largely retains the current model, whereas the base model CAPEX-true-up (DSO) would be a structural change of the regulation.

Second, the study discusses a selection of eight output-oriented regulatory (OOR) elements complementary to the base models:

- Item 1: FOCS (Fixed OPEX CAPEX Shares). FOCS is a variation of TOTEX-regulation aiming to internalize the OPEX-CAPEX incentive bias. This incentivizes innovative OPEX-based solutions for grid-reinforcement.
- Item 2: Flexshare (congestion and/or curtailment) in combination with FOCS. Flexshare aims to set efficiency incentives (bonus/malus-system) for a part of congestion and/or curtailment costs. Combining this with FOCS manages the risk of volatility of these incentivized costs.
- Item 3: Bonus/malus for connection time (DSO) and/or construction time (TSO). This entails a bonus (or malus) for timely construction and/or connection as compared to some reference value. This relies on a standard incentive mechanism.
- Item 4: Incentive mechanism on outage costs. Like items 2 and 3 this item is a bonus-malus scheme. It uses the external opportunity costs of network outages, e.g. reduction in economic welfare or extra CO2-emissions stemming from outages, as main metrics.
- Item 5: Key Performance Indicator (KPI)-based smart grid development. The development of smart grids can be expressed in a KPI-based smart grid index. To the extent that the development of a smart grid supports grid reinforcement, regulated revenues can be linked to a KPI-based smart grid index to incentivize the development of the smart grid. As smart grids are closely related with environmental goals, this would also support sustainability.
- Item 6: System Development Plan (SDP). The SDP is a cross-network and cross-sector extension of network development plans. It aims to improve coordination with a whole-system-approach and thereby optimize and reduce the need for investment.
- Item 7: Cost-benefit-sharing. Cost-benefit-sharing aims to internalize external effects of one network on other networks or sectors. As a full regulatory approach, covering all cross-network effects in a systematic way, we call this cross-network cost-allocation (CNCA). A reduced form would be cost-benefit-sharing for selected cooperation projects only.
- Item 8: Rate-of-return adders for large and risky investment projects. Selected qualifying projects can be allowed a higher rate-of-return on capital by adding a top-up on the normal rate-of-return. Usually, higher risk is a selection criterion.

Further regulatory options to incentivize grid reinforcement can be found in the appendix to this study. These are merely listed without evaluation.

Our multi-criteria analyses suggest that:

- Items 1, 6 and 8 have moderate effects, but do not face severe trade-offs. The effects for grid reinforcement may be moderate, but they can be implemented quickly and without risk. As always, details matter and should be considered carefully.
- Item 7 incentivizes network companies to take account of effects beyond the network and supports whole-system optimization. It optimizes and reduces investment

requirements. To reduce complexity, it might be best to start off with selected cases of cost-benefit-sharing to facilitate and promote cooperation.

- Item 4 faces implementation difficulties; especially data availability may be too much of a hurdle. Item 5, the smart grid index is very broad and contains many elements and goals; consequently, incentives from this item may overlap or be in conflict with incentives from other parts of the regulation.
- Items 2 and 3 are promising. Both do directly what they are intended to do: grid reinforcement. These items score relatively well on effectiveness, but less on affordability and sustainability.

An overall view in the concluding remarks (section 6) gives a comparative perspective and reflects on the situation in the Netherlands. Some options would constitute minor changes, others major changes; some options would increase overall complexity, whereas others seem fairly straightforward. In particular:

- A stronger focus on an approach with CAPEX true-up (models 1B and 2A) will be the least complex. Changes in the regulation for the TSO would then be moderate, but for the DSOs it would be significant. The CAPEX true-up approach is not very complicated, neither for the companies, nor for the regulator. More challenging will be the application of benchmarking, which is important in this model. However, the Netherlands can rely on many years of experience with benchmarking for both the TSO and DSOs. The primary focus of the CAPEX true-up approach is on grid-reinforcement. Therefore, we expect only moderate need for additional OOR elements. With one notable exception: this approach suffers from the CAPEX-bias. It may be necessary to address this, e.g. with FOCS.
- Widening the scope for output-based investment budgets (model 1A) for the TSO would be a significant step in the regulation. Notwithstanding the advantage of the flexibility in specifying regulatory goals (e.g. sustainability), implementation is a challenge. The use of OOR-elements is somewhat special in this case. First, the investment budget *is* output-based; thus, depending on the specification of the outputs, OOR-elements are probably implicitly part of the base model, in which case of course, we would not need additional OOR-elements. Second, if well-defined, the additional OOR-elements can help address the perverse incentives for strategic underspending: bonus-malus schemes, like OOR-item 3, can link payment of the budget to predefined milestones.
- The base model Price/revenue-cap relies on the current approach for DSO-regulation in the Netherlands. Therefore, this model does not require a significant regulatory change. However, it focusses on efficiency incentives and not on investment incentives. Investment incentives (and possibly other targets) should be strengthened with additional selected OOR-elements. This is possible, but requires further regulatory steps and increases complexity. If the use of additional OOR-elements intensifies, various incentives might start to overlap or worse, be in conflict.

2 Introduction

2.1 Goals and criteria

The electricity network in the Netherlands has become severely congested in recent years. The main reasons are the growth in renewable energies, especially solar installations, and electrification, causing the demand for electricity to grow. Network congestion displays itself in two ways. First, electricity cannot be transported to the location of demand. Congestion management, for example with redispatch, addresses this problem. Second, new connection requests (both supply and demand) cannot be facilitated within a reasonable time.

Many countries face this problem. The international debate revealed severe hurdles to network reinforcement (cf. Brunekreeft & Meyer, 2016). Among other reasons, one reason can be that the regulation of the network may give poor incentives for network investment. Lately, we have seen a shift in the focus of incentive regulation away from efficiency considerations towards investment incentives (cf. e.g. ENTSOE, 2021). Finding ways to improve investment incentives in the network regulation is the main aim of this study.

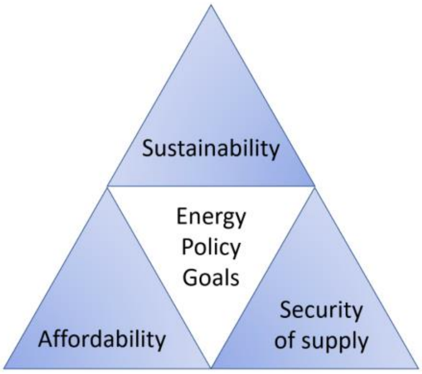


Figure 2: Energy policy triangle.

The goals of grid reinforcement are set by the energy policy triangle, as depicted in Figure 2. These will be particularly important in the overall assessment. Grid reinforcement aims to address network constraints; this can be specified in three derived goals:

- Reduction of congestion costs (primarily TSO)
  - System costs: Redispatch cost in general
  - CO2-reduction: RES curtailment
- Reduction of connection times (primarily DSO)
  - Opportunity costs of not being able to use the network
  - CO2-reduction: delayed RES production
- Increasing network or system stability and reliability (primarily TSO)
  - Grid reinforcement reduces network outages

We note that these goals aim at reduction of the external costs: external costs are the costs for network users if network access is constrained. This should be distinguished from internal costs, which are the costs for the network operator.

Regulation is a balance between different goals (cf. Eskesen, 2021). The selected items for improving the incentive for grid reinforcement will be evaluated with a multi-criteria analysis (MCA). For the MCA, we decided to use the criteria given in Table 1 below. It should be noted that the three goals of the policy triangle are covered in the criteria list.

Table 1: Criteria used in the multi-criteria analysis

Criterion	Assessment	Description
Effectiveness (supply security)		Does the option effectively meet the goal of grid reinforcement? Grid investment needs to be adequate and timely. Since the goal is to improve network availability, this criterion is linked to supply security and network adequacy. This includes less delay in connection times, less congestion (i.e. more network availability) and less outage. This criterion also covers reduced opportunity costs for network users (external costs).
Efficiency		This criterion aims at economic efficiency, both concerning the network operator and the overall system. Efficiency is defined as reaching the output at least costs or optimal use of resources.
Affordability		Do the costs of the overall system decrease or increase? In other words, do consumers pay more or less?
Implementation		This concerns the costs, hurdles and prospects of implementation. This includes primarily implementation costs for firm and regulator.
Sustainability		This criterion aims at environmental protection (RES, electrification, CO2-footprint).

The assessment will be in the range from – – (very negative) to 0 (neutral) to ++ (very positive). Thus, + for affordability means lower costs for consumers.

Effectiveness addresses the question whether the goal of grid reinforcement is met. Since grid reinforcement also aims to reduce outages and to increase network availability and network stability, this criterion covers supply security. Grid reinforcement is not an end in itself, but rather a means to an end: the goal is to reduce external (opportunity) costs for network users. Outages, congestion and late connection cause external opportunity costs for network users. These are covered in the criterion effectiveness.

The criterion efficiency pertains to the impact on the overall economy (allocative efficiency), not merely the effects for the firm (operational efficiency). The driver in the background are the efficiency incentives in the regulation. These will differ per item. Efficiency in economics means optimal use of scarce resources; economists typically assess analytical deviations from the (hypothetical) optimal outcome. Usually, we distinguish between short-term (i.e. for given capacity and technology) and long-term efficiency (adjusting capacity and technology). Grid reinforcement can mean more efficient use of given network capacity to reduce congestion; grid reinforcement can also mean expanding grid capacity with investment. Efficiency of investment is determined by the quantity, timing and technology of the investment. The optimal size of the network follows from a trade-off between investment costs and the *external* benefits for network users of network expansion.

The difference between effectiveness and efficiency can be illustrated nicely with the so-called OPEX-CAPEX-incentive-bias (see section 3.2). Regulation may set incentives in favour of CAPEX at the expense of more efficient OPEX-solutions. The regulation might thus effectively reach the goal of grid reinforcement, but it might do so inefficiently at higher costs.

Affordability aims primarily at the costs of the electricity system or the cost of network connection and usage for the network users. This criterion basically asks whether an item would increase or decrease the costs of the system. Moreover, in the MCA we take as given that necessary grid reinforcement is expensive and will increase costs in any case; the more relevant question is whether a policy increases the costs beyond this unavoidable level.

Implementation aims primarily at the challenges for implementation by the regulator, although sometimes implementation costs for the firms will also play a role. Reflecting more widely, in section 6 we give a wider discussion of complexity of the overall suggestions for the regulatory system.

Lastly, the criterion sustainability aims at environmental effects. Sometimes environmental effects are or can be a direct aim of an item (e.g. prioritizing RES); sometimes, environmental effects are indirect effects (especially if grid reinforcement reduces congestion and thus leads to less RES-curtailment). Grid reinforcement and sustainability are related but are not the same. Sometimes grid reinforcement has no effect on sustainability, for instance, a faster network for a paper factory is beneficial for the factory but has no impact on sustainability.

2.2 Scope and limits of the study

Some preliminary remarks delimit the scope of this study.

The study focusses on investment incentives in the network regulation. Importantly, hurdles to grid reinforcement that are not directly related to network regulation, like planning and permitting (cf. eg. Reed et al, 2021 for an overview), are largely ignored. Such hurdles will limit the effectiveness of monetary incentives in the regulation. The focus of the study is to make proposals to improve the incentives; problem analysis is in the background and is not the focus here.

The scope of the study is broad and is not restricted to the current regulatory framework in the Netherlands. It is quite possible that proposals would require adjustments of the current regulatory framework in the Netherlands. Yet, the regulation in the Netherlands is present in the background and we will see that the current TSO and DSO regulations underlie the analysis. Where applicable, the study will distinguish between suggestions for the regulation of the TSO versus that of the DSOs.

The qualitative analysis is a multi-criteria analysis. The analysis is theory- and literature-based. The study is purely analytical; neither an empirical study, nor a simulation is included. The study starts with a long list of possibilities for incentives for grid reinforcement; this list is not exhaustive. The long list can be found in the appendix in section 11; these are not assessed. From the long list, we selected a short list of items, which will be evaluated in detail below. The items on the lists are grouped around four main categories as described in Table 2.

Table 2: Four main categories for improving investment incentives

Main category	Remarks
A. Base regulation model	The base regulation can contain elements which promote investment implicitly or explicitly. Important is a possible trade-off between efficiency and investment incentives.
B. Output-oriented regulatory elements	In addition to the base model, output-oriented regulatory elements can directly or indirectly promote investment. Critical is the specification of desired output.
C. Aligning investment incentives	Coordination and signalling of network use and investments can reduce congestion and reduce investment needs. These options do not per se improve investment incentives for network expansion, but rather reduce investment needs, whilst improving grid reinforcement.
D. Stakeholder involvement	In addition to monetary incentives in the regulation, stakeholder involvement can improve governance towards better investment. These options are not always a direct part of the regulatory framework.

3 General remarks on regulation and investment

3.1 Cost-based, price-based and output-oriented regulation

Roughly speaking, regulation theory distinguishes between the two extremes of cost-based versus price-based regulation (cf. Joskow, 2014). In strictly cost-based models, prices and revenues should follow underlying cost developments. As a result, cost reductions do not lead to additional profits, so that the incentives to put effort into cost reductions are low. In contrast, in price-based models the idea is to make revenue or price constraints independent of firms' own underlying costs as far as reasonably possible. There are several ways to achieve this. One way is to make an allowed price path exogenous and ex ante for a long time, i.e. to incorporate an exogenous, predetermined and long regulatory lag. Another way is to rely completely on external factors (such as comparable firms) for price constraints, which leads to yardstick regulation (Shleifer, 1985). In either case, lower costs lead to increased profits and hence there are strong incentives to reduce costs. The basic models of cost-based and price-based regulation differ in the way and speed at which revenues are adjusted to underlying costs. In cost-based models the regulatory lag tends to be short and endogenous: the link between allowed revenues and costs is strong. Price-based models try to de-link allowed revenues and costs explicitly: the regulatory period is relatively long and exogenously predetermined. Importantly, as Joskow (1989 and 2014) convincingly points out, in practice the different types of regulation may actually be quite similar. Typically, cost-based models, like rate-of-return regulation have an endogenous, sometimes quite long regulatory lag. And reversely, price-based models can have all kinds of cost-adjustment elements. In practice, regulation is the sum of details and it is quite difficult to give an unambiguous label (cf. for an overview Armstrong & Sappington, 2005; Guthrie, 2006; Cambini & Rondi, 2010).

Cost-based regulation has a long tradition in monopoly regulation, especially in the US. The most well-known form of cost-based regulation is rate-of-return regulation, where the regulatory cost base is the capital base. Rate-of-return regulation allows a 'fair' rate-of-return on capital employed (Joskow, 1989); in addition, OPEX is usually full cost-pass-through without a mark-up.

Rate-of-return regulation, and more generally cost-based approaches, suffer from low-powered efficiency incentives. Assume that the cost-based regulation is strict and thus that the regulatory lag is zero. If the management of the firm manages to reduce costs, it will have to reduce prices immediately to fulfil the regulatory constraint. The reverse argument also holds: additional costs can be passed on to consumers immediately. In both cases we should expect that the incentives to control costs are low.

In 1983, professor Stephan Littlechild was asked by the British government to assess different regulatory regimes for the regulation of British Telecom, which was then to be liberalised and privatised. This resulted in what is now seen as a paradigm shift. Littlechild was quite critical of cost-based approaches and suggested price-based models instead (Littlechild, 1983). The British government followed this advice and implemented what came to be known as RPI-X regulation (or, price-cap regulation). Soon afterwards, price-based models gained popularity in both practice and theory.

As Beesley & Littlechild (1989) point out, the main reason for using price-based models are high-powered incentives to reduce costs: hence, the expression incentive-based regulation is used frequently to describe this regulation model.[2] The key point of price-based models is to explicitly de-link allowed revenues from underlying costs during the regulatory period. De-linking allowed revenues from costs results in high-powered incentives to reduce costs. If the regulated firm manages to reduce its cost during the control period by more than what is required by the regulator (expressed in the X-factor), it does not have to reduce prices for the additional cost reduction, but can instead keep these profits. This is precisely what leads to the incentives to reduce costs in the first place. This is what the literature calls an incentive mechanism (Laffont & Tirole, 1993).

The high-powered incentives to reduce costs are well established (cf. Ai & Sappington, 2002; Sappington & Weisman, 2010). But there is a downside: what if costs go up? More precisely, price-based models work well to bring costs down, but have difficulty with cost-increasing investment. Theoretically, we can think of a number of reasons why price-based regulation does not set strong investment incentives:

- Risk. Price-based regulation shifts risk from the consumer to the firm; cost-based approach are less risky for the firm. This is called the buffering-hypothesis, as put forth by Peltzman (1976). Poudineh et al. (2020) argue analytically that a stronger cost-based approach stimulates risky innovation and investment. Grout & Zalewska (2006) show the same phenomenon empirically.
- Time inconsistency. The argument is that cost-based regulation relies on an allowed just-and-reasonable rate-of-return on a regulatory cost base, whereas price-based

---

[2] The term is somewhat unfortunate, as it is a misnomer. *All* regulatory mechanisms set incentives one way or another and thus the term incentive regulation lacks meaning.

regulation has no such reference (cf. Gilbert and Newbery, 1994); under price-based regulation, the allowed price is just an agreed number. Therefore, the regulatory commitment to long-run sunk investments is lower and regulatory risk is higher.

- Timing of investment. Borrmann & Brunekreeft (2020) show that cost-based regulation accelerates investment as compared to price-based regulation. Basically, under cost-based regulation, a cost-increasing investment triggers a price increase. Analytically, this works as a rate-of-return top-up, which accelerates the investment.
- Regulatory period. The incentives in the price-based regulation rely on the regulatory lag: the length of the period in which revenues are not adjusted to underlying costs. This, however, also means that firms will hesitate to make cost-increasing investment early in the regulatory period (DENA, 2012).

A new development emerges: output-oriented regulation (OOR), which supplements the base regulation with revenue elements that reflect the achievement of specifically determined regulatory output targets or performances. Output-oriented regulation can incentivize activities that require cost increases and upfront expenditures and can capture external effects (cf. Brunekreeft et al, 2020a). We should stress that the main idea is to retain some kind of regulatory core for base activities, but supplement that with output-oriented components. Thus, in addition to the base regulation, selected output-oriented regulation elements can incentivize additional, predetermined goals, such as reducing congestion, or connecting RES.

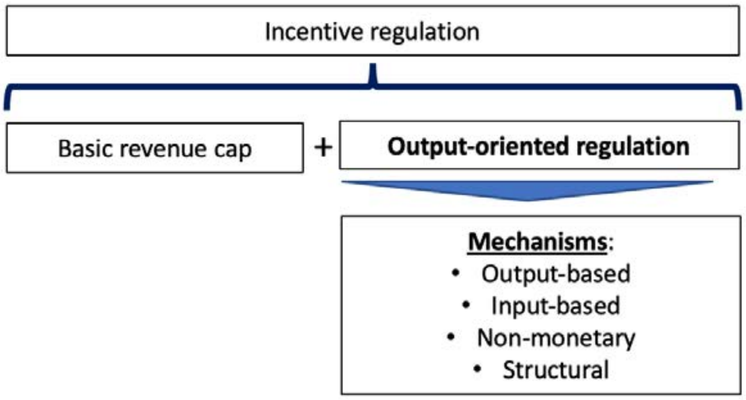


Figure 3: Output-oriented regulation (OOR).
Source: Brunekreeft et al, 2020b.

3.2 OPEX-CAPEX incentive bias

In their seminal paper, Averch and Johnson (1962) demonstrated the so-called gold-plating effect: regulation incentivizes firms towards CAPEX and away from OPEX when the regulated rate of return ("s") is higher than the cost of capital ("r"). This is called an OPEX-CAPEX-incentive-bias (in short: CAPEX-bias). While the Averch-Johnson effect is well understood, its empirical relevance is unclear (see Borrmann and Finsinger, 1999, p. 353). The phenomenon is also known as over-capitalization.

It is important to note that the existence of a CAPEX-bias is not self-evident and requires a specific cause in the rules of the regulation. Therefore, any asserted CAPEX-bias requires a detailed context-dependent analysis of the incentives set by the regulation.

In practice, the CAPEX-bias has gained renewed attention in recent years (Smith et al., 2019). Also for electricity networks, the CAPEX-OPEX-incentive-bias is back in the regulatory debate. First, smart grids typically rely on OPEX measures (e.g. IT-expertise, software, curtailment, demand response, etc.). A CAPEX-bias towards traditional network assets (e.g. network expansion) would thus hamper the development of smart grids in favour of non-smart network investment. Second, network operators increasingly face OPEX-related tasks. For instance, congestion management increases with the amount of renewable energies.

We should note the somewhat paradoxical effect of the CAPEX-bias in this study. If the CAPEX-bias is understood as an incentive for over-capitalization and if network expansion is the main goal, then the CAPEX-bias would actually do the job: it would strengthen investment incentives. However, at least theoretically, these investment incentives would be inefficient (cf. also Alvarez et al, 2022). Firstly, there may be too much investment. Secondly, the CAPEX-bias may crowd out more efficient OPEX-based solutions, which may also be effective for grid reinforcement.

3.3 Brief outline of the regulation for the TSO and the DSOs in the Netherlands

As mentioned in the introduction in section 2, although this study is for ACM in the Netherlands, the scope of the study is broader than being strictly applicable to the current network regulation in the Netherlands. Yet, current network regulation in the Netherlands will be present in the background and thus it is useful to briefly present the current regulation for the TSO and the DSOs in the Netherlands.

The regulation in the Netherlands is specified in the so-called *Methodebesluit*, which can be found on the ACM's website. For our purposes, three *Methodebesluiten* are important: ACM 2021a,[3] ACM 2021b[4] and ACM 2021c[5]. Below, we will present only those aspects which are important for this study; for all other aspects, we refer to the *Methodebesluiten*.

Incentive regulation for the electricity network in the Netherlands started in 2001. The current regulatory period of 5 years started in 2022 and lasts until 2026. Roughly, we could say that the incentive regulation is an efficiency-oriented tariff regulation (price cap) relying quite strongly on international and national benchmarking. With an adjustment of the law in 2017 and with the regulatory period starting in 2022, the regulation made a shift away from being efficiency-oriented towards being investment-oriented. Changes were especially significant for the TSO.

---

[3] https://www.acm.nl/nl/publicaties/methodebesluit-tennet-transport-2022-2026.

[4] https://www.acm.nl/nl/publicaties/methodebesluit-regionaal-netbeheer-elektriciteit-2022-2026.

[5] https://www.acm.nl/nl/publicaties/methodebesluit-tennet-systeem-2022-2026.

TSO

The base model for the TSO (TenneT) is basically a revenue cap, which implies that the TSO bears no volume risk. Efficiency incentives are set by efficiency abatements (x-factors) reflecting the frontier shift and individual efficiency changes derived from an international benchmark. For the TSO the regulation has no quality component. Recently, the revenue cap includes significant additions for expansion investments.

First, since 2017, for „large" expansion investments, there is now t-0-regulation with an annual CAPEX true-up. This is a step away from efficiency-oriented towards investment-oriented regulation. In addition to the CAPEX true-up, there is an OPEX-adder of 1% of the CAPEX. Efficiency of these projects is controlled by a project specific efficiency test.

Second, since 2022, for other expansion investments, the principle of „roll-over and update" applies. This is essentially a forward-looking budget approach for CAPEX and OPEX (1% of expected network growth or decline). Additionally, during the regulatory period an ex-post correction for realized capital costs for investments with lifespans of over 10 years is applied. In other words, there is a full ex-post cost-pass-through for new CAPEX. In the subsequent regulatory period, this CAPEX is included in the benchmark.

Congestion expenses are incentivized under the revenue cap for 5 % of estimated expenses; the other 95% are passed through.

DSOs

The current base regulatory model for the DSOs is a price-cap approach (tariff regulation) with 5-year regulatory time lag. The primary revenue driver is demand-side volume. This assumes that costs are scalable: when output increases, the additional revenue should exactly cover the additional costs. However, if costs are not scalable, DSOs earn profits or suffer losses when output does not match historic levels. In other words, DSOs bear volume risk.

In principle, if a network operator expands its network, volume and thus revenues might increase. Therefore, under a price cap, we would actually expect that revenues are adjusted to the costs of network expansion by mechanism. However, two reasons may impede this adjustment. Investments are often lumpy and anticipate volume growth over time. Therefore, it takes some time for full remuneration. Remuneration depends on the details of the volume driver. Importantly, the volume driver can be transported kWh, whereas the expansion was made to facilitate new RES. Additional RES may or may not increase transported kWh.

Growth of decentralized RES requires substantial grid reinforcement. If RES-connection or feed-in is not charged (and to the extent that higher feed-in is not associated with demand growth), the grid reinforcement will not be financed and thus the network operators would have low incentives to facilitate RES growth. To cover for this, the regulation includes an ex-post correction of decentralized feed-in volume (ACM, 2021b, section 10.1.3). We may call this generally a RES-expansion mechanism. The ex-post correction ensures that the part of grid reinforcement required to facilitate feed-in, while not covered by demand-side charges, will be financed by an ex-post correction (say, ex-post cost-pass-through). There are different ways to implement a RES-expansion mechanism.

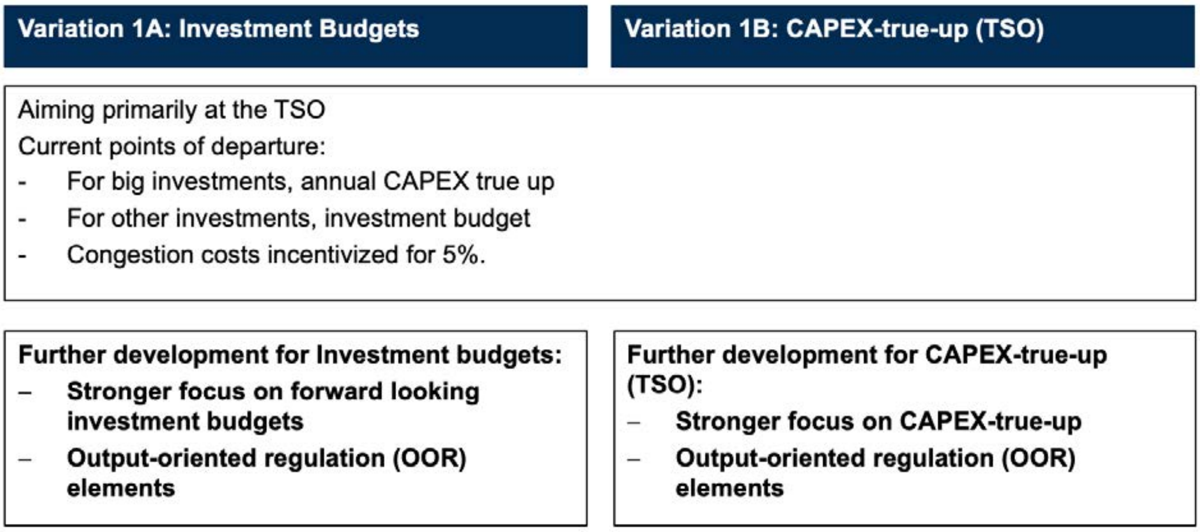
The efficiency incentive of the price cap relies quite heavily on a yardstick stemming from national benchmarking.

The price cap includes a Q-component for quality regulation. As argued *avant la lettre* by Spence (1975), there is justified concern that price-cap regulation impedes investment in quality of supply, which is an important indicator of network adequacy (and reliability). In line with international experience (cf. CEER, 2022), the price cap for the DSOs in the Netherlands includes a Q-component to correct for this deficit. This Q-component uses the indicators System Average Interruption Frequency Index (SAIFI) and Customer Average Interruption Duration Index (CAIDI).

4 Selected regulatory options to improve incentives for grid reinforcement

4.1 Overview

Section 3 described the difference in focus of different types of regulation. It is useful to distinguish price-based models, which are more efficiency-oriented, and cost-based models, which are more investment-oriented. Moreover, section 3.3 briefly outlined the current electricity network regulation in the Netherlands. As was described, this is a good illustration of the difference between the price-based efficiency-oriented regulation and the cost-based investment-oriented regulation. It provides a good point of departure for the refinements discussed in this study. Figure 4 and Figure 5 below present the four variations for regulatory approaches that we consider.



Variation 1A: Investment Budgets

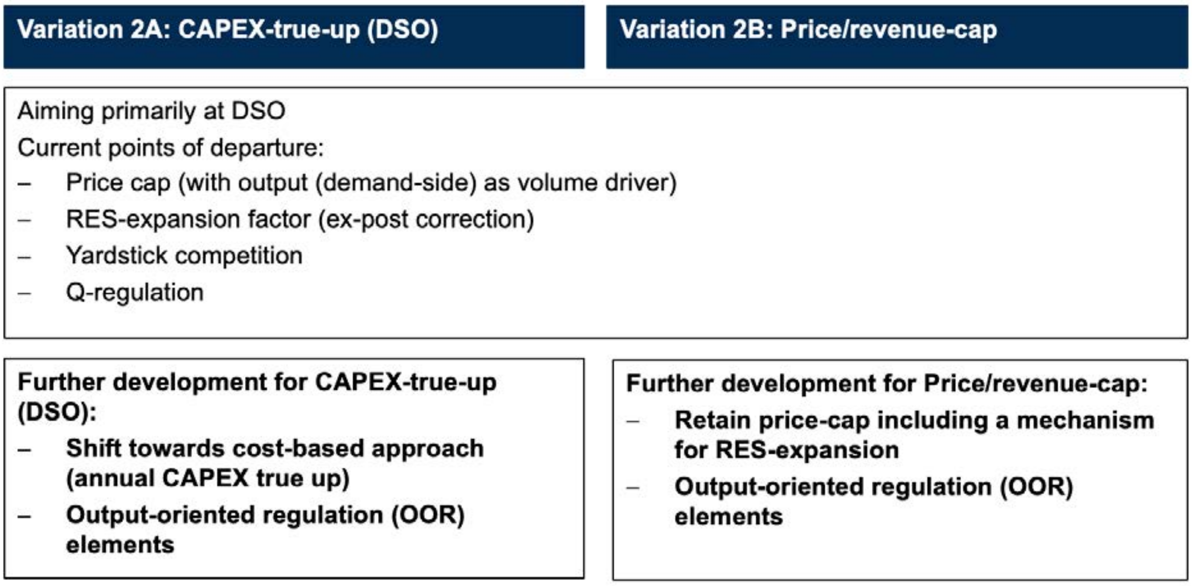
Variation 1B: CAPEX-true-up (TSO)

Aiming primarily at the TSO
Current points of departure:
- For big investments, annual CAPEX true up
- For other investments, investment budget
- Congestion costs incentivized for 5%.

Further development for Investment budgets:
- **Stronger focus on forward looking investment budgets**
- **Output-oriented regulation (OOR) elements**

Further development for CAPEX-true-up (TSO):
- **Stronger focus on CAPEX-true-up**
- **Output-oriented regulation (OOR) elements**

Figure 4: Two variations for regulatory approaches aiming at TSO level.



Variation 2A: CAPEX-true-up (DSO)

Variation 2B: Price/revenue-cap

Aiming primarily at DSO
Current points of departure:

- Price cap (with output (demand-side) as volume driver)
- RES-expansion factor (ex-post correction)
- Yardstick competition
- Q-regulation

Further development for CAPEX-true-up (DSO):

- **Shift towards cost-based approach (annual CAPEX true up)**
- **Output-oriented regulation (OOR) elements**

Further development for Price/revenue-cap:

- **Retain price-cap including a mechanism for RES-expansion**
- **Output-oriented regulation (OOR) elements**

Figure 5: Two variations for regulatory approaches aiming at DSO level.

We consider four variations. Variation 1A is called “Investment budgets” and relies predominantly on a forward-looking budget approach. Variation 1B is called “CAPEX-true-up (TSO)”. Variations 1A and 1B aim primarily at the TSO-level. Variation 2A is called “CAPEX-true-up (DSO)”. An annual CAPEX true-up is an annual update of the capital costs and is basically an annual pass-through of investment expenditures. Variation 2B is called “Price/revenue-cap” and relies predominantly on the price-based approach (price- or revenue-caps). Variations 2A and 2B aim primarily at the DSO-level.

Variations 1A and 1B aim at the TSO level. The reader may note that the current regulation of the TSO in the Netherlands is a hybrid of these two variations. As mentioned above, the current regulation is a mix of CAPEX-true-up for big investments and investment budgets for other investments. The current base regulation for the TSO is already investment-based. Thus, the current regulation is the starting point and the two variations shift the focus in either direction. Variation 1A shifts the focus towards a budget approach, while allowing for investment measures (with a CAPEX-true-up) for unanticipated investments. We note that 1A is in fact a significant shift as compared to the current regulation. Variation 1B shifts the focus to CAPEX-true-up, while allowing for budgets for selected qualifying (OPEX-based) projects.

Variations 2A and 2B aim primarily at the DSO-level. Variation 2B is close to the current DSO regulation in the Netherlands; changes would be small. This variation relies quite strongly on additional OOR-elements to strengthen investment incentives. Variation 2A, however, differs significantly from the current DSO regulation in the Netherlands.

The reader may note that variations 1B and 2A are very similar; both rely on a CAPEX-true-up. Yet, there is an important difference. A CAPEX-true-up is essentially a cost-pass-through of investment expenditures. This strengthens investment incentives. The downside is weak efficiency incentives; there may be too much investment and the investment expenditure as such can be inefficient. Efficiency incentives can be strengthened with the support of a benchmarking approach. The TSO is benchmarked internationally with structurally very different comparators; the DSOs are benchmarked with a national approach, with structurally similar comparators. In practice, this means that benchmarking of the DSOs is quite powerful, while benchmarking of the TSO is substantially more challenging and application of the benchmarking results of the TSO requires careful attention (cf. Haney & Pollitt, 2013). A CAPEX-true-up system requires some kind of benchmarking as an efficiency check; since benchmarking is easier and more powerful for the DSO than for the TSO, it follows that a CAPEX-true-up system is easier applied to DSOs (2A) than to a TSO (1B).

In addition to the base regulatory model, we present and discuss elements of output-oriented regulation (OOR), also called targeted performance incentive mechanisms (PIM), to strengthen investment incentives selectively. Below in section 4.2, we will first present and discuss the base model, and in section 4.3 the OOR-elements.

4.2 Base models: efficiency-oriented versus investment-oriented

4.2.1 Base model variation 1A: Investment budgets

Description

This variation shifts the focus towards forward-looking investment budgets. Section 3.3 explained that a similar approach has been introduced in 2022 for the TSO regulation in The Netherlands ("roll-over and update"). This variation suggests to follow and extend this approach: similar to the RIIO approach in the UK, the budget approach may be applied more widely.

Base regulation model Variation 1A: Investment budgets
• **Forward-looking investment (expense) budget**
• **Additional ad-hoc investment measures**
• **TOTEX-based sharing factors around the budget**

Figure 6: Base model variation 1A: Investment budgets

In a forward-looking budget approach, the firm requests an ex-ante budget for predefined projects or the entire business plan. The budget must be checked and approved by the regulator. Following expected expenses, the budget is specified for each year of the budget period. Hence if the planning is correct, there is no delay in the remuneration of the expenses.

There may be unanticipated investments not planned in the budget. To facilitate these, we suggest to add an arrangement for ad-hoc investment measures. The firm can apply for approval of investment projects outside the budget. If these are approved by the regulator, the expenses will be passed through without delay.

We suggest to apply a set of sharing factors (aka sliding scales) for ex-post cost-overruns or cost-underruns. With a high sharing factor the firm takes on a large share of the difference between planned and actual costs and the customers take on a small share. A low sharing factor means that the grid operator passes on a large share of the cost difference and the grid customers therefore carry most of it. The sharing factor affects efficiency incentives and risk (cf. Poudineh et al, 2020). The efficiency incentive and the risk for the firm are high with a high sharing factor and they are low with a low sharing factor (high cost-pass-through). In addition, it would be possible to differentiate between OPEX and CAPEX sharing factors (cf. Brunekreeft et al, 2021).

Furthermore, this variation relies on the application of a System Development Plan (SDP) (see section 4.3.6, item 6). A System Development Plan is useful to assess the requested budgets and make a used-and-useful test for budgets and requested investments. The main advantage of SDPs is that these are designed collectively by various network operator involving further stakeholders; thus any individual stakeholder is controlled by fellow stakeholders. For the purpose of better coordination, we suggest to use a SDP (see section 4.3.6, item 6). The same SDP might as well be used for regulatory purpose of approving and controlling the budgets.

Evaluation

Table 3 below provides an overview of the evaluation of the base model Investment budgets.

Table 3: Base model: Investment budgets

Criterion	Assessment	Arguments
Effectiveness (supply security)	+	• Forward-looking investment budgets and ad-hoc investment measures allow cost-increases. • Incentives for strategical underspending.
Efficiency	+	• Budgets plus sharing factors balance efficiency incentives and risk.
Affordability	– –	• Incentive to inflate the requested budget and incentives to underspend can make the system expensive.
Implementation	–	• Making and assessing the requested budgets will be challenging.
Sustainability	++	• Sustainability goals can be explicitly addressed in the budgets and/or investment measures.

The entire model is designed to facilitate cost-increasing investments. Hence, if grid enforcement is defined as an output in the budgets, we should expect a positive effect on effectiveness. Ad-hoc investment measures for unanticipated grid reinforcement investments will additionally strengthen effectiveness. On the other hand, the budget approach sets incentives for strategic underspending once the budget is set. Underspending would imply that grid reinforcement is delayed, which impedes effectiveness, at the expense of network users. Presumably though, these perverse incentives can be countered to some extent with a selection of the OOR-elements in section 4.3.

The budget approach with sharing factors for cost over- and underruns, strengthens efficiency incentives. The sharing factor is important to strike a balance between efficiency incentives and risk for the firms (cf. Grout and Zalewska, 2006).

A low score on affordability is a key disadvantage of the system: system cost may be comparatively high. The problem with a budget approach is that the firms have an incentive to inflate the requested budget, which increases the costs of the system.

Implementation will be challenging. Output-based models are implemented in e.g. the UK and Australia. Especially approval of the requested budgets will be a real challenge for the regulator. The regulator in the UK uses a wide range of tools to assess the requested budgets, among which benchmarking methods. In addition, we suggest that the plans and roadmaps specified in the system developments plans can provide useful information to support the regulator in the process of budget approval.

A main advantage of this model is the potential contribution to sustainability. The model is output-based and sustainability targets could be explicitly defined as priority outputs in the budgets. To this extent, the criterion sustainability should be considered positive.

4.2.2 Base model variation 1B: CAPEX true-up (TSO)

Description

This variation shifts the focus of the TSO regulation towards an approach with an annual CAPEX true-up. A similar change was made for the regulation for the TSOs in Germany for the regulatory period starting in 2024. As the current TSO regulation in the Netherlands already has this component for big investment projects, we would consider this a shift in focus, rather than a system change.

Base regulation model Variation 1B: CAPEX-true-up (TSO)
• **Annual CAPEX-true-up and OPEX under time-lagged revenue cap**
• **Project-based forward-looking budgets for qualifying projects**
• **Benchmarking for efficiency**

Figure 7: Base model variation 1B: CAPEX-true-up (TSO)

The base model is an annual CAPEX true-up, which is an annual update of capital costs, or in other words, an annual pass-through of capital cost. This implies that any capital costs following new investments are passed through into the revenue base at the latest at the end of the year. Depreciation is also accounted for annually. The annual CAPEX-true-up implies that the regulatory delay for CAPEX is almost zero and is no longer a hurdle for timely investment.

The above concerns CAPEX. For OPEX things are different. The main disadvantage of an annual true-up are the weak efficiency incentives, as this is basically a cost-pass-through. A benchmarking approach should set efficiency incentives. However, applying an efficiency abatement if OPEX are adjusted annually, is tricky. Therefore, it might be considered to leave OPEX under a regulatory time lag of 3 to 5 years; alternative approaches for OPEX are possible.

If OPEX remains under the regulatory time lag, the base-year problem remains for OPEX-based projects: firms have perverse incentives to delay OPEX-based projects till the next base year.

To address this, we suggest a project-based forward-looking budget for qualifying OPEX-based projects. This approach addresses the base year problem, as the budget starts whenever the project starts. Application should be limited to qualifying projects, which are sufficiently large and can be demarcated from other activities to avoid double counting and cross-subsidies.

It is important to secure that the variables and the parameters in the benchmarking are geared towards grid reinforcement. Especially the definition of output in the benchmark should include metrics for a “larger” or “stronger” or possibly “smarter” and “more sustainable” network. On the input-side, it is important to consider time and uncertainty effects. Grid reinforcement activities can require expenses now, aiming at uncertain output effects later.

Strict use of benchmarking can impede the investment incentives, which counters the investment incentives of the CAPEX true-up to some degree. Especially benchmarking of fixed assets is risky as these are irreversible: it is difficult to improve efficiency of inefficient assets once the investment has been made. To address this, it might be an option to benchmark fixed assets leniently, if investments are approved in some other way anyhow. In particular, investments which have been approved in a network development plan can be considered used-and-useful and can be excluded from the benchmark. Ex-ante approval, as an efficiency test, reduces investment risk.

Evaluation

The overview of the evaluation of this model is depicted in Table 4.

Table 4: Base model: CAPEX-true-up (TSO)

Criterion	Assessment	Arguments
Effectiveness (supply security)	++	• CAPEX true-up is basically cost-pass-through; investments are not delayed and there is no risk for the firm.
Efficiency	–	• CAPEX-true-up has weak efficiency incentives. • CAPEX-bias. • Efficiency relies on the power of benchmarking.
Affordability	–	• To the extent of the inefficiency, the system can be expensive.
Implementation	–/+	• Implementation is straightforward • International benchmarking for the TSO is challenging.
Sustainability	+	• The effect is only indirect; grid reinforcement will be incentivized and this can support sustainability.

The key advantage of this model is precisely its main aim to improve incentives for grid reinforcement. The annual CAPEX true-up promotes CAPEX-based investments. It does not promote OPEX-based grid reinforcement, but the project-specific budget approach for large OPEX-based projects addresses this problem. Taken together, this model is potentially highly effective to promote grid reinforcement. Strict application of benchmarking can impede the effectiveness, but we assume that in this variation (for the TSO), that asset investments are largely excluded from the benchmark.

On the downside, the model faces relatively low efficiency incentives. Under the annual CAPEX-true-up, efficiency must be controlled by benchmarking. As mentioned above, international benchmarking of TSOs is a challenge (cf. Haney & Pollitt, 2013). Moreover, the asymmetrical treatment of CAPEX and OPEX causes a CAPEX-bias, which further impedes efficiency.

Too much investment is expensive. Inefficiencies in the system increase the costs, which need to be paid by the network users. Hence, affordability suffers to the extent of the inefficiency. However, given that CAPEX is depreciated over many years, the annual cost increase will likely be moderate.

Implementation should be straightforward. There is adequate experience with large parts of this model. The addition of the budgets for large OPEX-based projects will be somewhat challenging to implement though; especially the selection and demarcation of the projects might prove difficult. International benchmarking is a real challenge, but the models have been developed and applied for many years now.

The effect for sustainability is indirect, but positive. Grid reinforcement aims to reduce congestion and will thus facilitate more RES feed-in.

4.2.3 Base model variation 2A: CAPEX-true-up (DSO)

Description

This variation changes the base regulation model to a cost-based investment-oriented approach. Compared to the current DSO-regulation in the Netherlands, the model is quite a big step. In fact, this base model is by and large similar to the approach for DSOs in Germany since 2019; the change in Germany was precisely to facilitate grid investment.

Base regulation model Variation 2A: CAPEX-true-up (DSO)
• **Annual CAPEX-true-up and OPEX under time-lagged revenue cap**
• **Project-based forward-looking budgets for qualifying projects**
• **Benchmarking for efficiency**

Figure 8: Base model variation 2A: CAPEX-true-up (DSO)

The approach is very similar to the approach in variation 1B; we can therefore be brief on the description and we refer to section 4.2.2 for more detail.

Evaluation

The overview of the evaluation of this model is depicted in Table 5.

Table 5: Base model: CAPEX-true-up (DSO)

Criterion	Assessment	Arguments
Effectiveness (supply security)	++/+	• CAPEX true up is basically cost-pass-through; investments contain no time delay and no risk for the firm. • Strict application of benchmarking may impede effectiveness.
Efficiency	–/0	• CAPEX-true-up has weak efficiency incentives. • CAPEX-bias. • Efficiency relies on the power of benchmarking.
Affordability	–	• To the extent of the inefficiency, the system can be expensive.
Implementation	+	• Implementation is straightforward.
Sustainability	+	• The effect is only indirect; grid reinforcement will be incentivized and this can support sustainability.

Unsurprisingly, also the evaluation of variation 2A is comparable to the evaluation of variation 1B; again, we can be brief and refer to section 4.2.2 for more detail.

There are some differences, however. We noted above that under the annual CAPEX true-up, efficiency must be controlled by benchmarking. Whereas international benchmarking of TSOs is a challenge, national benchmarking of DSOs is more straightforward (cf. Haney & Pollitt, 2013) and application can be stricter. For the evaluation, this has three consequences.

Stricter application of benchmarking would increase efficiency incentives, but might impede the investment incentives, which counters the investment incentives of the CAPEX true-up to some degree. Therefore, efficiency might be better, but effectiveness will be less for the DSOs (variation 2A) than for the TSO (variation 1B). As benchmarking of DSOs is less challenging than for the TSO, implementation will be somewhat more positive in variation 2A compared to variation 1B.

Implementation of the model as such is quite straightforward. However, we note that the model 2A is a significant change as compared to current regulation and might require adjustment of laws and ordinances.

To the extent that the incentives for grid reinforcement in this model are effective, we would expect an indirect positive effect on sustainability, as grid reinforcement will decrease RES-curtailment and accelerate RES-connection.

4.2.4 Base model variation 2B: Price/revenue-cap

Description

This variation aims at price-based models, i.e. price- or revenue-caps. As explained above these are primarily efficiency-oriented. The base model Price/revenue-cap basically relies on the current approach of DSO-regulation in The Netherlands. This variation retains the price-based approach.

Base regulation model Variation 2B: Price/revenue-cap

- **Price/revenue-cap (aka tariff regulation) with volume driver, including RES-expansion mechanism**

Figure 9: Base model variation 2B: Price/revenue-cap

As explained in section 3.3, the current DSO regulation in the Netherlands is a price-cap regulation (tariff-regulation), with a demand-side volume driver. It was pointed out that since 2022 the price-cap includes a RES-expansion mechanism, as an ex-post correction for RES-feed-in: the part of grid reinforcement that is required to facilitate feed-in (which is not covered by demand-side charges), will be financed via an ex-post correction. Consequently,, we assume that our base model variation Price/revenue-cap includes a RES-expansion mechanism in some form.

Evaluation

The assessment of the base model Price- or revenue-cap is shown in Table 6.

Table 6: Base model: Price/revenue-cap

Criterion	Assessment	Arguments
Effectiveness (supply security)	0	• Time lag of price- or revenue cap impedes investment incentives. • Expansion mechanism can relieve these weak investment incentives to some extent.
Efficiency	++	• Efficiency is main aim of a price-based system.
Affordability	+	• Efficiency lowers the internal cost of the system.
Implementation	+	• By and large, this system is already being used. • Implementation of a RES-expansion mechanism (incl. ex-post corrections) is non-trivial.
Sustainability	0	• The efficiency-based system does not promote sustainable outcomes. • The RES-expansion factor would promote RES-connection.

The potentially high efficiency is the key advantage of this model. Price-based models, like price or revenue caps, were developed and implemented to improve efficiency incentives. We should therefore expect that the efficiency incentives are strong in this approach.

The main disadvantage of this model is that it does not support grid reinforcement very much. In fact, the regulatory lag, which may be good for efficiency, can delay expenses for grid reinforcement, which impedes effectiveness. On the other hand, the RES-expansion mechanism (e.g. via an ex-post correction) as a revenue driver to cover the costs of RES-based network expansion strengthens the incentives for grid reinforcement and thus improves effectiveness.

It follows that system costs will be comparatively low: expenses for grid reinforcement will be moderate and efficiency will be high. Thus, affordability is moderately positive.

Implementation is rather straightforward. By and large the system is already being used, which shows that it can be done at reasonable costs. Implementation of the RES-expansion factor is something to consider carefully; there are different variations with pros and cons. This might be an issue for further study.

Lastly, sustainability suffers somewhat with this model. If grid reinforcement is not really supported, RES-curtailment and RES-connection will not be improved. Only the RES-expansion mechanism promotes sustainability.

4.3 Selected output-oriented elements

Section 4.2 discussed the base models; section 4.3 will turn to selected items of output-oriented regulation (OOR).[6]

OOR-elements base variation 1A: Investment budgets and 1B: CAPEX-true-up (TSO)
• **Fixed OPEX CAPEX Share (FOCS)**
• **Flexshare plus FOCS: Stronger incentivizing reduction of congestion costs**
• **Bonus/malus for construction of planned investment linked to predetermined metrics**
• **Bonus/malus on outage costs**
• **Rate-of-return adders for large and risky investment projects**
• **Lead in System Development Plan**
• **Cost-benefit-sharing: CNCA (cross-network-cost-allocation)**

Figure 10: OOR-elements for the base model Investment budgets and CAPEX-true-up (TSO), primarily aiming at the TSO.

OOR-elements Variation 2A: CAPEX-true-up (DSO) and Variation 2B: Price/revenue-cap
• **Fixed OPEX CAPEX Share (FOCS)**
• **Bonus/males for connection time**
• **KPI-based smart grid development**
• **Incentive mechanism to reduce external curtailment costs plus FOCS**
• **Rate-of-return adders for large and risky investment projects**
• **Participation in System Development Plan**
• **Cost-benefit-sharing: CNCA (cross-network-cost-allocation)**

Figure 11: OOR-elements for base models CAPEX-true-up (DSO) and Price/revenue-cap, which aim primarily at the DSOs.

Below, we will present and discuss the following OOR-items.

- Item 1: FOCS (Fixed OPEX CAPEX Share)

---

[6] The selection comes from the long list in the appendix, where various items were allocated to different main categories. In the short list in this section, for convenience's sake, we call all items OOR-elements.

- Item 2: Flexshare (congestion or curtailment) in combination with FOCS
- Item 3: Bonus/malus for connection time (DSO) and/or construction time (TSO)
- Item 4: Incentive mechanism on outage costs
- Item 5: KPI-based smart grid development
- Item 6: System Development Plan (SDP)
- Item 7: Cost-benefit-sharing
- Item 8: Rate-of-return adders for large and risky investment projects

The reader may note that innovation is not explicitly mentioned here. Although innovation is certainly very important (cf. ENTSOE, 2022; Brunekreeft et al. 2021; Cambini et al, 2016) we have decided not to include it. Incentivizing innovation is a difficult and somewhat confusing issue. Innovation is difficult to define and demarcate from investment, so there would possibly be overlap. It is difficult to say which innovations are the responsibility of network operators and which of the market parties, or in cooperation. In fact, we should secure that regulatory incentives do not crowd out market activities. In many cases, network operators may be a customer of innovative solutions, rather than the innovator. The goal of innovations is not always clear; innovations may aim at improving internal network efficiency, which is precisely the aim of incentive regulation. Alternatively, innovations may aim at external benefits. Depending on the precise external benefits, this may or may not already be incentivized by another mechanism. Lastly, it is not immediately clear how to incentivize innovation efficiently and effectively (Marques et al, 2022). Basically, the problem is to define good output indicators (Bauknecht, 2011; Biancardi et al, 2021). Yet, we acknowledge the importance of the topic; explicitly incentivizing innovation requires further research, which goes beyond the scope of this study.

4.3.1 Item 1: Fixed OPEX CAPEX Share (FOCS)

Description

A Fixed OPEX-CAPEX-share (FOCS) is a tool to address the OPEX-CAPEX-incentive-bias (short: CAPEX-bias). In addition to grid expansion, there are "smart" solution approaches to address network congestion, for instance using flexibility instead of building an additional line. However, smart grid technologies often have a higher share of operating costs (OPEX) than conventional grid investments. In practice, regulation sometimes treats OPEX and CAPEX asymmetrically, such that smart OPEX-heavy solutions are more risky and less worthwhile for grid operators. This is referred to as an OPEX-CAPEX-incentive-bias (CAPEX-bias).

FOCS is a variation of TOTEX regulation. TOTEX regulation is well established in the literature, notably by Braeutigam (1981) and Finsinger and Kraft (1984), who refer to this approach as mark-up regulation. TOTEX regulation has been implemented in the UK for the regulation of water and energy networks (cf. Smith et al, 2019; Oxera, 2019).

The basic idea is illustrated in Figure 12 (see also Bebenburg et al, 2023). A predefined fixed part of OPEX is activated and treated like CAPEX: a “Fixed-OPEX-CAPEX-share (FOCS)”. Under FOCS, all expenditures, whether for capital goods (CAPEX) or operational measures (OPEX), are treated equally as TOTEX. A fixed share, the capitalization rate “x”, of this TOTEX is then "capitalized" (quasi-CAPEX) and the remaining part ("1-x") is volatilized as quasi-OPEX ("pay-as-you-go"). In the regulation, the resulting quasi-CAPEX and quasi-OPEX are treated in exactly the same way as CAPEX respectively OPEX would normally be treated. The quasi-CAPEX go into the regulatory capital base and generate depreciation and interest. The quasi-OPEX are booked within the fiscal year. This way, cet. par. the firm is actually indifferent between CAPEX and OPEX and thus there is no CAPEX-bias.

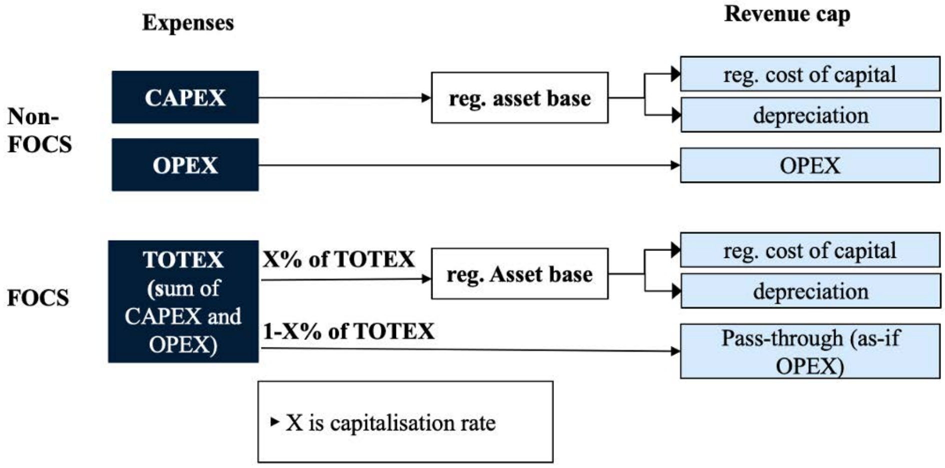


Figure 12: Fixed-OPEX-CAPEX-share (FOCS)
Source: Bebenburg et al (2023)

At first glance, the mechanism may seem counterintuitive: OPEX that is treated as quasi-CAPEX receives a rate-of-return. This may feel unreasonable, but it is not. OPEX which is transferred into quasi-CAPEX does indeed receive a rate-of-return, but as it is quasi-CAPEX it also incurs cost of capital, because it has to be pre-financed.

Evaluation

Table *7* gives the assessment for FOCS in overview.

The scheme aims predominantly at efficiency. It primarily addresses the OPEX-CAPEX-incentive-bias. If successful, it sets incentives for the network operators to use the least-cost options, irrespective of whether these are OPEX- or CAPEX-based. The aim is that network operator also consider innovative new technologies or administrative options, which may be geared towards OPEX, instead of only the CAPEX option of investment in new assets. Thus, efficiency is evaluated positively.

FOCS does not directly aim for grid reinforcement. But as a side-effect of improved incentives to consider innovative solutions, FOCS accelerates grid reinforcement, partly because these innovative technologies do precisely that, and partly because innovative solutions may relieve congestion. Yet, FOCS has a counter-effect: as it addresses the CAPEX-bias, it sets incentives away from CAPEX and thus reduces incentives for direct network expansion. Thus, effectiveness is neutral or moderately positive.

The scheme would most likely improve affordability, as increased efficiency would lower the cost of the system and lower the cost for network users. Grid reinforcement might actually increase the costs, but the increase would be less than it otherwise might be.

Table 7: Item 1: Fixed OPEX CAPEX Share (FOCS)

Criterion	Assessment	Arguments
Effectiveness (supply security)	0/+	• Indirect: If more efficient OPEX-based technologies can achieve the same goals of grid reinforcement, while CAPEX is slow (planning & permitting issues), network congestion is addressed and thus grid reinforcement is actually accelerated.
Efficiency	++	• Promoting innovative least-cost-options (especially OPEX-based) is actually the main goal of FOCS.
Affordability	+	• Implementing least-cost options imply lower overall system costs. • FOCS affects the (discounted) revenue flow in time; this can have a negative impact on what consumers pay on balance.
Implementation	0	• Implementation details matter, especially the capitalization ratio. • Projects need to be demarcated and cross-subsidies need to be avoided.
Sustainability	0	• The effect is indirect: grid reinforcement implies more sustainability. But FOCS does not directly aim at sustainable solutions.

Although the mechanism seems new and at first glance somewhat unintuitive, implementation is actually not really challenging. Under the name of TOTEX regulation, first practical experience has been made in, e.g., the UK. Further experience with TOTEX regulation can be found in Italy, Australia and Portugal. Details need to be cleared; in particular:

- Scope of application. Should FOCS apply to entire divisions of the firm or to individual projects and, if so, to which projects?
- Depreciation. The life-duration of the artificially constructed quasi-CAPEX has to be determined.
- Capitalization rate. Bebenburg et al (2023) note that in practice, setting the capitalization rate close to the current CAPEX-OPEX share helps to avoid large changes (e.g. variations in tariffs). Under RIIO-1, Ofgem took into account the CAPEX-OPEX shares estimated by companies, as well as historical rates and the level of technological innovation for the purpose of setting capitalization rates. In some cases, Ofgem accepted companies' proposals to reduce the capitalization rates, which has no effect on the overall value of the allowed revenue but improves cash flows. For RIIO-2, capitalization rates are set ex-ante, based on forecast CAPEX proportions. Different capitalization rates are used for different types of regulatory expenditure categories.

FOCS does not explicitly aim at sustainability. Any effect on sustainability would only be indirect: accelerated grid reinforcement would improve sustainability.

4.3.2 Item 2: Flexshare (congestion or curtailment) in combination with FOCS

Description

Congestion and curtailment costs are both in a broader sense redispatch costs or in more recent terminology flexibility costs. These expenses are directly related to grid reinforcement: grid reinforcement reduces these expenses. This involves a trade-off: more costs for grid reinforcement implies lower flexibility costs and vice versa. To ensure that the network operator makes the right investment decisions, flexibility expenses and grid reinforcement should be subject to similar regulatory incentives.

In practice, flexibility expenses are incentivized for a very small part. For instance, in the Netherlands, for the TSO a maximum of 5% of congestion costs are incentivized. Germany has a similar approach. The problem is that flexibility expenses are volatile and to a large extent beyond the control of the network operator. Therefore, for the network operator flexibility expenses are risky. To deal with this risk, flexibility expenses are usually largely treated as cost-pass-through and are not part of the incentive regulation. The cost-pass-through deals effectively with the risk, but at the expense of lower efficiency as it lowers the incentives to reduce flexibility expenses, especially by grid reinforcement.

The key idea of this item is to increase the share of flexibility that is subjected to incentives of the regulation; following Meyer (2021), this may be called "flexshare". As pointed out, the challenge is to deal with the associated risk for the network operator. To reduce the risk, the flexshare can be combined with FOCS. Above, we explained that FOCS is a tool to address the CAPEX-bias. Under certain circumstances, as a side-effect, FOCS is also a tool for risk management. The mechanism flexshare plus FOCS is illustrated in Figure 13 below.

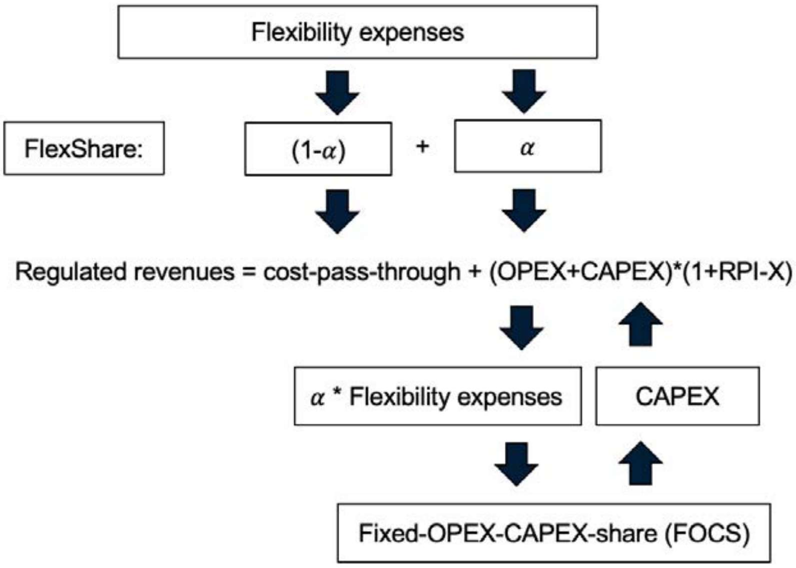


Figure 13: Flexshare plus FOCS
Source: own illustration, based on Meyer (2021). Note: The regulation, expressed by the line in the middle, has been substantially simplified for notational reasons.

The key idea is that flexshare takes a part α of the flexibility expenses (such as congestion or curtailment costs) out of the cost-pass-through and into the incentive regulation. At the same time, flexshare is subject to FOCS. As flexibility expenses are largely OPEX, application of FOCS turns a large part of these into quasi-CAPEX. The primary advantage of this is that it reduces the risk of volatile flexibility expenses. First, quasi-CAPEX is depreciated over a long period, such that fluctuations in one year are spread over many years. Second, this process would be repeated year after year; as a result annual fluctuations in flexibility expenses would start to level out over time. Third, if the allowed risk-adjusted rate-of-return on capital contains a risk premium, flexibility expenses turned into quasi-CAPEX also receive this premium. In sum, we can increase the incentives while not increasing the risk.

Evaluation

An overview of the assessment of the item Flexshare plus FOCS is provided in Table 8.

Overall, the item is promising. Both effectiveness and efficiency can be assessed positively. Incentives for grid reinforcement can be directly strengthened with incentives to lower congestion. Efficiency improves if the network operator faces a better trade-off between grid expansion and congestion costs.

The effect on affordability would likely be positive. If the system gets more efficient, costs will be lower. Changes in congestion costs can be large quantitatively; therefore, the effect on system costs and thus affordability can also be large. We note explicitly, that congestion costs also fluctuate significantly beyond control of the network operator. On the downside, if network operators face higher risk, sooner or later, this will be reflected in a higher risk-adjusted rate-of-return on capital.

Table 8: Item 2: Flexshare and FOCS

Criterion	Assessment	Arguments
Effectiveness (supply security)	++	• Incentives to reduce congestion and curtailment costs improve incentives to expand the network.
Efficiency	++	• Better incentives to reduce congestion and curtailment costs. • Better trade-off between CAPEX (grid expansion) and OPEX (congestion and curtailment costs).
Affordability	+	• Potentially substantial, if congestion costs can be significantly reduced. But this depends on the share that is incentivized. • FOCS affects the revenue stream in time, which may be negative for users. But volatility of congestion and curtailment will be less.
Implementation	– –	• It may be problematic to demarcate the flexshare part from the rest of the regulated company and avoid cross-subsidies. • Despite FOCS, incentivizing congestion and curtailment costs may increase the risks operators face. • We have no experience with the combination of flexshare and FOCS.
Sustainability	+	• Reduction of congestion and especially curtailment has a direct positive effect on sustainability.

Implementation is tricky and needs careful consideration. Experience with a bonus/malus system for congestion costs (in e.g. Germany) or network losses (in e.g. Great Britain) exists. As mentioned above, experience with TOTEX-regulation also exists (in Great Britain and Italy). However, to the best of our knowledge, we do not have experience with the combination of the two. In particular, we have no experience with FOCS as a risk-management tool. The effects of this item on risk for the firms need to be studied carefully.

Sustainability would gain; incentives to reduce congestion and especially RES-curtailment have a direct positive effect on sustainability.

4.3.3 Item 3: Bonus/malus for connection (DSO) and/or construction (TSO) time

The costs and benefits of the actions of network operators may be external. External means that costs and/or benefits are incurred by third parties (e.g. society as a whole or other system operators) and not by decision-makers. External benefits are usually not or weakly incentivized by the regulation. Incentive mechanisms can be used to incentivize projects with predominantly external benefits. Typically, an incentive mechanism looks as follows:

$$Inc_{i,t} = C_{i,t} + \alpha_i \cdot [W_t - R_x]$$

Here:

- i – network operator i
- t – year t; base year is t=0
- $Inc_{i,t}$ – Incentive (bonus/malus) in year t for network operator i
- $C_{i,t}$ – project-specific cost in year t for network operator i
- α_i – incentive parameter for network operator i
- W_t – welfare in year t
- R_x – reference welfare value at time x

Incentives for system operators are based on some kind of indicator for the welfare gain for society. The scheme aligns the objectives of the firm and society: if firms act to maximise profits under the incentive scheme, welfare increases. In this formulation, for the reference value, we use “R_x” with x to denote time. There are various options for x (eg. x=0, x=t-1, a weighted average of some years, etc.).

The incentive mechanism looks straightforward, but in practical implementation, details matter a lot. The main challenges are:

- Definition of project scope
- Indicators / metrics:
  - Output/welfare
  - Reference value
- Determination of the incentive parameters α_i.

Here, we suggest an incentive mechanism for the core goals in this study: grid reinforcement to accelerate the connection of RES and other network users. This goal has two separate aspects. First, facilitate connection to the network; for decentralized RES and most demand-side network users, this concerns the DSOs. Second, new connections may require grid reinforcement “deeper” in the network. Currently, this is primarily the concern of the TSO.

In this item, we suggest two related, but slightly different incentive mechanisms:

- A DSO-oriented incentive mechanism for timely connection. Strictly speaking, connection is not constrained to RES; if so desired, the mechanism can be differentiated to give RES priority. Ireland has experience in this direction.
- A TSO-oriented incentive mechanism for timely construction of grid reinforcement projects. NorNed, the DC-interconnector between the Netherlands and Norway, built around 2008 actually contained a bonus for timely construction (cf. DTe, 2004, p. 21, #121).

Evaluation

Table 9 gives the evaluation of this item in overview.

This item scores unambiguously positive on effectiveness, because it aims directly at the main goals of grid reinforcement: reduce congestion and accelerate connection. Yet, we should note that effectiveness depends strongly on the implementation; if targets and parameters are flawed, the mechanism is not effective.

The mechanism does not contribute much to efficiency. There is no explicit efficiency incentive for the expenses as such; it is not an efficiency mechanism.

As the bonus/malus applies only selectively, we would expect that the costs of the mechanism are likely comparatively low. Because the magnitude depends on the parameters, which are difficult to calibrate, the effect on affordability is a bit uncertain. A bonus/malus system implies higher risk for the network companies, which will somehow be translated into a higher risk-adjusted rate-of-return on capital. Moreover, if firms self-select projects, there will be an asymmetry bias towards the bonus-payment at the expense of network users. But since the mechanism applies only to a small part of the overall costs base, we would expect this effect to be moderate. Overall, we would expect the effect on affordability to be neutral.

Table 9: Item 3: Bonus/malus for connection time (DSO) and/or construction time (TSO)

Criterion	Assessment	Arguments
Effectiveness (supply security)	++	• If well designed and if the bonus is sufficiently strong, it will set effective incentives for timely grid reinforcement.
Efficiency	0	• The mechanism does not set efficiency incentives.
Affordability	0	• Bonus applies selectively; cost will likely be modest
Implementation	–	• Design (esp. of reference values) is tricky • Selection of projects and setting effective parameters requires data • Perverse incentives with self-selection of projects
Sustainability	+	• Grid reinforcement reduces congestion and RES curtailment • The scheme can prioritize RES

Implementation is challenging. First, it is not clear which projects would qualify. If the firms propose projects themselves, the mechanism may lead to perverse incentives, because the firms will select projects with easily achievable targets. Second, and related to the first point, it will be challenging to set the target values. Clearly, the regulator is at an informational disadvantage vis-à-vis the firm. For the TSO projects, it might be useful to rely on the information of the system development plan (SDP; see item 6, section 4.3.6). Many projects are described in the SDP and presumably this information can be used to attach a target date to finish construction, perhaps setting out a roadmap with different steps. For the DSOs, experience values may set an overall target for connection, starting from the moment of request.

The effect on sustainability would be positive, as the reduction of congestion and RES-curtailment and possibly accelerated connection of RES directly improves sustainability. Yet, the positive effect on sustainability is limited because the mechanism is not exclusively geared to sustainability targets.

4.3.4 Item 4: Incentive mechanism on outage costs

Description

As an extension of the mechanisms presented in item 3, we suggest an incentive mechanism for the wider external benefits of reduced outage costs. The main principles of incentive mechanisms as such are as explained above in item 3; the concept is similar, but the metric is different.

Here, the external benefits are defined very broadly. Grid reinforcement increases network reliability and availability; thus, users will face less outage. Outage could be RES, unable to feed-in due to congestion; or it could be factory, which cannot produce, because it is not connected to the network. For welfare indicators two options come to mind. First, less outage leads to less opportunity costs, which can be an indicator for economic welfare. Second, more in line with the energy transition, less outage often means less CO2-emission (e.g. because RES does not need to be curtailed).

Evaluation

The evaluation of the incentive mechanism on outage costs can be found in Table 10.

The mechanism aims at increasing external benefits and reducing external opportunity costs. As these are derived goals of grid reinforcement, the mechanism scores positive on effectiveness. The drawback follows immediately with implementation; clearly, calculating economic welfare will be very challenging. The same trade-off applies to the slightly less ambitious goal of using (avoided) CO2-emissions as the output target. Moreover, we are not aware of comparable practical experience with this scheme.

The mechanism does not contribute much to efficiency. There is no explicit efficiency incentive for the expenses as such; it is not an efficiency mechanism.

Table 10: Item 4: Incentive mechanism on outage costs

Criterion	Assessment	Arguments
Effectiveness (supply security)	+	• If designed well, the scheme is effective, as it increases external benefits and reduce external opportunity costs. • The effects for grid reinforcement are only indirect
Efficiency	0	The mechanism does not set efficiency incentives.
Affordability	–	• Affordability fully depends on the parameters. As the metrics (additional welfare) may be large, the bonus (and possibly malus) can be large as well.
Implementation	– –	• Unambiguous calculation of external opportunity costs will be difficult and subject to legal challenges. • In general, regulation theory and practice have little experience with incentive schemes for broadly defined external welfare. • The scheme may be risky for the network operators.
Sustainability	+	• The scheme can focus on welfare in general, which is not per se related to sustainability. But, if the metric is (avoided) CO2-emission, it will be strongly related to sustainability.

The effect on affordability depends strongly on the parameters. Depending on the incentive parameters, the bonus/malus can be very large. This implies that the mechanism can potentially affect the cost of the system and the risk for the firms quite substantially.

The effect on sustainability depends on the targets defined in the mechanism. The mechanism can be designed to support sustainability targets, especially of course, if the (avoided) CO2-emissions is the target output. On the other hand, economic welfare in general is not per se related to sustainability goals.

4.3.5 Item 5: KPI-based smart grid development

Description

The energy transition is closely associated with the development of smart grids. Smart grids aim for two related goals. First, smart technologies and rules (like smart pricing which requires smart meters) can reduce the need for expanding the network, for the same level of network reliability. Second, as indicated by the examples of the smart-grid-index below, smartness can aim directly for sustainable solutions (eg. connection of RES). Smart grids seem to be more associated with the DSO level than with the TSO level.

The development of smart grids can be indicated with a smart-grid-index (SGI). An SGI can be used to incentivize the development of a smart grid. It can be the metric in a bonus/malus system in the regulation (see the formula in section 4.3.3). Beating a reference value would lead to a bonus and reverse. Alternatively, the SGI can be used as a benchmark to compare different network operators, which can somehow be linked to a bonus-system. Still alternatively, the SGI can be used for a published ranking; the incentive for the companies would then be public appreciation.

Several projects try to make a smart grid development index using a set of key performance indicators (KPIs). Two examples may illustrate. We note explicitly that these examples are mere rankings; they are not intended to be applied for incentive mechanisms for the regulation.

The GMI (grid modernization index) developed by Gridwise Alliance,[7] which is a consortium with a wide group of members from stakeholders from the electricity industry in the USA. The GMI makes a ranking (with a number) for states of the USA. The calculation relies on four pillars (which have more detailed subcategories):

- State policy
- Customer adoption and options
- Grid optimization
- System design and regional coordination

The GMI acknowledges five drivers of smart grids:

- Large-scale deployment of wind and solar power
- Distributed energy resources
- Electrified transportation
- Strengthened grid resilience
- Electrified buildings

Another example is the Smart Grid Index developed by the SP Group, a utility group in the Asia Pacific based in Singapore.[8] The so-called SGI-2022 makes a ranking of 94 utilities in 39 countries/markets. Hence, this SGI is an international comparison on a company base. The SGI relies on seven dimensions of a smart grid:

1. Monitoring & control
2. Data analytics
3. Supply reliability
4. Integration of distributed energy resources (DER)
5. Green energy
6. Security
7. Customer empowerment & satisfaction

Evaluation

The assessment of KPI-based smart-grid development is shown in Table 11.

The key advantage of this scheme is that it can be geared easily towards sustainable outcomes. The SGI examples provided above suggest that smart grids are associated with sustainability; renewables energies and electric vehicles play a prominent role. Yet, we stress that

---

[7] https://gridwise.org/.

[8] https://www.spgroup.com.sg/sp-powergrid/overview/smart-grid-index.

sustainability is not the exclusive goal of smart grids. If so desired, more key performance indicators linked to sustainability goals can be included in the smart-grid-index.

Implementation is more challenging than it may seem. The flexibility in the selection and definition of the KPIs is also the main downside of the item: basically, anything goes. The selection and definition of the KPIs also determine the direction of grid development and should therefore be chosen very carefully. As is also clear from the examples above, a smart grid index contains more than merely grid reinforcement; eg. RES integration is not grid reinforcement. Therefore, an SGI likely includes metrics that are not related to grid reinforcement.

For some KPIs, it may be particularly challenging to relate the KPI-score to underlying costs; setting the parameters for the level of the bonus or malus may be challenging.

Effectiveness may be modest. Smart grids are only indirectly related to grid reinforcement, mostly via reliability and supply security. The selection and definition of the KPIs determine the direction of grid development, which may or may not lead to grid reinforcement.

Table 11: Item 5: KPI-based smart grid development

Criterion	Assessment	Arguments
Effectiveness (supply security)	0	• Whether grid reinforcement will be achieved, depends critically on the selected KPI in the smart grid index. Can be an ineffective catch-all. • Smart grid is only indirectly related to grid reinforcement.
Efficiency	–/+	• If well designed, the scheme would set incentives for efficient development of smart grids. • However, design flaws might cause significant inefficiencies.
Affordability	0	• Not clear and depends strongly on the parameters. Presumably, however, fluctuation of the metrics and the level of the bonus might be modest, such that the cost of the scheme are low.
Implementation	–	• Definition of the smart grid index is key and will be challenging and open to debate. • Selection and weighing of the KPI determine the outcome. • Depending on the SGI, possible conflicts with other schemes
Sustainability	++	• Smart grids are closely related to sustainability.

The effects on efficiency are ambiguous, as these depend strongly on the design of the incentive mechanism. In particular, if the selection of KPIs is flawed, the outcome is bound to be inefficient.

The cost and quantitative effect of this item are likely moderate, such that the effect on affordability will be moderate.

4.3.6 Item 6: System Development Plan (SDP)

Description

Coordination of system and network development has gained attention in recent years. The primary interest here is that better coordination improves network usage and thereby reduces the need for grid reinforcement.

The McNulty report from 2011 may have been a key background here. It was written for the British government and examined the efficiency of the British railway system, drawing two main conclusions: 1) the British railway system was (in 2011) significantly less efficient than comparable railway systems, 2) the main cause for this inefficiency was a far-reaching fragmentation of the system, leading to misaligned incentives. The report makes many recommendations for action: but above all, improved system coordination.

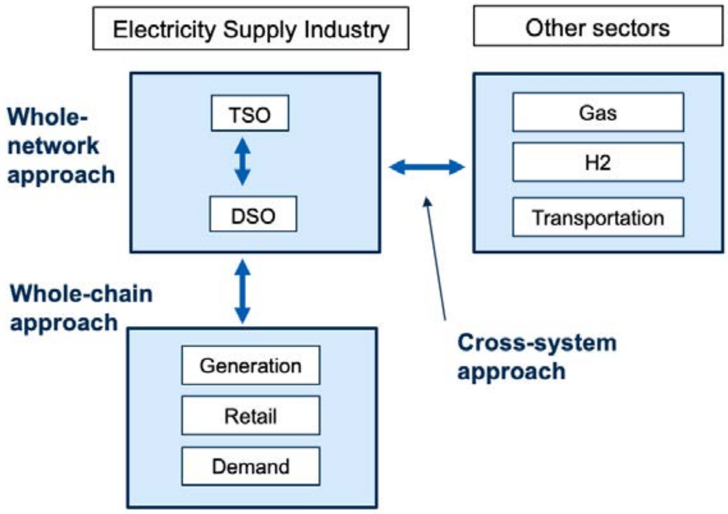
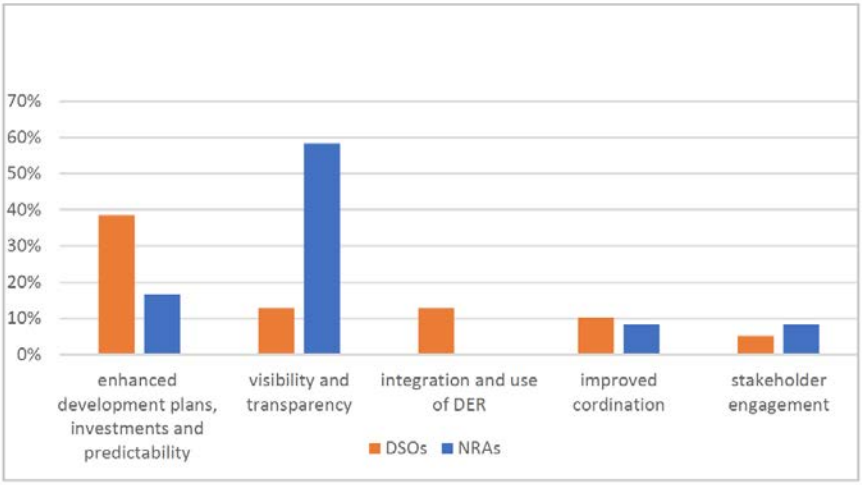


Figure 14: Whole System Approach
Source: Own illustration based upon CEER (2020)

The Council of European Energy Regulators (CEER, 2020) acknowledges the need for further coordination in energy systems and calls this whole system approach (WSA). Palovic and Poudineh (2022) consider the WSA, which they coin as “polygrid 2050” and explore the required institutions in some detail. CEER (2020) distinguishes between three levels of WSA, each corresponding to a particular interface where coordination problems can occur: 1) whole-network approach, 2) whole-chain-approach, and 3) cross-systems approach. These three versions of system coordination are illustrated in Figure 14.

One way to improve system coordination is to design and use a System Development Plan (SDP), involving relevant stakeholders. CERRE (2021, p. 54 ff.) calls this indicative planning.

The survey by CERRE (see Figure 15) indicates that the DSOs find improved network planning and the NRAs visibility and transparency the main advantage of indicative planning. The latter is noteworthy: the information in a System Development Plan can be used for regulatory purposes. It should be noted that CERRE considers a sector-specific network development plan (here for the electricity network), not a whole-system development plan. Separate network development plans are well-established practice meanwhile; a system development plan is an extension of network development plans. An example is the development of an SDP for Germany in a large project involving many stakeholders (DENA, 2020), with system optimization as the primary goal.



	DSOs	NRAs
Enhanced developments plans, investments and predictability	39%	16%
Visibility and transparency	12%	59%
Integration and use of DER	12%	0%
Improved coordination	10%	9%
Stakeholder engagement	5%	9%

Figure 15: Perceived advantages of indicative planning.
Note: The percentages indicate the percentage of total respondents reacting positively to the stated advantage.
Note: Table by author; numbers in the table are approximate.
Source: CERRE, 2021, p. 54, fig. 21.

Evaluation

The assessment of this system development plan (SDP) is presented in Table 12 below.

Overall, the assessment of the system development plan is moderately positive. There are actually no real drawbacks. The SDP reduces the need for investment. However, actual investment requires an additional step beyond making the SDP: the SDP itself does not set incentives. Sustainability would gain from this scheme, if (and only if) the SDP is geared towards sustainable outcome. Both efficiency and affordability would improve; better coordination improves overall system efficiency, quite likely avoid unnecessary investment and thus lower the costs of the system. Moreover, we would expect that the costs of making the SDP are relatively low.

An additional advantage is that the information and in fact the investment plans by the network operators specified in the SDP can be used for other incentive schemes, e.g. the budget approval and bonus-malus-systems for connection or construction time.

Table 12: Item 6: System Development Plan

Criterion	Assessment	Arguments
Effectiveness (supply security)	0/+	• Better coordination reduces the need for investment and thus relieves the problem. • The SDP itself does not set incentives; it only sets out the need for investment.
Efficiency	+	• The aim is to improve overall system efficiency (whole system approach). • The SDP does not set incentives for the network firms itself; it is primarily a coordination tool.
Affordability	+	• The cost will be comparably low. • Coordination aims to reduce investment requirement and will thus lower system costs
Implementation	+	• Implementation as such is straightforward, especially as NDPs already exist. • Details of the governance (e.g. selection of stakeholders, voting rights) may be tricky.
Sustainability	+	• The scheme is indirect, but the SDP can easily be geared towards a more sustainable outcomes if so desired

Implementation seems manageable (cf. DENA, 2020). It will be a technical challenge to set up a detailed system development plan. Apart from the technical challenge, the institutional challenge is to involve relevant stakeholders. Which stakeholders and what are their roles and responsibilities? For this question, we need to distinguish between the planning and the construction phase. In the planning phase, stakeholders can provide data and projections; moreover, which third parties can be involved in constructing a part of the SDP and how?

4.3.7 Item 7: Cost-benefit-sharing

Description

The actions of a network operator have direct effects on other actors in the overall system and vice versa. What is optimal for individual grid operators can therefore conflict with the economic goal of whole system optimization. CEER (2018, p. 29) notes that: "The WSA requires the DSO to look at net benefits on a wider basis than their own grid." The regulatory challenge here is, as CEER (2018, p. 29) notes: "in some situations, externalities not fully priced in must be considered by regulators."

The interaction between various actors within and between the sectors creates spillover effects (external effects): the actions of one actor affect the outcome of another actor. If these effects are not monetized, they may lead to misaligned incentives, as individual actors optimize their own interest: too much or too little investment in the wrong technology at the wrong place. A more detailed analysis of misaligned incentives can be found in Brunekreeft (2015).

One way to address the problem of misaligned incentives is by a complete set of contracts with cost-benefit sharing. We call this a cross-network-cost-allocation mechanism (CNCA). The idea of a CNCA bears resemblance with the notion of cross-border-cost allocation (CBCA), a European mechanism to promote investment in projects of common interests (PCIs), worked out by ACER (2015). The key idea of a CBCA is that interconnectors typically have cross-border benefits for parties who do not incur costs. If parties do not consider these external benefits, not all interconnectors with overall net benefit will be built. For example, say country A considers investing in a line with a cost of 100 and a benefit for country A of 90. Assume the line has a cross-border benefit in country B of 20. Although the overall net benefit is positive (10), the line will not be built if country A pays all the costs, because the net benefit of country A alone is negative (-10). The CBCA-rule aims to internalize this externality, by making country B contribute to the costs (some amount between 10 and 20). We can use the same idea in a cross-network-cost-allocation mechanism. Ireland provides some experience with joint TSO-DSO-incentives, which may go in this direction.

Evaluation

Table 13 presents the assessment of the cost-benefit-sharing scheme.

Table 13: Item 7: Cost-benefit-sharing

Criterion	Assessment	Arguments
Effectiveness (supply security)	+	• The scheme is indirect. it aims to optimize and reduce overall investment requirement; it does not explicitly aim to set incentives for network investment. • Experience with ACER's CBCA suggests that the mechanism is not widely used.
Efficiency	++	• Provided the system is well-designed, the system would improve whole system efficiency.
Affordability	+	• The aim is to optimize and reduce investment needs of the electricity network, but also of networks of other sectors (hydrogen, gas).
Implementation	– –/–	• In this context, a CNCA is new and we have no experience to fall back on. Experience might come from similar systems in other sectors. • Determining the level of the cross-network costs and benefits will be a challenge. • Implementation will be less challenging for selective project-wise cost-benefit sharing contracts.
Sustainability	0	• The scheme generally aims to improve coordination (whole system approach) and reduce investment requirements. Sustainability effects are only indirect.

Efficiency can be assessed strongly positive: creating effective incentives for network operators to coordinate the overall system and consider effects on other parts of the system (look beyond their own network), would improve overall system efficiency.

The main drawback of the scheme is the implementation. First experiences with the above-mentioned CBCA were somewhat disappointing (ACER, 2016). The main challenge for CNCA would be first and foremost to calculate the costs and benefits of the spillover effects. These costs and benefits subsequently need to enter the regulation of the network companies. To make the system effective, these costs and benefits need to be incentivized.

There may be different approaches. One approach would be a systematic attempt to internalize all external effects. This is clearly very ambitious and challenging. Another approach would to be allow ad-hoc, unsystematic cost-benefit-sharing for selected projects. There is a lot of experience with cost-benefit-sharing models, which are normal in other economic sectors. This is clearly less challenging.

The scheme has an indirect effect on grid reinforcement, as better coordination aims to reduce investment needs. Effectiveness may be impeded if implementation is poor, by lack of experience. We would expect a positive effect on affordability, as improved whole-system optimization would lower the costs of the system. Lastly, sustainability is not explicitly included in the scheme. It would merely improve indirectly if the congestion problem is reduced.

4.3.8 Item 8: Rate-of-return adders for large and risky investment projects

Description

A temporary rate-of-return adder (aka investment bonus, priority premium or top-up) for specific types of investment would be an effective investment incentive. A higher rate-of-return for investment accelerates investment activity (cf. Borrmann & Brunekreeft, 2020). Investment bonuses are not uncommon in incentive regulation and are used in e.g. the USA, France, Italy and Austria.

Here we have constrained application to large and risky investments. Large because these projects can be identified and demarcated; risky, as a relatively high project-specific risk is the usual justification for top-ups (see e.g. ACER (2014)). This constraint of application is not strict; certainly, application could be wider and could for instance include all new investments.

Furthermore, we note that the analysis below concerns the onshore grid. Evaluation for offshore may be significantly different.

Evaluation

Table 14 below presents the assessment of this item.

The overall assessment is average on all accounts. The rate-of-return adder will accelerate the selected project, but all other investments are not affected. Hence, effectiveness might be limited. Large and risky projects are only indirectly related to sustainability; they may or may not relieve congestion or connect new RES. Therefore, the effect on sustainability is ambiguous. The scheme may increase inefficiency. First, it is biased towards large and risky projects, possibly at the expense of other projects. Second, it may create a CAPEX-bias, because the rate-of-return adder concerns CAPEX, but does nothing for OPEX-based projects.

The overall system gets more expensive, but probably only moderately so; the adder is likely small and applies only to selected projects.

Implementation is probably the most problematic criterion here. For a different context, art. 13 of the Regulation 2013 for Projects of Common Interest (PCIs) aims to improve incentives for PCIs with higher systematic risk with *inter alia* rate-of-return adders. These should be requested by the project promoter at the national regulator. ACER (2014) developed a 7-steps procedure for these requests, where the burden of proof is on the project promoter:

- Step 1: Availability of information on project risks
- Step 2: Identification of the nature of the risk from a regulatory point of view
- Step 3: Risk-mitigation measures by the project promoters
- Step 4: Assessment of systematic risk and definition of cost of capital
- Step 5: Risk-mitigation measures already applied by NRAs
- Step 6: Risk quantification
- Step 7: Comparable project

Table 14: Item 8: Rate-of-return adders for large and risky investment projects

Criterion	Assessment	Arguments
Effectiveness (supply security)	+	• A higher rate of return will accelerate investment. • Normal grid reinforcement or smart projects are not included.
Efficiency	–	• It sets a bias for large and risky projects. • Creates a CAPEX bias.
Affordability	0	• The overall system gets more expensive
Implementation	0	• Selection of large and risky projects is cumbersome and bureaucratic
Sustainability	0	• It helps sustainability only indirectly

Note: This concerns onshore grids; offshore lines are excluded from the analysis. An assessment for offshore lines may actually differ.

Three challenges stand out. First, it will be difficult to demarcate qualifying investment projects. The danger of a slippery slope obviously exists: investors will always try to argue in favour of the higher rate-of-return and once precedents are set, these should be honoured a next time. Second, it is not always clear what precisely the higher risks are and whether these are systematic. Third, whereas the calculations of the risk-adjusted WACC rests on a solid theoretical and empirical base, such a base lacks for the adders, which seems to be a mere matter of negotiations.

5 Overall assessment

This section collects the insights of section 4 to come to an overall assessment. This overall assessment is intended to spur further discussion.; In this study, we do not intend to give ready-to-eat recommendations.

The focus of this study is to improve incentives for grid reinforcement in the network regulation. This is the main criterion in the discussion and assessment. However, this criterion may conflict with other criteria.

It should be stressed that the regulatory incentives discussed in this study are merely a small part in a wider discussion on grid reinforcement. There are limits to what incentives in the regulation can do. A larger part of the problem of grid reinforcement lies in planning and permitting. These problems are not solved by monetary incentives in the regulation and should be addressed elsewhere.

We note explicitly that there is no silver bullet; all the options discussed in this study face trade-offs. This gets particularly clear in the trade-offs in the energy policy triangle: supply security, affordability and sustainability.

5.1 Base models

Table 15 below shows the evaluations of the base models in overview.

Table 15: Overview base models

Criterion	**Investment budget**	**CAPEX-true-up (TSO)**	**CAPEX-true-up (DSO)**	**Price/revenue-cap**
Aiming at	**TSO**	**TSO**	**DSO**	**DSO**
Effectiveness (supply security)	+	++	++/+	0
Efficiency	+	–	–/0	++
Affordability	– –	–	–	+
Implementation	–	–/+	+	+
Sustainability	++	+	+	0

The investment budget is essentially an output-based approach. A key advantage is that incentives for grid reinforcement can easily be geared towards sustainability output targets (and, if so desired, other targets). The main disadvantage are the perverse incentive to inflate the requested budget and the perverse incentive for strategic underspending once the budget has been approved. This would increase system costs and affect affordability negatively. Implementation is a real challenge because the budgets have to be approved by the regulator.

The key advantage of the base model CAPEX-true-up (for both TSO and DSO) is the potential to promote and accelerate grid reinforcement, in particular with CAPEX-based network expansion. As this model relies on a cost-pass-through, the downside is that high effectiveness might come at the expense of low efficiency. Efficiency incentives can be strengthened with benchmarking. The use of benchmarking will be different for TSO and DSOs (cf. Haney & Pollitt, 2013); national benchmarking of DSOs is less challenging than international benchmarking of the TSO. Stricter application of benchmarking would increase efficiency incentives, but might impede the investment incentives, which counters the investment incentives of the CAPEX-true-up to some degree. Therefore, the efficiency criterion might be better, but the effectiveness criterion will be less favourable for the DSOs than for the TSO. As benchmarking of DSOs is less challenging than for the TSO, implementation will be somewhat more positive for the DSOs than for the TSO. We would expect that the effect of the base model CAPEX-true-up on sustainability is positive as an indirect effect of accelerated grid reinforcement.

The Price/revenue-cap approach aims explicitly at efficiency incentives; this comes at the expense of relatively weak incentives for grid reinforcement. Much depends on the power of the RES-expansion mechanism. The focus on efficiency leads to a positive score on affordability, because of the relatively low system costs. As a side-effect of the relatively weak incentives for grid reinforcement, and absent other incentives, the effect on sustainability is weak as well.

5.2 Output-oriented regulatory elements

An overview of the assessment of the OOR-elements can be found in Table 16. The OOR-items associated with the numbers in the table are:

- Item 1: FOCS (Fixed OPEX CAPEX Share)
- Item 2: Flexshare (congestion or curtailment) in combination with FOCS
- Item 3: Bonus/malus for connection time (DSO) and/or construction time (TSO)
- Item 4: Incentive mechanism on outage costs
- Item 5: KPI-based smart grid development
- Item 6: System Development Plan (SDP)
- Item 7: Cost-benefit-sharing
- Item 8: Rate-of-return adders for large and risky investment projects

Table 16: Overview of the items for output-oriented regulatory (OOR) elements

Criterion	1	2	3	4	5	6	7	8
Effectiveness (supply security)	0/+	++	++	+	0	0/+	+	+
Efficiency	++	++	0	0	–/+	+	++	–
Affordability	+	+	0	–	0	+	+	0
Implementation	0	– –	–	– –	–	+	– –/–	0
Sustainability	0	+	+	+	++	+	0	0

Items 2 and 3 stand out in effectiveness: they focus on accelerating grid reinforcement and therefore support supply security and network availability. The reason is that these items directly address the problem: they aim directly at reducing congestion and accelerating (RES) connection.

These eight items have been selected because they somehow support grid reinforcement. Unsurprisingly thus, none scores negative on effectiveness. However, some (items 1, 7 and 8) contribute indirectly: they do not promote network expansion as such, but reduce the need for investment. For items 4, 5 and 6, the incentives for grid reinforcement are unclear or relatively weak.

We see that items 1, 2 and 7 score high on efficiency. This is for two reasons: items 1 and 2 rely on FOCS, which aims at efficiency; in addition, item 2 strengthens the incentives to reduce congestion and curtailment cost. Item 7 improves efficiency by the incentives for systemwide coordination (whole system approach).

By and large, we expect the effect on affordability between neutral and moderately positive. Of course, investment for network expansion as such will increase the costs of the system, which affects affordability negatively. In the analysis we ignore this unavoidable cost increase. More relevant is that costs may be unnecessarily high, thus affecting affordability negatively. From this perspective, none of the items score very negative on affordability. In fact, high efficiency and avoiding investment by better coordination (items 6 and 7) reduce the increase in costs and is positive for affordability. We see one notable exception. The potentially large effects of the metrics in item 4 (welfare changes) are uncertain; consequently, the potentially large effect on the bonus-malus payment is uncertain as well. We consider this a negative risk for affordability.

At this stage of the energy transition, grid reinforcement aims to reduce congestion and accelerate connection. This will benefit a wide group of network users, but in particular renewable energy suppliers (RES), with faster and better network access. Some of the items above can prioritize RES intentionally. Generally, grid reinforcement works out positively on sustainability.

Item 5 (KPI-based smart grid development) scores high on sustainability. Smart grids are closely associated with sustainability. Targeted selection of smart grid indicators could further strengthen the goal of sustainability. Items 2, 3, 4 and 6 support sustainability indirectly, mainly because of the effect of grid reinforcement on congestion and connection. In some cases, the item (esp. 3 and 6) could prioritize sustainability targets. We note that the contribution of items 1, 7 and 8 to sustainability is relatively weak; these instruments do not aim explicitly for sustainability targets and any effects in this direction would be a positive side-effect.

Practical implementation may be challenging. With one exception, all the items score low on implementation, suggesting challenges. The positive exception is item 6: the system development plan is an extended network development plan and there is already experience with network development plans. Items 2, 4 and 7 may be a significant challenge. For item 4, data availability will be a practical challenge. To the best of our knowledge, there is no or hardly any practical experience with items 2 and 7 in the context of electricity network regulation. To reduce complexity, item 7 could be started off in a reduced form. A reduced form would be selected cases of cooperation with cost-benefit-sharing, instead of a far-reaching full regulatory approach.

Summing up, items 1, 6 and 8 have moderate effects, but do not entail severe trade-offs. The effects for grid reinforcement may be moderate, but they could be implemented without risk. As always, details matter and should be considered carefully.

Item 7 incentivizes network companies to take account of effects beyond the network and support whole-system optimization. It reduces investment needs and improves system efficiency. Yet, the contribution to sustainability is indirect. To reduce complexity, it might be best to start off with selected cases of cost-benefit-sharing to facilitate and promote cooperation.

Item 4 seems farfetched for now. Implementation difficulties, especially data availability, may be too much of a hurdle. Item 5 is potentially promising, but may be in conflict with other parts of the regulation and it may not do much for grid reinforcement. On the other hand, it may be attractive to promote sustainability.

Items 2 and 3 are promising. Both do directly what they are intended to do: grid reinforcement. However, both items may face implementation challenges, where details need to be considered very carefully.

6 Concluding remarks

Regulation theory and practice are once again changing. First, we observe in many countries a shift in focus away from efficiency-oriented towards investment-oriented regulation. This is not because efficiency-oriented regulation would not work. It does work: it sets incentives to improve efficiency. But the goals have changed; in particular, the energy transition requires adjustment and expansion of the electricity networks. To this end, efficiency-oriented regulation is not well-equipped and the search now is for investment-oriented regulation.

A second change in the regulation is the development of output-oriented regulation (OOR), which supplements the base regulation with revenue elements that reflect the achievement of specifically determined regulatory output targets or performance. Output-oriented regulation can incentivize activities that require cost increases and upfront expenditures and it can capture external effects (cf. Brunekreeft et al, 2020a).

This study captures both developments. It presents and evaluates a variety of regulatory approaches aiming for grid-reinforcement. First, four base models were discussed:

- Investment budgets
- CAPEX-true-up (TSO)
- CAPEX-true-up (DSO)
- Price/revenue-caps

The first two aim primarily at the TSO-regulation, and the latter two at DSO-regulation.

Second, the study discusses a selection of eight output-oriented regulatory elements with which the base models can be extended:

- Item 1: FOCS (Fixed OPEX CAPEX Share)
- Item 2: Flexshare (congestion or curtailment) in combination with FOCS
- Item 3: Bonus/malus for connection (DSO) and/or construction (TSO) time
- Item 4: Incentive mechanism on outage costs
- Item 5: KPI-based smart grid development
- Item 6: System Development Plan (SDP)
- Item 7: Cost-benefit-sharing

- Item 8: Rate-of-return adders for large and risky investment projects

The lists with base models and OOR-elements are not exhaustive. Certainly, other options are available and worth discussing. More options can be found in the long list in the appendix to this report.

In conclusion, we may reflect on what this means for regulation in the Netherlands. How big and complex are the steps necessary to implement the suggested models?

A stronger focus on an approach with CAPEX-true-up will be least complex. The current TSO-regulation already has a CAPEX-true-up approach for large investment; the model CAPEX-true-up (TSO) would extend this approach to a wider investment base, not change something structurally. The current DSO-regulation is a price-cap approach (with a RES-expansion mechanism). A move towards the CAPEX-true-up (DSO) model is a structural step and would constitute a significant change in the regulation. However, as the CAPEX-true-up is partly already in effect for the TSO, implementing a similar approach also for the DSOs would be a fairly straightforward step.

The CAPEX-true-up approach is not very complicated, neither for the companies, nor for the regulator. More challenging will be application of benchmarking, which is important in this model. However, the Netherlands can rely on many years of experience with benchmarking for both the TSO and DSOs. The primary focus of the CAPEX-true-up approach is on grid-reinforcement; therefore, we expect only moderate need for additional OOR-elements. One notable exception: this approach suffers from the CAPEX-bias; it may be necessary to address this, e.g. with FOCS.

Widening the scope for output-based investment budgets for the TSO would be a significant step in the regulation. Implementation is challenging. The regulator would have to check and approve the business plans for the requested investment budgets. Moreover, the regulator would have to address the perverse incentive for strategic underspending once the budget is approved. The use of OOR-elements is somewhat special in this case. First, the investment budget *is* output-based. Thus, depending on the specification of the outputs, OOR-elements can be implicitly part of the base model, in which case we would not need additional OOR-elements. Those elements would be redundant. Second, if well designed, additional OOR-elements can help address perverse incentives for strategic underspending. In particular, the bonus-malus schemes (like in OOR-item 3) can link payment of the budget to predefined milestones. Possibly the information contained in a system development plan (item 6) can help.

Lastly, the base model Price/revenue-cap relies on the current approach for DSO-regulation in the Netherlands; therefore, this model does not require a structural regulatory change. However, this model focusses on efficiency incentives and not on investment incentives; it does not support grid reinforcement very well. Investment incentives (and possibly other targets) should be strengthened with additional selected OOR-elements; in particular, bonus-malus-schemes to accelerate construction and connection may set powerful incentives. As explained in this study, using additional OOR-elements is possible, but it would require further regulatory steps and it would increase complexity. If the use of additional OOR-elements intensifies, various incentives might start to overlap or be in conflict.

7 References

ACER (2014), Recommendation of ACER No. 03/2014 of 27 June 2014 on incentives for projects common interest and on a common methodology for risk evaluation. ACER, June 30, 2014.

ACER (2015), Recommendation of ACER No. 5/2015 of 18 December 2015 on good practices for the treatment of the investment requests, including cross border cost allocation requests, for electricity and gas projects of common interest, ACER, December 18, 2015.

ACER (2016), *Consolidated report on the progress of electricity and gas projects of common interest for the year 2015*, ACER, July 22, 2015.

ACM (2021a), Methodebesluit Transporttaken TenneT 2022-2026, ACM, Den Haag.

ACM (2021b), Methodebesluit regionale netbeheerders elektriciteit 2022-2026, ACM, Den Haag.

ACM (2021c), Methodebesluit Systeemtaken TenneT 2022-2026, ACM, Den Haag.

Ai, C. & D.E.M. Sappington, D.E.M. (2002), The Impact of State Incentive Regulation on the U.S. Telecommunications Industry, *Journal of Regulatory Economics,* Vol. 22, No. 2, pp. 107–132.

Alvareza, P.J., Stephensa, D. & Costello, K.W. (2022), Alternative ratemaking in the US: A prerequisite for grid modernization or an unwarranted shift of risk to customers?, *Electricity Journal*, Vol. 35, pp. 1-7.

Armstrong, M. & D.E.M. Sappington D.E.M. (2005), Recent Developments in the Theory of Regulation, in: Armstrong, M., und R.H. Porter, *Handbook of Industrial Organization*, Vol. III, North-Holland, Amsterdam.

Averch, H. & Johnson, L.L. (1962), Behavior of the firm under regulatory constrain. *American Economic Review*, Vol. 52, No. 5, pp. 1052–1069.

Bauknecht, D. (2011), Incentive Regulation and Network Innovations. EUI Working Paper RSCAS 2011/02 & IRIN Working paper. Öko-Institut Freiburg.

Bebenburg, C. von, Brunekreeft, G. & Burger, A. (2023), How to deal with a CAPEX-bias: fixed-OPEX-CAPEX-share (FOCS), *Zeitschrift für Energiewirtschaft*, Vol. 47, No. 1, pp. 54-63.

Beesley, M. E. & Littlechild, S.C. (1989), The regulation of privatized monopolies in the United Kingdom, *RAND Journal of Economics*, Vol. 20, pp. 454–472.

Biancardi, A., Di Castelnuovo, M. & Staffell, I. (2021), A framework to evaluate how European Transmission System Operators approach innovation, *Energy Policy*, Vol. 158, pp. 1-14.

Borrmann, J., & Brunekreeft G. (2020), The timing of monopoly investment under cost-based and price-based regulation, *Utilities Policy*, Vol. 66, pp. 1-10.

Borrmann, J. & Finsinger, J. (1999), *Markt und Regulierung*, Verlag Vahlen, München.

Braeutigam, R. (1981), Regulation of multiproduct enterprises by rate of return, mark-up, and operation ratio. *Research in Law and Economics*, Vol. 3, pp. 15–38.

Brunekreeft, G. (2015), Network unbundling and flawed coordination: Experience from electricity, *Utilities Policy*, Vol. 34, pp. 11-18.

Brunekreeft, G. & Meyer, R. (2016), Anreizregulierung bei Stromverteilnetzen: Effizienz versus Investitionen, *Perspektiven der Wirtschaftspolitik*. Vol. 17, No. 2, pp. 172-187.

Brunekreeft, G., Kusznir, J. & Meyer, R., (2020a), The emergence of output-oriented network regulation, *Oxford Energy Forum*, Issue 124, pp. 34-38.

Brunekreeft, G., Kusznir, J. & Meyer, R. (2020b), Output-orientierte Regulierung – ein Überblick, *Bremen Energy Working Papers* No. 35, Jacobs University Bremen.

Brunekreeft, G., Buchmann, M., Kusznir, J., Meyer, R., et.al. (2021), *Further developing incentives for digitalisation and innovation in incentive regulation for TSOs*, Study prepared for TransnetBW, Stuttgart.

Cambini, C. & Rondi, L. (2010), Incentive regulation and investment: Evidence from European energy utilities, *Journal of Regulatory Economics* Vol. 38, pp. 1–26.

Cambini, C., Meletiou, A., Bompard, E. & Masera, M. (2016), Market and regulatory factors influencing smart-grid investment in Europe: Evidence from pilot projects and implications for reform, *Utilities Policy*, Vol. 40, pp. 36-47.

CEER (2018), Cyber Security Report Cybersecurity Report on Europe’s Electricity and Gas Sectors, Ref: C18-CS-44-04, Brussels, published 26. October 2018.

CEER (2020), CEER Paper on Whole System Approaches. Distribution Systems Working Group. Ref: C19-DS-58-03, Brussels, published 30. June 2020.

CEER (2022), 7TH CEER-ECRB Benchmarking Report on the Quality of Electricity and Gas Supply. Brussels.

CERRE (2021), Optimal regulation for European DSOs to 2025 and beyond, CERRE, Brussels, April 2021.

DENA (2012), Dena-Verteilnetzstudie: Ausbau und Innovationsbedarf der Stromverteilnetze in Deutschland bis 2030, DENA, Berlin, Dec. 2012.

DENA (2020), Der Systementwicklungsplan; Umsetzungsvorschlag für eine integrierte Infrastrukturplanung in Deutschland – Zwischenbericht, DENA, Berlin, Dec. 2020.

DTe, (2004), Besluit op de aanvraag van TenneT tot het toestaan van de financiering van de NorNed-kabel op grond van artikel 31, zesde lid van de Elektriciteitswet 1998, DTe, Den Haag.

ENTSOE (2021), European electricity transmission grids and the energy transition; Why remuneration frameworks need to evolve, ENTSOE, Brussels, 2021.

ENTSOE (2022), Innovation uptake through regulation, ENTSOE, Brussels, June 2022.

Eskesen, A. (2021), A contract design perspective on balancing the goals of utility regulation, *Utilities Policy*, Vol. 69, pp. 1-13.

Finsinger J. & Kraft, K. (1984), Markup Pricing and Firm Decision. *Journal of Institutional and Theoretical Economics*, Vol. 140, pp. 500-509.

Gilbert, R. & Newbery, D.N. (1994), The dynamic efficiency of regulatory constitutions, *RAND Journal of Economics*, Vol. 25, No. 4, pp. 538-554.

Grout, P.A., & Zalewska, A. (2006), The Impact of regulation on market risk, *Journal of Financial Economics*, Vol. 80, No. 1, pp. 149–84.

Guthrie, G.A. (2006), Regulating infrastructure: The impact on risk and investment, *Journal of Economic Literature*, Vol. 44, No. 4, pp. 925-972.

Haney, A.B. & Pollitt, M. (2013), International benchmarking of electricity transmission by regulators: A contrast between theory and practice?, *Energy Policy*, Vol. 62, pp. 267-281.

Joskow, P. L. (1989), Regulatory failure, regulatory reform, and structural change in the electric power industry. Cambridge: Massachusetts Institute of Technology (MIT), Department of Economics.

Joskow, P.L., (2014), Incentive Regulation in Theory and Practice: Electricity Distribution and Transmission Networks, *in Rose, N. (2014, ed.) Economic Regulation and Its Reform: What Have We Learned?*, pp. 291-344.

Laffont, J-J & Tirole, J. (1993), *A theory of incentives in regulation and procurement*, Cambridge, MA., MIT Press.

Littlechild, S. C. (1983), Regulation of British telecommunications' profitability. London: Department of industry.

Marques, V., Moises Costa, P. & Bento, N. (2022), Greater than the sum: On regulating innovation in electricity distribution networks with externalities, *Utilities Policy*, Vol. 79, pp. 1-11.

McNulty report (2011), Realising the Potential of GB Rail; Final Independent Report of the Rail Value for Money Study, Report for Department for Transport (DfT) and the Office of Rail Regulation (ORR), London, May 2011.

Meyer, R. (2021), Regulatorische Anreize für ein zukünftiges Engpassmanagement unter NABEG 2.0: FlexShare und FOCS, *Zeitschrift für Energiewirtschaft*, Vol. 45, No. 2.

Oxera (2019), *Smarter incentives for transmission system operators - Volumes 1 and 2*. Report prepared for TenneT-TSO, 2018/2019.

Palovic, M. & Poudineh, R. (2022), PolyGrid 2050: Integrating hydrogen into the European energy transfer infrastructure landscape, *OIES Paper ET19*, Oxford Institute for Energy Studies.

Peltzman, S. (1976), Toward a more general theory of regulation, *Journal of Law and Economics*, Vol. 19, pp. 211–240.

Poudineh, R., Peng, D. & Mirnezami, S.R. (2020), Innovation in regulated electricity networks: Incentivising tasks with highly uncertain outcomes, *Competition and Regulation in Network Industries*, Vol. 21, No. 2, pp. 166–192.

Reed, L., Abrahams, L., Cohen, A., Majkut, J. Place, A., Phillips, B. & Prochnik. J. (2021), How are we going to build all that clean energy infrastructure? Considering private enterprise, public initiative, and hybrid approaches to the challenge of electricity transmission, *Electricity Journal*, Vol. 34, pp. 1-9.

Sappington, D.E.L. & Weisman, D.L. (2010), Price cap regulation: what have we learned from 25 years of experience in the telecommunications industry?, *Journal of Regulatory Economics*, Vol. 38, pp. 227-257.

Shleifer, A. (1985), A theory of yardstick competition, *RAND Journal of Economics* Vol. 16, No. 3, pp. 319–327.

Smith, A., Wheat, P., Thiebaud, J.-Chr. & Stead, A. (2019), CAPEX bias and adverse incentives in incentive regulation; Issues and solutions, Working Group Paper, *International Transportation Forum*, OECD, Paris.

Spence, A. M. (1975), Monopoly, quality and regulation, *Bell Journal of Economics*, Vol. 6, pp. 417-429.

8 List of abbreviations

ACM	*Autoriteit Consument en Markt*
CAIDI	customer average interruption duration index
CAPEX	capital expenditure
CBCA	cross-border cost-allocation
CNCA	cross-network cost-allocation
CO2	carbon-dioxide
DC	direct current
DER	distributed energy resources
DSO	distribution system operator
FOCS	fixed OPEX CAPEX share
GMI	grid modernization index
KPI	key performance indicators
kWh	kilowatthour
MCA	multi-criteria analysis
NDP	network development plan
OOR	output-oriented regulation
OPEX	operating expenditure
PCI	project of common interest
PIM	performance incentive mechanism
RES	renewable energy sources
RIIO	revenue = incentives + innovation + outputs
SAIFI	system average interruption frequency index
SDP	system development plan
SGI	smart grid index
SO	system operation/operator
TOTEX	total expenditure
TSO	transmission system operator
WACC	weighted average cost of capital
WSA	whole-system approach

9 List of figures

10 List of tables

11 Appendix: Long list of options

Main category	Items	Description
A. Base regulation model		
	Base model (price-based, cost-based or hybrid approaches)	
	• CAPEX-true-up (CAPEX annual adjustment, while OPEX price-based) / building-block approach	See sections 4.2.2 and 4.2.3.
	• Forward-looking budget approach (project or overall), including sharing-factors	See section 4.2.1.
	• Investment measure / investment factor	See section 4.2.1
	• Length of the regulatory period	During the regulatory period, allowed revenues are predetermined and delinked from underlying own costs. The length of the regulatory period, usually between 0 and 5 years, determines how quickly costs can be passed through. Faster cost-pass-through and less risk promote investment.
	Level of remuneration	
	• Level of WACC / RoR	WACC is weighted average cost of capital; RoR is rate of return (on capital). Both are the regulatory constraints on profits. The regulator will aim to match the true of cost of capital. Higher RoR on capital clearly makes investment more attractive.
	• Selective WACC- or RoR-adders for large and/or risky investment	See section 4.3.8.

• X-factors (Xgen and X_i)	The (general and individual) X-factors are indicators for expected productivity increase in the regulation, which are abatements on allowed revenues. Lower X-factors allow more revenue and thus facilitate finance of investment.
• Pre-construction funding: Remuneration of expenses in construction- or planning-phase	Output and revenues of a network expansion start only after the project is in operation. This can take a long time. Starting remuneration earlier in the planning- and construction-phase will ease financing of the investment.
Uncertainty mechanisms	
• Shorter depreciation period	Deprecation periods are regulated. Shorter depreciation periods accelerate remuneration and reduce risk, and therefore promote investment.
• Menu of contracts	A menu of contracts creates options for the company. Usually, a menu of contracts is applied in cases of strong asymmetric information between regulator and firms and if firms differ a lot. It aims to self-select an optimal balance between risk and investment needs.
• Ex ante mechanisms (eg. indexation, volume drivers, revenue triggers, use-it-or-lose-it mechanism)	Ex-ante uncertainty mechanisms predefine events (triggers), in which cases regulation will be adjusted (possibly also predefined, eg. an index).
• Ex post mechanisms (eg. pass-through items, logging-up, backward-looking revenue adjustment)	Ex-post uncertainty mechanisms respond to unexpected events as they happen. Responses will mostly be backward-looking full or part adjustments.
OPEX-CAPEX-bias	
• Selective TOTEX-regulation / fixed-OPEX-CAPEX-share (FOCS)	See section 4.3.1.
• OPEX mark-up (RoR-adder for OPEX)	Normally there is no rate-of-return for OPEX. Technically it is possible to allow a rate-of-return on OPEX. This would promote OPEX-based grid reinforcement.
• Incentivizing efficient system operation (SO), indirectly incentivizing grid reinforcement	See section 4.3.2 (congestion and curtailment expenses)

B. Output-oriented regulatory elements	
Aiming at network expansion	
• Bonus/Males on congestion costs	See section 4.3.2.
• RES-expansion mechanisms	Mechanisms which link revenues to network expansion related with connection or feed-in of renewable energy sources (RES).
• Timely commissioning of new assets / timely implementation of projects	See section 4.3.3.
• Utilization-factor	Allowed revenues or a bonus can be linked to the actual utilization of a line. This promotes more efficient use of existing capacity directly and new capacity indirectly.
• Value creation (eg. market facilitation, cross-border trade, environmental protection)	See section 4.3.4.
Innovation enhancing tools to address network constraints	
• Regulatory sandboxes	Regulatory sandboxes allow testing new technical solutions and business models under real conditions and gather insights into regulatory problems that arise during the implementation of innovations.
• Pioneer bonus	A pioneer bonus allows several grid operators to collaborate on an innovation with one grid operator actually conducting the activity, which receives a payment to cover the cost of the innovation activity.
• Innovation budget	A common or individual fund to finance innovation activities beyond the revenue constraint. Qualifying projects must be approved by the regulator.
• KPI-based incentives for innovation	Revenues are linked to achieving a predefined set of key performance indicators (KPI) concerning innovations.
• KPI-based smart-grid-development	See section 4.3.5.

C. Aligning investment incentives	
Network charging	
- Peak-reduction targets	Incentives to reduce peaks in network usage reduce required capacity and thus investment.
- Locational signals in network (or energy) tariffs	Components of network- and/or energy-charging can contain locational signals for network scarcity and locational investment for network users. The effect is more efficient use of existing capacity and optimized network expansion.
- Smart connection (or capacity) agreements	Smart connection agreements (or smart contracts) offer an alternative option to the standardised grid connection tariff, intended to incentivize grid users to avoid or deal with network scarcity.
- Deep charging	Deep charges include part of the costs for grid reinforcements that become necessary in deeper parts of the network following new connections; this signals and internalizes external network costs to new connections and thereby optimizes network expansion.
- Flexibility procurement	Network operators can optimize the use of flexibility (eg. install local markets) for congestion management to make better use of existing network capacity.
Coordination (whole-system approach (WSA))	
- Cost-benefit-sharing models	See section 4.3.7.
- System Development Plan	See section 4.3.6.
- Cooperation-platforms	Coordination can be more formalized in an institutional setting (platform) with members, voting rights and rules.
- Integration (network or system operation)	Coordination may go as far as the formal integration of different entities (eg. an independent energy system operator for gas and electricity).

D. Stakeholder involvement	
Third-party investment	
• Merchant investment	Network investment can be undertaken by third parties (i.e. others than certified network operators in their own area). This is not uncommon for DC-interconnectors.
• Auctions / competitive procurement	Network investment can be auctioned to include third parties. This is not uncommon for offshore lines.
• Open seasons	An open-season procedure can be used to get information about required capacity, allocate scarce capacity and involve third parties. Rather unusual for electricity networks, open seasons are common in gas networks.
Government or other high-level institutions	
• Initiative, coordination and organization	Ministries can seize initiatives where the market might be in a lock-in. Possibly, first steps in an uncertain world can be supported financially.
• Command & control	The government can simply set and enforce tasks and goals by law. Obviously, the subsequent costs for the firms should be acknowledged in the regulatory costs base.
• (Partly) public ownership	If private parties are perceived to invest too little or too slowly, the government can increase and accelerate investment with (partly) public ownership. Note: in the Netherlands, electricity networks are already in public ownership.
Social responsibility	
• Consumer-centric planning	Network users can be involved more explicitly in network planning and grid reinforcement, especially for priority rankings.
• Include public value in management bonus	Management-bonusses could be designed explicitly for reaching goals in grid-reinforcement.