

Harmonizing the Nordic Regulation of Electricity Distribution

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Abstract Regulators for electricity network infrastructure, such as electricity distribution system operations (DSOs) face some particular challenges in the Nordic countries. Due to institutional, economic, and historical reasons the DSOs in the Nordic area are relatively numerous and heterogeneous in terms of ownership structure, size, and operating conditions. Since the deregulation in 1994–1999, the national regulators have independently devised regulation mechanisms that address the heterogeneity through econometric or engineering cost models as a basis for high-powered regimes. The frontier analysis models (such as data envelopment analysis in, e.g., Norway and Finland) are particularly useful here, given their incentive properties and cautious estimation of the production set. However, the total information rents in yardstick regimes and the bias in the frontier estimation are related to the number of observations (firms), which undermine their future application in the Nordic area under increasing interregional concentration. This paper develops a proposal for an alternative model, the revenue yardstick model, that can be applied across the national regulations and permit frontier estimations on final user cost rather than cost estimates, sensitive to, e.g., capital cost estimates, periodization, and allocation keys. The core of the model is a dynamic frontier yardstick model such as Agrell et al. (2005), but here applied only to strictly exogenous conditions, the output dimensions and the claimed revenues of the DSO. An equilibrium is implemented using asymmetric penalties for positive and negative deviations from the ex post frontier revenue, the yardstick, using the classic super-

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efficiency model in analogy with [Shleifer \(1985\)](#). The model is particularly aimed at an international (interregional) application as it may embed national differences in regulation without jeopardizing the long-term sustainability of the model.

1 Scope and Introduction

1.1 Background

The objectives of this paper are to:

- Evaluate the advantages and disadvantages of a pan-Nordic regulation model and benchmarking tools viewed from all perspectives of the stakeholders, i.e., customers, regulator, owner, and distribution system operator
- Identify the most critical factors in cross-border regulation and benchmarking
- Present a common model for regulation of electricity distribution companies

The paper is interesting from several theoretical viewpoints. First, it proposes a partial harmonization of the national regulation mechanisms in anticipation of problems related to data access and consolidated operators. This problem has not been acknowledged in the scientific literature. Second, it extends the stream of literature on dynamic yardstick regimes, following the seminal papers by [Shleifer \(1985\)](#) and [Meyer and Vickers \(1997\)](#), among others. The proposed model uses an *ex post* correction of collected revenues rather than estimated costs, which has not earlier been studied. Although requiring a set of penalties to mitigate distortions and collusive outcomes, the regime offers advantages under international network regulation, when heterogeneous capital valuation techniques and accounting information convey less information than prospective investment information.

From a policy perspective, the proposal evokes the discussion on the challenges related to harmonizing network regulation for various stakeholders, even when empirical work shows strong consistency in client preferences. It also provides a rare example of regional industry initiative, the NEMESYS project as being research commissioned by Nordenergi, the industry association for electricity sector in the Nordic countries, for a common regulation model for electricity distribution in the Nordic region (NordPool region). Clearly, it is the improved incentive properties and the closer resemblance to competitive mechanisms that have persuaded the industry. On the regulatory side, the still open question is to which extent regulatory harmonization is compatible with the current institutional setting for the integrated energy market.

Although we have chosen to present the framework uniquely in the context of economic regulation of distribution system operators, there are also analogies and synergies in the specific Scandinavian segment of regional transmission operators. Some ideas on the potential harmonized regulation between (in particular) Norway and Sweden are developed in [Agrell and Bogetoft \(2008\)](#) and left outside of this paper.

2 Harmonization of Regulatory Systems

2.1 Current Situation

In NEMESYS (2005a), we demonstrated how the current regulatory systems for distribution system operations (DSOs) are based on somewhat different mechanisms. The regulation systems in each country can be summarized as follows:

- Denmark abandoned in 2003 the somewhat complicated revenue cap and rate of return regime first introduced in 2000, and moved to a temporary price fixation scheme with the aim to construct a new price cap system and settle issues regarding capital ownership.
- Finland has a well-established rate-of-return *ex post* approach. Since 2005, it has been refined and complemented with an *ex ante* cost cap component of CPI-X type. A company specific X-factor based on data envelopment analysis (DEA) and stochastic frontier analysis (SFA) models was introduced for the 2008–2011 regulatory period (EMV 2008).
- Norway has adopted a CPI-X type of revenue cap approach with clear *ex ante* emphasis. The system is established and stable. DEA benchmarking (yardstick) is used for defining the company specific X factors intended to be more important from 2007, NVE (2007).
- Sweden has moved from the light-handed *ex post* regulation (and an interim price freeze) to use of *ex post* technical norm model (network performance assessment model, NPAM) during the period. Concession granting is seen as a long-term component in the regulation. A DEA based benchmarking serves for information dissemination purposes. The regulation will undergo a major reform in 2012 (SOU 2007).

This illustrates that even though the systems aim at rather similar goals (creating markets in production and sales and guaranteeing reasonable tariffs), they are philosophically and technically somewhat different. Table 1 summarizes the different approaches used in regulation in the four countries.

The main philosophical difference is probably between Sweden relying on a light-handed *ex post* approach and Norway relying on a somewhat heavy-handed

Table 1 Summary of regulatory approaches used in the Nordic countries and year of deregulation

	Denmark	Finland	Norway	Sweden
Regime	1999	1995	1990	1996
Light-handed				1996–2002
Rate-of-return	2000–2003	1996–2004	1990–1996	
Cost cap		2005–2011	(2012–?)	
Price cap	2003–2007			2001–2002
Revenue cap			1997–2006	
Yardstick DEA			2007–2010	
Yardstick comp.				2003–2011

ex ante regulation. Still the difference between the *ex ante* and *ex post* perspectives are not always large in practical implementations – and EU regulation is calling for a common approach emphasizing *ex ante* applications. Technically, the main difference is probably between the Swedish network performance assessment model (NPAM) and the empirical frontier models used in the other countries. Again, however, the complementary DEA model in Sweden has many similarities with the benchmarking model in the other countries, even the Danish one that relies on a simple variant, the so-called COLS approach.

The countries are on very different stages in the implementation of the regulation systems. Both Sweden and Denmark have experienced problems with their regulation systems, and this has resulted in changes in the regulation principles. The Swedish regulation is about to change radically; the proposal SOU (2008) for 2012 advances abandoning the controversial NPAM in favor of rate-of-return regulation on capital and a cost-yardstick regime for controllable operating expenses. Norway has proceeded relatively consistently with the same approach. The Finnish situation is somewhere between the extreme cases. In spite of open and frequent information exchange between the Nordic regulators in FNER/NordREG and bilaterally, there has been no natural harmonization of the systems.

Although there have been some attempts to coordinate certain tasks, such as the Nordic DSO benchmarking 2001 (Førsund and Edvardsen 2001), data sharing is of limited usefulness as long as the DSO tasks are somewhat different without any estimate of their relative or absolute importance. There are also more practical differences even on the information collection level. Due to historical reasons, division between transmission, regional networks and distribution differ (voltage levels) varies. There are also many other smaller differences in the ways the key indicators are defined. As the time lags in the collection of data are long, this is one practical issue that hinders harmonization and even less formal benchmarking, etc.

2.2 *Effects of Harmonization*

The *advantages* of harmonization of regulation are effects inducing:

- Improved long-term stability and hereby protection of specific investments by making the commitment at an international level
- Better structural adaptation by making it easier for DSOs to operate in different countries, by compensating for the small sample bias problem, by avoiding that the regulator reduces mergers, etc., to keep a sufficiently large number of observations
- Improved learning across DSOs, regulators, and other stakeholders
- Increased competition for DSO role by making it easier for DSO to offer services in different countries
- Increased EU influence by taking the EU initiative in terms of network regulation, energy market design, and coordination

- Improved competition at the suppliers' level – e.g., among equipment manufacturers, constructors, and software providers that have to only learn one rather than multiple regulations, i.e., low barriers to entry and greater returns to scale on specific investments upstream
- Less trial and error by learning from best practice in regulation and from pooling regulatory resources
- Improved foresight and predictability for network users, e.g., with respect to tariff development, investments, and quality
- Lower administrative costs for the regulation in the reporting, accounting, etc
- Lower costs for regulators to refine tools and instruments for a common model
- Symmetric Nordic coordination of the electricity sector via a semistructured coordination at DSO level, matching well the existing coordination at TSO and generation levels

There are also some *limitations* to the harmonization approach:

- Stranded investments adapted to regulation that is discontinued or radically changed, e.g., specific assets or processes
- Risk of hampering regulatory innovation
- Time spent to set up and launch legal and institutional obstacles
- Contradictions with current Electricity Acts, preambles, or other laws
- Internal DSO conflicts may overlook regional differences

Hence, we should strive for an optimal level of harmonization: touching the principles of regulation as to gain commitment; defining a set of common tasks as to improve data quality; and gathering cost information, creating sound and equal incentives of investment, and efficient operation across the region. The harmonization should not limit national prerogatives unnecessarily, force potentially arbitrary institutional reforms upon countries or sacrifice rational national adaptations to operating conditions in order to achieve common standards.

2.3 Analyzing the Nordic Case

The Nordic area shows, as argued above, signs of suboptimal costs of regulation at several levels. First, the tasks are defined nationally, if at all, leading to high coordination and information costs. Second, the due to the different approaches and stages of implementation, the Nordic regulation systems provide quite different incentives for DSOs. The incentives for efficiency improvements depend heavily on the possibility to gain additional profits by making improvements that exceed expected levels. In Finland and Norway, this is possible during the regulation period, but the effect on the base line for the next period gives a mixed signal (the *ratchet effect*). The effect on the tariff level depends on the tightness of regulation, the clarity of the requirements *ex ante*, and the obligation for the return of excess profits to the customers. For example, in Finland the last two aspects have been changed and the incentive for tariff changes has increased significantly. None of the countries offer very clear

incentives related to security of supply or other quality issues. This reflects the fact that historically the quality performance has been perceived as good. None of the current models provide any clear (wanted or unwanted) signals for consolidation. Finally, and most alarming, the current changing regulatory landscape does nothing to address the poor investment incentives in the sector, where the regulatory risk is evaluated strictly nationally even for consolidated firms.

2.4 NEMESYS View on Harmonization

A process of harmonization could significantly improve the network regulation based on the analysis above for the Nordic scenario. A harmonization would require two necessary stages: a definition of the scope of the common and individual tasks and the elements of the common regulatory framework. Before outlining the stages, let us quickly clarify some aspects that are not in the scope of this paper:

- No creation of regional or European meta-regulator. We acknowledge that network regulation outside of the studied area may be heterogeneous for other reasons than those investigated and, furthermore, the institutional complexities involved in the centralization of legal powers contrary to the subsidiarity principle of the Moreno doctrine (cf. [Majone 1997](#), for a discussion of this issue).
- No imposition of common tariffs or delivery conditions across regions. In choosing the term *harmonization* rather than *standardization*, we acknowledge that the principal benefits from a common regulatory framework do not derive from identical tariffs (in fact, the Nordic area has always had individual tariffs even within jurisdictions), but from a consistent set of regulatory expectations and contracts.

2.4.1 Definition of DSO Task Portfolio

Any coordinated regulation system requires a clear definition of the scope of the tasks to be performed by the regulated firms. In the case of a harmonization, i.e., the creation of a common set of regulations and a set of compatible regulations for other tasks, this definition is primordial. Let us call the common definition the *Core DSO Task* (cf. [NEMESYS 2005c](#)). Although the definition may be done as the minimal intersection of all national DSO tasks, the true implication is that information acquisition should be decomposed in the core task to allow for straight-forward comparisons, which might require some changes of the national reporting systems.

- *Core DSO Tasks* form the least common subset of DSO tasks to be fulfilled by any DSO in the Nordic area and for which common data is collected and common regulation could apply.
- *Nationally Regulated DSO tasks* are defined DSO activities that are not harmonized in the Core DSO Task but that remain regulatory obligation in at least one country. This could apply to, e.g., tasks related to safety inspections, line dismantling and energy planning. All compensation for such tasks should be transparent

TASK DESCRIPTION

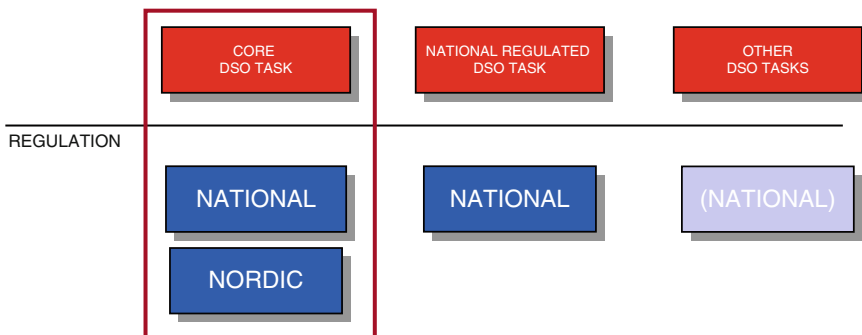


Fig. 1 DSO tasks and corresponding regulation

(and preferably based on tendering) to avoid cross-subsidies to incumbents. To maintain this transparency and promote development, we propose that the regulated payments for the National Regulated DSO Task should be separated from the Core DSO Task. In practice, this could render these tasks more attractive to non-DSO providers or at least informing the regulator of the real costs involved to permit social trade-offs.

- *Other DSO Tasks* are activities that are not regulated, but compatible with the national and European directive with respect to nondiscrimination, independence and competition. In the regulatory regime proposed below, such competitive activities can be freely performed under residual competition law so far as they bring coordination gains (Fig. 1).

2.4.2 Regulation and Information Harmonization

- *Framework agreement*, a common regulatory vision statement for both model structure and the time plan need to be agreed upon by all regulators. This does not mean a streamlined legislation, but a high-level commitment to the principles and tools for all further revisions. A fully integrated regulatory body like NORDREG could easily administer the regulation, but the proposal is flexible with respect to institutional solution. The competency to define national parameters (e.g., interruption costs), nationally regulated DSO tasks and to define concession areas is also a national prerogative, as all monitoring of the noneconomic and equity aspects of the directive.
- *Common information system*. Any quality-oriented, output-based regulation needs access to high-quality data in common formats, but so does the sector itself for its coordination and restructuring. We propose a common client metering standard, including format for transmission of hourly data, connection and disconnection. We propose that the meter standard defined by a *Metering Agent*, formally responsible for the metering, reporting, and administration of technical data from customer level to other parties.

- *Transparency in financial conditions.* To increase transparency and avoid regulatory competition, the regulators need to coordinate the financial conditions also for Nationally Regulated DSO Tasks. However, this should be seen in connection with a common information system, leading to equal performance criteria in, e.g., reliability and commercial quality. Note that this does not mean that the average realized profits need to be equal in all countries, since they are the outcomes of the regulation itself.

3 Regulatory Toolbox

This section draws on a richer discussion on design of economic regulatory instruments for network regulation in [NEMESYS \(2005b\)](#). The practice and theory of network regulation exhibits a plethora of models and approaches, which basically can be classified into five categories of regimes:

- *Cost-recovery.* A rate-of-return, cost-oriented regime such as widely present in USA and earlier in, e.g., Finland and Norway. Firms are authorized to a predetermined capital cost on pre-approved investments in addition to direct by-pass of certain operating costs.
- *Price cap.* A regime of the Anglo-Saxon CPI-X type (cf. [Littlechild 1983](#)) where the regulator *ex ante* determines a fixed reduction (X) of some base-level price or revenue. In practice, the regulatory asset base is approved by the regulator that also decides on the return for investments in the period. At the end of some period, the base is reset to current cost.
- *Yardstick regime.* A regime in which costs or revenues are set competitively across comparable firms by using averages, best practice or frontier models. Allowable revenues next period depend on performance the previous period. For electricity distribution, the models of the [Agrell and Bogetoft \(2005\)](#) type are considered due to their capacity to cope with multi-dimensional performance under weak prior technology assumptions.
- *Franchise auctions.* Firms are awarded concessions based on tender auctions formulated in tariff level using a pre-defined task specification. The concessions are defined on time periods between 5 and 15 years and then resubmitted. The proposed model in [NEMESYS \(2005b\)](#) draws on the contestable licensing model in [Neeman and Orosel \(1999\)](#), but the seminal reference for infrastructure franchises is [Williamson \(1976\)](#).
- *Technical norms.* The allowable revenues for the firms are determined using an engineering cost model. The model presumes a complete task description, including quality provision and technical development.

[NEMESYS \(2005b\)](#) evaluates the five categories with respect to the overall criteria to find guidance in [Table 2](#) for the development of interesting candidates for a common regulation regime. Green areas indicate relative strengths, red indicate weaknesses, and yellow the aspects dependent on parameters. Two findings are

Table 2 Comparison of model alternatives

Concern	Cost-recovery	Price/revenue caps	Yardstick regimes	Franchise auctions	Technical norms
Optimal allocation of decisions and information	—	—	+	+	—
Incentives for sound industry structural changes	—	+	+	+	—
Incentives for efficiency improvements	—	0	+	+	+
Incentives for tariff reductions	—	0	+	++	—
Incentives for service quality improvements	+	—	?	—	—
Incentives for (re)investments	+	?	?	++ ²	—
Long-term regulatory credibility	0	0	+	0	—
Unbiased DSO performance assessment	+	+	+	?	?
Low administrative costs of regulation	—	0	0	—	—

²The investment incentives under franchise auctions depend on the number of firm bidders (supply market), the information available for and among operators about the operating conditions and costs in the concessions (information asymmetry) and the commitment and credibility of the regulator to keep the settlement (regulatory uncertainty). Here we assume that the bargaining power will be stronger at the firm level and that the regulators would not renege on their contracts.

apparent: the behavioral advantages of yardstick and franchising systems and the specific need to address service quality in the regime. On the one hand, the two methods bridge the information gap between the regulator and the firm, in that they form a “pseudo”-market for the firms. This allows the regulator to concentrate its efforts to areas where it is necessary and relevant, such as monitoring of terms, industry structure, and quality development. On the other hand being highly incentivized, their effectiveness depends crucially on the regulatory commitment, which is where the regulatory integration comes into play. A specific section is devoted to the economic regulation of service quality as a consequence of its *public good* properties and the interest to create explicit incentives for continued investments in service provision. The investment incentives crucially depend on the parameters and regulatory commitment to the system, they can be either very good or very poor. In NEMESYS (2005b), this analysis is taken as a starting point to develop in more detail alternatives for quality, yardstick, and franchising regimes.

3.1 *Dynamic Cost-Based Yardstick*

Dynamic yardstick schemes based on DEA solve many of the usual CPI-X problems, including the risk of bankruptcy with a too high X, risk of excessive rents with a too low X, ratchet effect when updating X, arbitrariness of the CPI measure, arbitrariness of the X parameter, and inability to include changing output profiles. The most important difference between a yardstick schemes and a more traditional CPI-X regime is that the firms are compared to actual cost frontiers rather than projected cost frontiers. The incentive for an efficient firm to improve performance is assured by using the so-called *superefficiency* specification (e.g., Bogetoft 1997), whereby the frontier for each firm excludes its own observation. This reduces the informational and analytical requirement put on the regulator and allows for a more precise inference of actual performance. It hereby also allows for better incentives. The business risk is not increased as revenues follow more closely the cost development.

3.2 *Dynamic Revenue-Based Yardstick*

To relax the input-dependency of the previous regime and in particular to alleviate the capital evaluation problem an innovative model based on net revenues rather than costs is developed in NEMESYS (2005b). What matters to consumers is the *final tariff = revenue*, not the *cost* as such. Using actual unregulated prices in the yardstick the return on investment is endogenous and not regulated. DSO charges are set by all firms and regulated afterwards depending on the “value for money” set by the other firms. In this way, firms may budget for reinvestments prior to investment, rather than getting caught up in the jerky and artificial problem of network age.

The basis for the dynamic revenue-based yardstick is still a benchmarking or frontier model that calculates for a given level of output in all its dimensions, taking into account the operating conditions, efficient revenue by a comparable operator. The positive or negative difference between the efficient revenue and the actual revenue charged becomes a *carry-forward* that is to be repaid or charged with interest rates, just like a loan to and from the rate-payers. Since the total relevant cost includes all operating, capital and financing charges, cost pass-through can be limited to standard costs for network losses, transmission charges, nondistribution tasks, and taxes.

3.3 *Dynamic Network Auction Model*

The strength of the yardstick model is also its weakness in the long run when the market consolidates. The annual revisions become ineffective if only very few firms compete on the market. In fact, the uncertainty shifts to the clients, risking to pay all cost shocks and the rents of market power. To address this situation, one may augment the yardstick model with a fixed element, which also solves possible

imperfections in the environmental correction. A new model in NEMESYS (2005b) solves the residual benchmarking estimation problem by a repeated auction design.

Briefly, in the dynamic network auction model the DSOs tender for the fixed tariff in their concession area, knowing that their variable tariff will be regulated as in the dynamic revenue yardstick above during the duration of the license. In this way, the consumers are assured to get higher competition for the market, while still being protected from any attempt to recover an artificially low fixed tariff by an inflated variable tariff. On the other hand, the firm is protected by the fixed component against possible systematic errors (up or down) in the yardstick model. In case the operating conditions are understated in an area, the DSOs would require an extra payment; if they are less severe they may even pay to get the license.

3.4 *Quality Regulation Model*

As discussed above and in NEMESYS (2005a,b), the quality dimension is ever more important for the network regulation at all levels. The ability of the regulation to adequately and credibly provide incentives for long-run quality provision will be one of the acid tests for the regulation. First, supported by the theory and the scientific consensus of SESSA (2005), we conclude that a regulation for electricity distribution that is entirely restriction-based is likely infeasible in the long run. However, the large number of measurable dimensions suggests a hybrid approach using restrictions, since many of them are correlated to reliability of supply. Thus, we argue for the explicit inclusion and marginal pricing of reliability of supply, such as is currently done in Norway, Germany, and Sweden. Other quality aspects, related to voltage and commercial quality, may be defined with target and threshold values in the DSO Task Description, preferably jointly with clients and industry organizations.

4 The NEMESYS Approach

The approach, fully documented in NEMESYS (2005d) is composed of two elements: the *Revenue Yardstick Model* and the *Quality Incentive Scheme*.

4.1 *Revenue Yardstick Model*

The yardstick model is founded on the virtues of yardstick competition, i.e., the DSOs can compete even though they do not meet directly at the market. This safeguards the consumers against too high tariffs and it safeguards the DSOs against unreasonable impact from regulatory interference based on limited information. The economic condition of one DSO is basically defined by the other DSOs, not by a regulator.

The revenue yardstick model defines the *revenue base* $RB(t)$ for a given DSO in period t as

$$RB(t) = C^*(t - 2)$$

where $C^*(t - 2)$ is the yardstick revenue for period $t - 2$ determined by the benchmark model estimated on the data from all other DSOs except the one in question (superefficiency evaluation), cf., below. Invoking a 2-year delay enables (1) the DSOs to do their financial accounting in the usual way, (2) the regulator to collect and process tariff and service data in time, and (3) the consumers to know tariffs a priori.

The (benchmarked) *DSO charges* in period $t - 2$, $C(t - 2)$ may deviate from the yardstick revenue. If these DSO charges have exceeded the yardstick revenue, it corresponds to the DSO having taken a loan with the consumers. If it falls short of the yardstick revenue, it corresponds to the DSO having provided a loan to the consumers. These loans should be repaid with interest.

We shall think of these as *carry-forwards* in period t , $CF(t)$, i.e., we have

$$CF(t) = \begin{cases} (1 + \alpha) [C^*(t - 2) - C(t - 2)] & \text{if } C^*(t - 2) \geq C(t - 2) \\ (1 + \beta) [C^*(t - 2) - C(t - 2)] & \text{if } C^*(t - 2) < C(t - 2) \end{cases}$$

The parameter α is the two-period borrowing interest rate in period $t - 2$ applying to the first case of *undercharging*. The second case in CF is the *overcharging* which is penalized with a lending rate $\beta = \alpha + \delta$ that exceeds the two period costs of borrowing with some extra margin $\delta > 0$. In the following, we shall think of a period as 1 year.

The sum of the revenue base and the carry-forward defines the *revenue target* for period t as

$$RT(t) = C^*(t - 2) + CF(t).$$

The revenue target RT is indicative as a budget for tariffsetting. It defines the actual charges the DSO in question should make in period t to come out on equal footing with the other DSOs presuming that they do not change from period $t - 2$ to period t . The indicative revenue target can be used by the regulator when ruling on or confirming actual charging proposals $AC(t)$ for period t at the end of period $t - 1$, cf. below. Exactly how the regulator rules here is not very important for the incentive properties of the scheme and the regulators in the different countries need not even use the same principles. What is important for the convergence and the compatibility with the Directive is that the methodology for determining the revenue yardstick and target is defined *ex ante*.

In period t the actual charges of the DSO is denoted $AC(t)$.

The actual charges will, however, reflect not only the costs and profits to the DSO in period t but also the settlements of negative or positive carry-forwards. Therefore, the real in-period DSO charges in period t , the benchmarked charges $C(t)$ is

$$C(t) = AC(t) - CF(t)$$

The benchmarked charges form, together with the provided services, the basis for the benchmarking exercise that set the revenue base $RT(t+2)$ for period $t+2$, i.e., $C^*(t)$.

4.1.1 Example

To illustrate the mechanics, consider a case with three DSOs that have so far in each and every period charged their full cost ($C(1) = 100$). Let the interest rate be $\alpha = 5\%$ and the penalty rate $\delta = 5\%$. The development in underlying minimal costs is illustrated in *italics* and the actual charges are given as *AC* in Table 3 below. DSO One and Three realize a cost decreasing change to lower their cost to 90 in Period 2. We see that DSO Two faces idiosyncratic extra costs of 10 in Period 2 and that DSO Three uses its relatively low costs to extract extraordinary profits in Period 2. The decision not to lower the tariffs to the optimal level by DSO Three is then providing the incentive for DSO One, a positive carry-forward that is collected in Period 4 (with interest).

The example not only illustrates the formulae above. It also illustrates that companies carry their idiosyncratic risks, are ensured against general variations in costs and that there is pressure on the DSOs to reduce charges to the minimal level

Table 3 Example of revenue yardstick regime, five periods, three firms

		Period 1	Period 2	Period 3	Period 4	Period 5
<i>DSO One</i>						
Yardstick revenue	$RB(t) = C^*(t-2)$	100	100	100	100	90
Carry-forward	$CF(t)$	0	0	0	10.5	0
Total costs	$c(t)$	100	90	90	90	90
Actual charges	$AC(t)$	100	90	90	100.5	90
Benchmarked charges	$BC(t) = C(t)$ $= AC(t) - CF(t)$	100	90	90	90	90
Extraordinary profit	$AC(t) - c(t)$	0	0	0	10.5	0
<i>DSO Two</i>						
Yardstick revenue	$C^*(t-2)$	100	100	100	90	90
Carry-forward	$CF(t)$	0	0	0	-11.5	0
Total costs	$c(t)$	100	100	90	90	90
Actual charges	$AC(t)$	100	100	90	78.5	90
Benchmarked charges	$BC(t) = C(t)$ $= AC(t) - CF(t)$	100	100	90	90	90
Extraordinary profit	$AC(t) - c(t)$	0	0	0	-11.5	0
<i>DSO Three</i>						
Yardstick revenue	$C^*(t-2)$	100	100	100	90	90
Carry-forward	$CF(t)$	0	0	0	-11.5	0
Total costs	$c(t)$	100	90	90	90	90
Actual charges	$AC(t)$	100	100	90	78.5	90
Benchmarked charges	$BC(t) = C(t)$ $= AC(t) - CF(t)$ $AC(t) - c(t)$	100	100	90	90	90
Extraordinary profit	$AC(t) - c(t)$	0	10	0	-11.5	0

that covers all costs, including capital costs. Note the superefficiency method in operation, without which DSO One would have had no incentive to reveal the true cost information in Period 2.

4.1.2 The Intuition

The intuition of the revenue yardstick model is as follows: In period $t - 2$, the DSO is first and foremost allowed the efficient tariff charges, $C^*(t - 2)$. For practical purposes, however, the allowed income is determined based on data with a two period delay. This will allow the regulator time to collect data from period $t - 2$ during the first half of year $t - 1$, and to calculate the allowed revenue for period t during the last part of year $t - 1$. The DSO and regulator can therefore settle on period t charges a priori. This has two advantages compared to a direct implementation of the revenue yardstick without time-delay. First, it allows a DSO to close its financial statement according to normal procedures. Secondly, it ensures that the regulation complies with even strict interpretations of the *ex ante* provision in the EC directive.

The model works with asymmetric interest rents. Undercharging carries the normal interest rate α . Overcharging must be paid back using a higher rate β . In principle, the scheme is incentive compatible even when lending and borrowing carry the same interest rate, $\alpha = \beta$, but to make the scheme more high-powered, and clear we propose to add an extra charge $\delta > 0$ in the case of overcharging. Coupled with the uncertainty of the yardstick level, this will give the DSOs extra incentives to reduce charges.

The revenue yardstick scheme is illustrated in Fig. 2 below. The minimal costs of an efficient DSO is indicated with a non-filled point below the yardstick level,

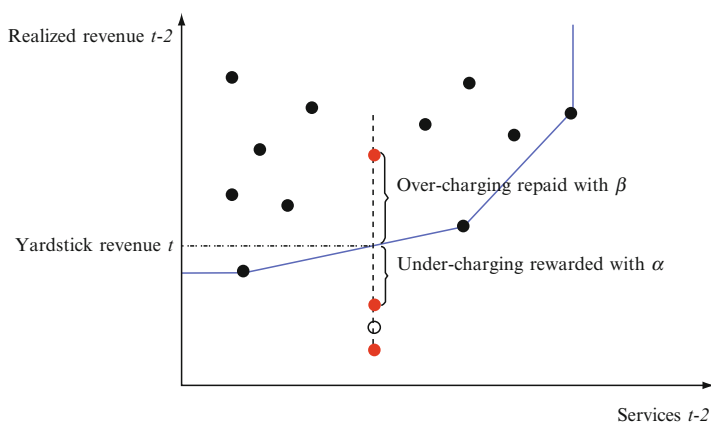


Fig. 2 Yardstick revenue scheme

but the DSO can choose to charge the consumers more or less as indicated by the solid points on the vertical line through the minimal cost point. Overcharging occurs when the charging exceeded the yardstick level.

4.1.3 Incentive Effects

The proposed scheme gives the DSOs incentives to participate and to reduce tariffs to the smallest level that is consistent with continued operation. In short, the mechanics is based on rational forward-looking decision making, where a DSO would not charge lower tariffs than what corresponds to continued operation, including reserves for future investments and a fair long-run average rate of return. The difference is particularly visible for old networks before reinvestment or expansion, where an input-based regulation (using some book-value estimate of capital) would artificially “strangle” the build-up of reserves prior to investment, later to hike tariffs up after the investment. In the new model, this problem disappears as it is the value of continued operation, the tariff, that is evaluated, not the age or state of its assets.

4.2 Benchmarking Model

The benchmarking model is the engine in the yardstick model to determine the revenue target C^* for any kind of DSO; rural or urban, with any kind of service profile, mix of high voltage/low voltage. NEMESYS (2005c) is entirely devoted to this model, for which we briefly touch the specification and the choice of model below.

In the *specification*, the model should take into account inputs, outputs and environmental conditions. On the input or cost side, we need the *revenue levels*. Since the total relevant cost includes all operating, capital and financing charges, cost pass-through can be limited to standard costs for net losses, transmission charges, nondistribution tasks, and taxes. On the output or *services* side the scientific as well as the technical literature converges on a specification that reflects three dimensions: customer service, transportation work, and capacity provision. The first dimension is usually measured by the total number of clients, potentially divided into voltage levels or market segments. The second corresponds to total delivered energy, if needed differentiated by voltage level. The third dimension is measured by proxies for capacity such as installed transformer power or peak power. Environmental conditions can be covered by network length (all studies), delivery area (UK), climate zone (previously in Sweden), or other proxies, cf. Agrell and Bogetoft (2003, 2005, 2007).

Concerning the *type of model*, we draw on the economic optimality and international experience of the DEA model for network regulation, already in regulatory use in Austria, Germany, Finland, Norway, and Sweden. The model has the advantage of giving a conservative estimate of efficiency and draws on a solid production

economic base. However, other models can also be applied, from simple partial averages (€/kWh delivered, etc.), linear cost functions (e.g., based on simple linear regression), or more advanced frontier functions such as SFA (cf. Agrell and Bogetoft 2005, 2007), in use in Germany, Finland, and Portugal.

4.2.1 Quality Incentive Scheme

As discussed above and in Chap. 4, the quality dimension is ever more important for the network regulation at all levels. The ability of the regulation to adequately and credibly provide incentives for long-run quality provision will be one of the acid tests for the regulation. Three dimensions emerged from the analysis in Sects. 2 and 4 above: (1) the quality steering, (2) the information requirement, and (3) the timing of information and settlement (*ex ante*, *ex post*).

For reasons of visibility and commitment, we propose a strict application of an *ex ante* marginal pricing scheme (cf., Sect. 4) on reliability. That is, while the tariff levels should be regulated by a yardstick scheme with the advantages of *ex post* evaluations, we propose that quality is regulated using a strict *ex ante* approach. The *Quality Incentive Scheme* is based on data collected per customer segments for each operator on ENS and SAIFI, defined as

- *ENS* (Energy Not Supplied, GWh), defined at client connection level (<1 kV) for interruptions longer than 1 min, divided into notified and non-notified interruptions.
- *SAIFI* (System Average Interruption Frequency Index), defined as the number of sustained interruptions reported at distribution delivery point (<1 kV), irrespective of interruption time, divided into notified and non-notified interruptions.

The proposed scheme has some similarity with the Norwegian cost of energy not supplied (CENS) as originally described in ECON (2000). The Norwegian CENS regulation is updated from 2009, cf. NVE (2007). Compared to the Norwegian CENS regime, the quality regulation involves a series of important improvements to get a better adjustment of realized quality levels to the socially optimal ones. Similarly, the proposed regulation resembles that implemented in The Netherlands. The proposed approach also has similarities to the Swedish customer reimbursement system although care should be taken to avoid unnecessary administrative burdens.

4.2.2 Compensation Scheme

The structure of the quality incentive scheme is simple

$$Q = A + pq$$

where Q is the quality payment to the DSO, A is a fixed payment q is the supplied level of quality dimension and p is a vector of prices per output dimension.

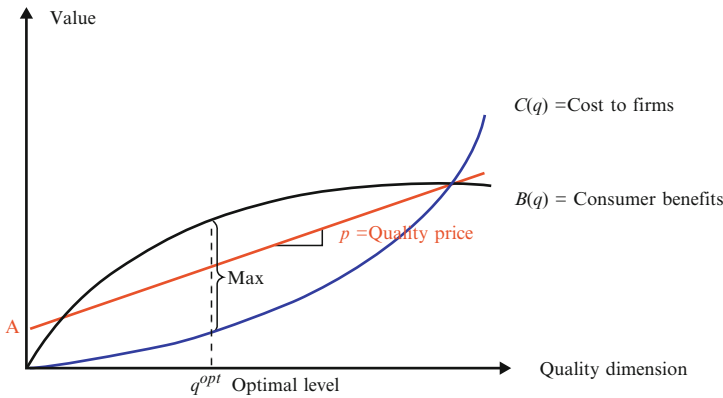


Fig. 3 Quality regulation

The quality reimbursement shall be added to the allowed revenue according to the revenue frontier yardstick model to form the total regulated revenue to the DSO. Specifically, this can be done by including the positive or negative quality charges in the carry-forwards into a carry-forward with quality CF_{wQ} so as to settle these with a 2-year delay.

- *Base payment A* is the preferred equilibrium point (base level) of ENS and SAIFI is to be determined once for each operator and concession area, without updating, using statistical, technical and socio-economic analysis. It shall reflect the underlying costs of quality provision and the socially preferred equilibrium values of ENS and SAIFI. In the analysis care should be taken to include the environmental, load and service factors that have an impact on historical reliability. The optimal levels, the base levels, trade off the benefits to consumers against the costs to the DSO of providing quality. The optimal levels will depend on the country, connection level and the DSO, but have no link to historical levels of cost or performance.
- *Marginal price p* is defined without ambiguity based on type of connection, for each customer segment by the regulators for a 10-year period (cf. Fig. 3) per unit of energy not delivered (ENS) and outage occasion (SAIFI), for notified and non-notified interruptions, respectively.

4.2.3 Regulatory Settlements

Based on objective and verifiable measurements of ENS and SAIFI at customer level compensations to individual customers can be calculated and the customers can be reimbursed with a time delay corresponding to the one used in the revenue regulation. To the extent that ENS and SAIFI cannot be measured and controlled at customer level, then the lowest, most customer close measure points shall be used.

In these points, the ENS price will equal an average of the consumer-based prices below while the SAIFI price will be the sum of the SAIFI prices for the customers below. To avoid unnecessary administrative burdens, small consumer reimbursements could also be accumulated on a solidarity account and be used to lower the general charges to the DSO’s consumers.

4.2.4 Regulatory Procedure

The proposed regulatory procedure is illustrated in Fig. 4 below for the three parties DSO, regulator and metering agent.

- 1. DSO reports electronically financial, service and concession data for *Core DSO Tasks*, *National Regulated DSO Tasks*, and *Other DSO Tasks*, after closing the accounts for year 1.
- 2. Metering Agent reports low-level reliability data for year 1 and total supplied energy from higher grids.
- 3. Regulator calculates DSO Net Revenue by deducting for the preceding year, charges to higher grids, standard costs for network losses, *National Regulated* and *Other DSO Tasks* from the submitted total revenues. If the Net Revenue is negative, the firm is deleted from the list of comparators, otherwise not.
- 4. Regulator runs revenue yardstick model is run for all firms, using the eligible comparators, and the Efficient Revenue for year 1 is calculated for each firm.

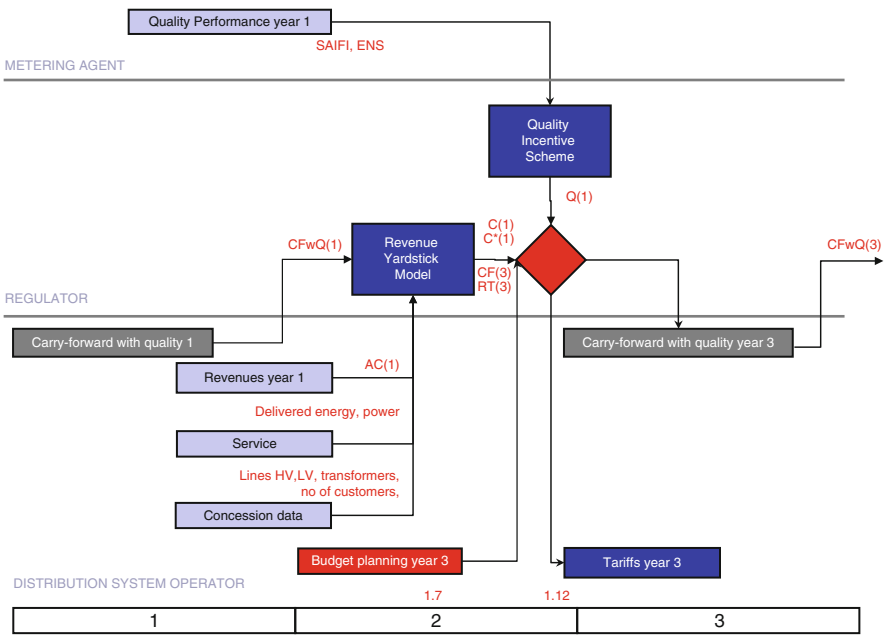


Fig. 4 The NEMESYS regulatory process

5. *Regulator* calculates the quality incentive scheme and the result can be either negative or positive. In the first case where less than optimal quality has been supplied, the result shall be processed as an ENS compensation to be paid out to consumers in year 3. To limit the administrative burdens, we may choose only to compensate individuals when the compensations exceed a given threshold, and to simply pool small amounts and use these to compensate the collective of consumers. In case of positive quality outcomes, i.e., when the supplied quality level exceeds the base level, we propose to simply charge the consumer collective in year 3.
6. *Regulator* announces the carry-forward for year 1, including the negative or positive difference from the revenue yardstick and the pooled difference from the quality incentive scheme, adding *National Regulated Tasks* as the settlement for the DSOs in year 3.
7. *DSO* incorporates the carry-forward for year 1 in the establishment of tariffs and a projected budget for year 3. The tariffs and the projected budget are submitted to the regulator as an acknowledgment of the carry-forward.
8. *Regulator* formally approves (orthodox *ex ante*) the proposed tariffs for year 3. In this step, discretion may be exercised based on, e.g., upcoming investments in the budget or negative carry-forwards.

5 Stakeholder Analysis

To investigate whether the institutional differences in regulation reflects underlying national differences in preferences and prioritization, the project collected structured data on the goals and objectives of different stakeholders (DSOs regulators, government, industrial clients, residential clients, associations) in the four countries. The study [NEMESYS \(2005a\)](#) comprised both questionnaires and semidirected interviews of the group.

5.1 Results: Stability, Quality, and Efficiency

The survey and interview material show that different stakeholder groups are to a large extent unanimous about the goals and objectives related to electricity distribution (cf. Fig. 5). Most important economic aspects are stable tariffs (clients) and stable return on investment (owners), and high efficiency. Natural conflicts are related to the level of tariffs and profits. Quality aspects are as important as the economic aspects and security of supply is the most important single goal. Other studies [TNS Gallup \(2005a,b\)](#) confirm increasing orientation towards customer service and reliability of information from the sector. Many clients are also uneasy with the basis and justification for the distribution tariffs, suspecting inefficiency. Equity and fairness issues, in particular open network access, are mostly seen as requirements

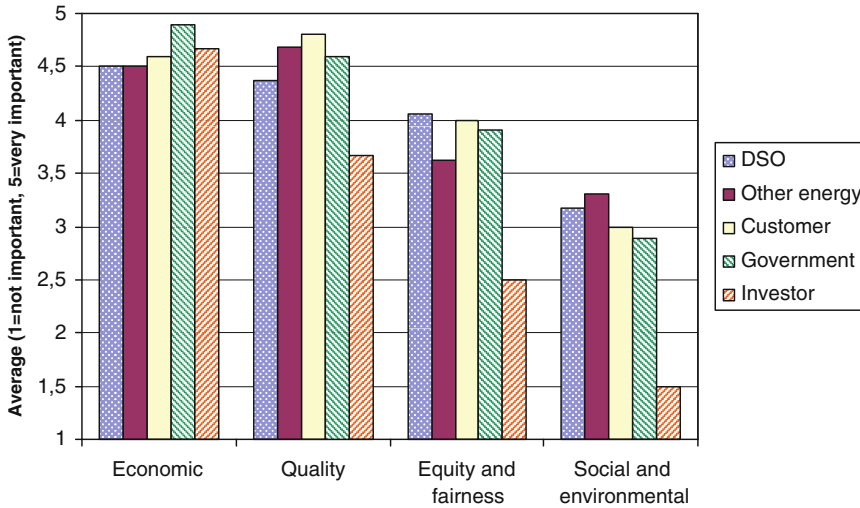


Fig. 5 Relative importance of DSO service dimensions under well functioning regulation (NEMESYS 2005d)

but not primary goals. Depending on the stakeholder groups, equity of customers and fairness for different types of companies are also seen important. Social and environmental aspects are ranked less important for network regulation.

5.1.1 Stakeholder Consequences

Summarizing a richer consequence analysis for firms, customers, market, and government in NEMESYS (2005d), the most important changes would be related to the incentives for lowering tariffs and improving cost efficiency. The suggested mechanism would set a high cost reduction and tariff cut pressure on those companies that are classified as inefficient. This would have a very significant local effect, and it would probably lead to structural changes in the industry. On the other hand the efficient companies would probably make more profit than under the current regimes. Hence, the suggested approach would give stronger incentives for improving efficiency and assuring capital for investment in grid expansion and reinforcement. In the short run, the suggested mechanism would decrease the stability of tariffs and profits, but in the long run it should lead to a stable situation.

5.2 Further Work

Many detailed questions remain before an actual implementation of either harmonized regulation or the specific proposal. Below we specify a prioritized list of suggested further work. Note, however, that these projects in no way can or should

substitute for development work made directly by, or for, the regulators. The active involvement of the sector in the development and convergence of regulation enables and facilitates the necessary implication of the national institutions. To further analyze the properties of the proposal we propose work on three themes: internal evaluation, enablers, and principal challenges.

5.2.1 Consequence Analysis

A harmonization like the one proposed in the paper is also associated with direct costs related to the change of system at a regional scale. It is, thus, indispensable to anchor the reform among the stakeholders and to evaluate the consequences in order to define the optimal scope and scale of the harmonization.

- *In-dept quantifications of the consequences* for the grid companies of changing the regulatory design from the current national regulatory models to the by the working group preferred Nordic regulatory model. The analysis should include quantifications for different types of grid companies as well as an industry-wide quantification.
- *Live simulations* could be done to explore the yardstick logic using a “virtual laboratory” with real decision makers subject to a dynamic simulation. The purpose of these experiments is to validate whether the decision makers perform according to the assumptions of the *new logic* and to collect data on behavior to facilitate parameterization.

5.2.2 Initiative on Regulatory Enablers

From the harmonization enablers mentioned above, further work is needed in:

- *Task definitions* among the membership countries as to determine a possible set of core DSO Tasks, including a set of indicators to measure the output of the tasks if necessary.
- *Data harmonization* should be defined in collaboration with regulators as to converge on data collection routines, metering standards, information systems, definitions, and standards that permit pan-Nordic open information systems.

5.2.3 Principal Challenges in the Model: Non-Profit Firms

The application of a high-powered regime (such as the proposed yardstick) to non-profit maximizing firms would need specific instruments to control for their impact on the revenue norm. A specific study should be conducted on (1) the prevalence and behavior of nonprofit firms and (2) an in-depth investigation to validate the accommodation of such firms in yardstick competition schemes.

6 Conclusions

The NEMESYS proposal is an innovative attempt to design a regulatory approach that improves on the most important dimensions for the Nordic stakeholders, the incentives for investment and efficiency, stable tariffs, and quality of service. The proposed approach differs from existing regulation in detail, but primarily in philosophy, as it is a consistently output-based regulation that delegates the process to the regulated firms. In doing so, it changes the information requirements in the regulatory approach in the direction of increased attention to what really matters to the final consumer, i.e., a clear and consistent description of the regulated task and performance assessment. It also constitutes a true paradigm shift in that it restores the role of the regulator to market design and surveillance of structure and development, rather than direct negotiation partners in a proxy-bargaining process on behalf of the customers. Hence, the competition in the NEMESYS approach is played between *firms* in operation achieving stable and low tariffs at high-quality, not towards the regulator using asymmetric information on current and upcoming investments.

The *harmonization* of DSO tasks, defining responsibilities, data and compensation norms clearly across the Nordic countries leads to a more transparent and constructive dialog with regulators. Further harmonization of regulation principles, instruments and regimes improves both the *effectiveness* of the regulation, by commitment to the key issues rather than details, and the *efficiency* of the sector in the creation of equitable, stable, and sound business conditions under lower regulatory risk premiums.

The *yardstick idea* is practically implementable, compatible with the EC Directive 2009/72/EC and open for several types of cost functions. It leaves the difficult problem of asset valuation to the DSOs and the capital market. It also combines the firm's need for financial stability (*ex ante* tariff delegation) with the regulator's mission to ensure efficiency (*ex post* yardstick correction). The incentive parameters can be set to "tune" the regime to different capital risks.

The *quality incentive scheme* supports the optimal trade-off between cost and benefits of security of supply. Moreover, it provides quality incentive for DSOs irrespective of their performances in the revenue yardstick competition. That is, even inefficient DSOs are encouraged to care about security of supply, investment analyses on quality provision can always be performed, irrespective of profit level.

The *proposal* is advanced in its use of mechanisms (revenue-based yardstick), yet the logic is intuitive and simple to explain to any stakeholder. Any Nordic customer in the NEMESYS model pays the lowest tariff that any comparable firm offers its clients. Any Nordic firm can define its profit as the difference between its costs and the lowest tariff charged by any other comparable firm. Comparability is defined on measurable dimensions of output, not accounting and process indicators. That's it.

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