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Scientific Review on Regulation Models for Electricity Distribution Networks

Final Report

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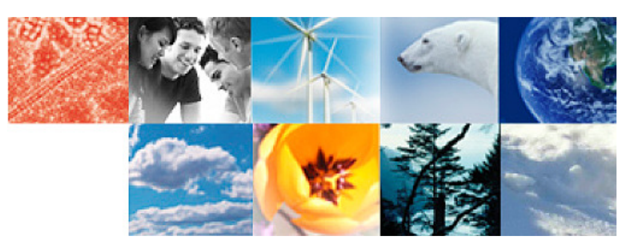

Contents

Yhteenveto

Viimeisen viiden vuoden aikana regulaatiomallien kannustavuuden tutkimuksessa on edistytty niin teorian kuin käytännön tasolla. Monet perustavaa laatua olevat mallien kannustinvaikutuksiin liittyvät kysymykset edellyttävät kuitenkin vielä tieteellisiä tutkimuksia. Uusien lähestymistapojen ja mallien käytännön sovellettavuudesta sekä vaikuttavuudesta tarvitaan lisää tietoa. Erityisesti viime vuosina kestävään kehitykseen ja hiiliniukkaan energiajärjestelmään liittyvät asiat ovat nousseet voimakkaasti esille useiden maiden regulaatiomallien kehittämisen yhteydessä. Toistaiseksi näistä asioista on vain vähän käytännön kokemusta.

Tässä raportissa on tarkasteltu erilaisia regulaatiomalleja ja niiden kykyä luoda kannustimia alhaiseen kuluttajahintaan, hyvään laatutasoon ja hiiliniukkaan energiajärjestelmään. Neuvottelumenettelyyn ja huutokauppaan pohjautuvat regulaatiomallit mahdollistavat teoriassa kaikkien regulaattorin edellyttämien tavoitteiden kattavan huomioimisen. Kirjallisuudessa esitettyjen käytännön kokemusten perusteella neuvottelumenettelyyn perustuvat mallit ovat osoittautuneet varsin tehokkaiksi, vaikka ne ovatkin hallinnollisesti raskaita. Täten niiden hyödyntäminen Suomen olosuhteissa, jossa sähköverkkoyhtiöiden lukumäärä on lähellä sataa, olisi käytännössä varsin työlästä. Yhtenä mahdollisuutena voisi olla neuvottelumenettelyn soveltaminen ainoastaan suurimpiin yhtiöihin, kun taas suurin osa yhtiöistä käsiteltäisiin nykyisenkaltaisella regulaatiomallilla. Tämä johtaisi kuitenkin yritysten erilaiseen kohteluun ja olisi todennäköisesti juridisesti hankala toteuttaa. Huutokauppamalleja puolestaan voitaisiin soveltaa täysin uusilla verkkoalueilla. Tällaisia voisivat olla esimerkiksi siirtopalvelujen tarjoaminen suurille tuulivoimapuistoille.

Vaihtoehtoisten sopimusten mallit tarjoavat asteittaisen parannuksen hinta- ja tulokattomalleihin verrattuna paljastamalla tehokkaammin valvottavan todellisen kyvyn tehostaa toimintaa. Näitä malleja olisi kuitenkin käytettävä useita vuosia, jotta todellinen hyöty saataisiin esille. Koska näiden mallien soveltaminen olisi käytännössä hallinnollisesti raskaampaa kuin puhtaiden hinta- tai tuottokattomallien käyttö, olisivat todelliset hyödyt kokonaisuudessaan rajalliset.

Mittatikkumallit ovat malleina varsin tehokkaita ja käytännöllisiä, koska vertaamalla eri yhtiötä keskenään voidaan paljastaa yhtiöiden tehottomuudet. Lisäksi mittatikkumalleihin voidaan kätevästi sisällyttää myös muita kuin taloudellisia tekijöitä ja näin luoda kannustimet muun muassa laadun parantamiseen sekä hiiliniukkaan energiajärjestelmään tähtäävien tavoitteiden huomioimiseen. Esimerkiksi uusiutuvan sähköntuotannon verkkoon liittäminen voidaan huomioida mittatikkumallissa kustannusajurina. Täten mittatikkumallit ovat kiintoisa vaihtoehto tulevaisuudessa, jolloin laatu ja vähähiiliseen energiajärjestelmään tähtäävät toimenpiteet ovat merkittävässä asemassa.

Vaikka mittatikkumalleilla on monia etuja, voi hinta- tai tulokattomallit olla myös tulevaisuuden regulaatiokehikon pohjana, kuten on päädytty Iso-Britanniassa. Tässä tapauksessa muut tarvittavat osa-alueet, kuten laatu ja kestävä kehitys, pitää yhdistää kokonaismalliin erillisinä moduuleina, joiden kautta taloudelliset kannustimet näihin asioihin konkretisoituvat.

Perustuen selvityksen havaintoihin voidaan suositella, että sähköverkkojen regulointi perustuisi tulevaisuudessa joko mittatikkumalliin tai nykyisenkaltaisen tulokattomalliin. Mikäli mallin pohjana käytettäisiin nykyistä mallia, olisi laatukannustimen lisäksi malliin sisällytettävä kannustimet hiiliniukkaan energiajärjestelmään. Jotta kokonaismalli pysyisi ymmärrettävänä, suositellaan, että laatu ja hiiliniukkuus huomioitaisiin mallissa erillisinä moduuleina, joiden kautta luotaisiin selvät taloudelliset kannustimet näiden asioiden edistämiseksi. Hiiliniukkuuden näkökulmasta olisi keskeistä, että tulevaisuuden regulaatioympäristö loisi selkeät kannustimet erityisesti uusiutuvan sähköntuotannon ja kysyntäjouston käyttöönoton edistämiseksi. Olisi myös suotuisaa varmistaa, että tulevaisuudessa tehtävät investoinnit palvelisivat näitä tavoitteita samalla välttäen investointeja, jotka eivät edistä yllä mainittuja tavoitteita.

Riippumatta teoreettisesta regulaatiomallista tulevaisuuden suuret haasteet liittyvät siihen, kuinka käytännön tasolla voidaan huomioida hiiliniukkaa energiajärjestelmää koskevat tavoitteet? Tällä hetkellä moni käytännön kysymys on vastausta vailla. Tämän vuoksi tarvitaan tarkempia tutkimuksia siitä, kuinka varmistetaan mahdollisten toimenpiteiden tehokkuus ja todellinen vaikuttavuus.

1 Introduction

Finnish energy market authority (EMV) has launched a project called Roadmap 2020. The objective of the roadmap project is to develop framework for regulation models of electricity networks up to year 2020. As a part of this project, EMV has started a scientific oriented sub-project focusing on recent development in regulation theory and its practical applications. The objective of this sub-project is to carry out literature review on recent scientific papers and other relevant publications, and to make recommendations for EMV to develop regulation models within the timeframe of 2015 – 2020.

The main tasks of this sub-project are:

1. Carry out literature review on recent publications in regulation theory of electricity distribution networks. The main emphasis of the study is in incentives of alternative regulation models.
2. Analyse recent development of regulation models and evaluate their applicability to Finnish regulation environment focusing especially on incentives to fulfil objectives of the regulation. The models to be studied are price and revenue cap models, yardstick models, contract of menus as well as concession auctions. In addition technical norms and negotiation based models are briefly discussed.
3. Make recommendations for EMV to develop their regulation system based on the previous analyses.

The results of this study are summarised in this report. In chapter 2, the rationale of regulation and alternative classical regulation models are introduced. Chapter 3 summarises recent developments in regulation theory based on the literature review of scientific and other relevant publications. Both theoretical and practical advances are described, and more detailed review of some selected publications is carried out.

In Chapter 4, an incentive analysis of alternative regulation models is carried out. The incentives to be examined are price control, quality and security of supply as well as sustainability issues, especially focusing on ability of regulation models to enhance change towards low carbon energy systems. In chapter 5, Finnish regulation environment with its special characteristics is studied more closely. Especially suitability of alternative regulation models are analysed and also regulatory challenges are described. Finally, the conclusions and recommendations are given in chapter 6.

2 Regulatory toolbox

2.1 Regulatory economics

Early regulatory theory largely ignored incentive and information issues, heavily drawing on conventional wisdom and industry studies. This kind of institutional regulatory economics was challenged already in the seventies with economists as Friedman, Baumol, Demsetz and Williamson questioning the organization and potential restructuring of natural monopolies. However, the main breakthrough came in the late eighties with information economics and agency theory (Holmström, Laffont, Tirole). An authoritative reading in the area is Laffont and Tirole (1993). Contemporary economic theory pursues the private goals and strategic behavior of the individual agent, with particular emphasis at the access, cost and use of information. The practical applications from this stream of research have had a profound impact on modern markets, market instruments, contracts and economic restructuring.

2.1.1 Why regulate?

The guiding principle for all economic activity in the Western society is the *market*. Network activities, such as distribution of electricity or water, are examples of natural monopolies or market failures. For electricity distribution, the monopoly is accentuated by (i) the existence of a single supplier of the service for each customer, (ii) no substitute for the offered service and very low price elasticity, and (iii) high economic and legal barriers to market entry.

In addition to the desire to incite productive and allocative efficiency, there may be non-economic reasons to impose regulation on a network industry. Attention paid to public safety, continuity of supply, public service obligations, environmental externalities and information disclosure are examples of such objectives.

Thus, in return for granting exclusive monopoly rights, for a limited or unlimited period of time, the society empowers a regulator to act as a proxy purchaser of the service, imposing constraints on the prices and the modalities of the production.

2.1.2 The regulator's problem

In modern economic theory, the regulatory problem is expressed as a game between a principal (the regulator) and a number of agents (the regulated firms). The objective of the regulator is to maximize social welfare, which may be thought of as the difference between the customers' and the firms' utility (profit) and the costs incurred. Immediately, it is clear that minimization of costs is a societal priority, as well as the inevitable trade-off between the consumer and industry interests. The objective of the regulated firms may be maximization of surplus, which in addition to monetary profit also includes managerial utility (effort level, benefits and conditions).

The availability and access to information is a key issue in the regulatory game. With perfect access to information, the regulator could impose socially optimal price and service quality. However, the information is *asymmetrically* distributed between the regulator and the agents. The regulator faces a double asymmetry, where neither efficient costs, nor optimal efforts are verifiable. Costs and prices in the market are not true reflections of supply and demand, but are set by the actors themselves in a monopoly– oligopoly setting. Since the regulator has an information disadvantage against the agents, the attainable goal of the regulation cannot be to implement the first best competitive solution, but to *mimic* the market by carefully using elicited information. We claim that the closer the regulation gets to market functions, the less harmful it will be in the long run through the distortion or incentives, information and production. Facing efficiency improvements, innovation and technical development, a mis-specified regulation will be likely to dampen progress and achieve lower social welfare.

2.2 Classical regulation models

The regulatory toolbox contains numerous more or less ingenious solutions to different instances of market failure. Starting from state-of-the-art in the practice of regulation and moving towards state of the art in the theory of regulation, we shall discuss four types of regulatory mechanisms here, namely cost-recovery regimes (cost of service, cost-plus, and rate of return) and negotiation/consultation based models including:

- Fixed price (revenue) regimes (price-cap, RPI-X),
- Yardstick regimes,
- Concession auctions regime
- Technical norm models
- Menu of contracts
- Quality regulation
- Cost-recovery and negotiation/consultation based regimes

Taking the cost information supplied by the agents for granted the regulator may choose to fully reimburse the reported costs, often padded with some fixed mark-up factor. To illustrate, the reimbursement in a given period may be determined as

$$R = C^{OpEx} + D + (r + \delta)K$$

where C^{OpEx} is the operating expenses , K is the capital (rate base), D is the depreciation of the capital reflecting capital usage, r is an interest rate reflecting the credit costs of investments with similar risks and δ is a mark-up.

Unless subject to costly information verification (regulatory administration), the approach results in poor performance with skewed investment incentives (no investment risk, yet fixed return on investment), perverse efficiency incentives (loss of revenue when reducing costs) and lack of managerial effort (distorted market signals and limited managerial rewards).

In reality, such schemes have involved considerable regulatory administration trying to avoid imprudent or unreasonable operating expenditures or investments to enter the compensation and rate base. However, even with large investments in information gathering, the information asymmetry and the burden of proof resting on the regulator still cripple the efforts to induce efficiency.

Regulatory authorities worldwide are gradually abandoning these regimes as administratively costly and technologically inadequate, also in the UK and USA, where the approach have been heavily used.

Cost recovery is often organized as negotiation and consultation based regimes. Whether rate reviews are initialized by complaints or are planned, reviews are often done as individual consultations. In contrast to the methods below, where a joint framework is used to evaluate all DSOs, the consultations are typically case specific and the rely more on negotiations than on a comprehensive model estimation for the whole sector.

An idea is to combine negotiations with systematic investigations and benchmarking that can limit the negotiation space. Hereby the negotiations become more structured. Such restrained negotiations were proposed in NL for the regulation of hospitals; the idea would be that the regulator sets constraints on the acceptable outcomes but leaves the negotiation to industry partners. In this way, the regulation becomes a hybrid between a traditional revenue or price cap regulation and a negotiation based approach, cf. Agrell, Bogetoft, Halbersma, and Mikkers (2007).

2.2.1 Fixed price regimes (price-cap, revenue cap, RPI-X)

In response to the apparent problems of the cost-recovery regimes, Littlechild (1983) launched a so-called high-powered regime allowing the regulated firms to retain any realized efficiency gains. In the price-cap regime, the regulator caps the allowable price or revenue for each firm for a pre-determined period.

Based on a review period, a model of likely development in costs is developed, and this model is used to fix the revenue or price baskets for a typically 4-5 years regulation period. The model is usually quite simple, involving a predicted productivity development per year x plus perhaps individual requirements on firms, say x_i, to reflect the level of historical costs and hereby the need to catch up to best practice. The resulting allowed development in the revenue for firm i is then

$$R_i(t) = C_i(0)(1 - x - x_i)^t \quad \text{for } t = 1,\ldots,T$$

where $R_i(t)$ is the revenue in period t, and $C_i(0)$ is the cost of firm i in period 0.

There are of course many modifications to this model and we shall consider some more specific ones later. The crucial thing to observe, at this stage, is the fixed (performance independent) payment. This is the key to the incentive to reduce costs.

Another feature is the fixation of payments for a regulation period and hereby a regulatory lag in the updating of the productivity development. The last feature is often emphasized by calling such schemes ex ante regulation as illustrated in Figure 2-1, where the allowed revenue for years 1 to T is fixed prior to year 1.

Figure 2-1 Ex ante revenue cap

As observed, the performance independent payment - effectively making the firm the residual claimant - is the key to the incentives: to maximize profits, the firms minimize their costs and optimize their efforts, achieving cost efficiency. Also, to the extent cost include capital costs, this scheme incentivize the DSOs to make relevant investments and to optimally trade-off OPEX and CAPEX.

However, in practice, the revenue cap is regularly reset with hindsight to the realized profits in the past period, which limits the efficiency incentives. It might in such situation pay-off to increase costs towards the end of the regulation period. The advantage of this is to inflate the revenue level for the coming regulation period. Empirical research (Giulietti and Waddams-Price, 2000) has shown that utilities indeed do play strategic games under revenue-cap regimes in anticipation of future cap reviews (ratchet effect).

Another difficulty is the initial price/revenue level when firms initially charge differing prices. Either the conditions are homogenous, in which case the price differences reflect inefficiency, or the price levels reflect heterogeneous delivery conditions. In any case, the initial price caps would have to strike a careful balance between informational rents, incentives for restructuring and the bankruptcy risks.

In most ways, a price cap and a revenue cap systems are similar – they basically limits the charges a DSO can make and incentivize them to reduce costs. As long as demand is not sensitive to distribution costs, both systems lead to much the same results. With elastic demand, however, it may be advantage for a DSO under revenue cap regulation to limit it services and hereby increase profits by charging high prices for low service levels. A price cap system may prevent this.

Most countries leave the allocation of these charges on different user groups to the decision of the DSOs, sector agreements or supplementary regulation.

Revenue and price cap systems constitute the regulatory frameworks adopted by most European countries.

2.2.2 Yardstick regimes

The idea behind yardstick regimes is to mimic the market by using real observations to estimate the production or cost function of the period in question. Thus for example, in its simplest form, the allowed revenue for firm i in period t would be set ex post and be determined by the costs in the same period of others firms $j = 1,..,i-1,i+1,..n$ operating under similar conditions

$$R_i(t) = \frac{1}{n-1}\sum_{j\neq i} C_i(t) \text{ for } t = 1,2,.....$$

The regime is attractive in the sense that the revenue of the firm is not determined by his own cost, but by the performance of the market (the other firms). The scheme is therefore effectively a fixed price scheme making the firm a residual claimant like in the revenue cap model above and this is the key to the incentive properties.

The second crucial feature is that the allowed revenue is determined ex-post, i.e. after each period. This is illustrated in Figure 2-2 below where the allowed revenue for year t is determined at the end of year t using data from year t. Exogenous and dynamic risks will directly affect the costs in the industry, lifting the yardstick. Innovation and technical progress will tend to lower the yardstick.

Figure 2-2 Ex post revenue cap

Lazear and Rosen (1981), Nalebuff and Stiglitz (1983) and Schleifer (1985) show condition for the implementation of first-best solutions for correlated states of nature. The results carry over even for imperfectly correlated states of nature (Tirole, 1988). Hence, the comparators do not have to be identical, but the relative difference in the exogenous operating conditions has to be known. In reality this means that full scale benchmarking models shall be developed like in the revenue cap framework, but the analyses must now be done more frequently.

A major advantage of yardstick competition is that the productivity development is observed rather than predicted. This provides insurance for the DSOs, and it limits the information rents. A drawback is that when the comparators are few, there is risk of collusion.

A DEA based yardstick scheme was introduced in Norway 2007. Also, the Dutch regulation has yardstick features.

2.2.3 Concession (franchise) auctions regime

A simple mean to elicit accurate cost information while assuring participation is to arrange franchise auctions (Demsetz, 1968, Laffont and Tirole, 1993, Baldwin and Cave, 1996). The idea is to award the delivery rights and obligations based on an auction among qualified bidders. Thus for example if each of n bidders for a projects demands C_i , $i=1,..n$ we may award it to the bidder i with the lowest bid $C_i = \min_j C_j$ and compensate him

$$R_i = \min_{j \neq i} C_j$$

The regime conserves the simplicity of the fixed-price regimes, but limits the informational rent. It also offers perfect adjustment to heterogeneity, since prices may vary across franchises.

Problems are for limited markets with high concentration that bidding may be collusive, that excessive informational rents may be extracted and that competition may be hampered by asymmetric information among incumbents and entrants (McMillan, 1992). Even under more favorable circumstances, the problems of succession and investment incentives remain to be addressed (Williamson, 1976).

In the energy sector for example and due to the current oligopolistic structure of the incumbent electricity distribution industry, the franchising instrument is likely to be used sparingly in Europe in the near future unless subject to more advanced designs.

2.2.4 Technical norm models

Roughly, three kinds of regulatory production functions may be distinguished with respect to information requirement and potential application: statistical, benchmarking and (technical) normative models. The benchmarking model elicits the information directly from the assessed data and makes minimal extrapolation from the data to form the “best practice” frontier. However, unless the industry shows some examples of best practice, this frontier is likely to be strictly inside the true frontier. A statistical frontier (such as an average cost function) also extracts information solely from the observations, but adds the assumption that good performance is as random as poor performance. If there is any variation in the sample, this frontier will be strictly dominated by the benchmarking frontier. The technical normative model, finally, is based on an attempt to come closer to the true production frontier, or to draw on other information than merely the observations. The concept is tempting in regulation because of its potential profit reduction possibility and its integration in yardstick regulation. However, given the high cost of failure and service interruption in network services, the issue of feasibility in the normative estimation is primordial. In Figure 2-3 this is indicated by a zone where the normative model (being a simplification of reality) actually dominates the true frontier, i.e., predicts a lower cost than feasible in reality using best practice.

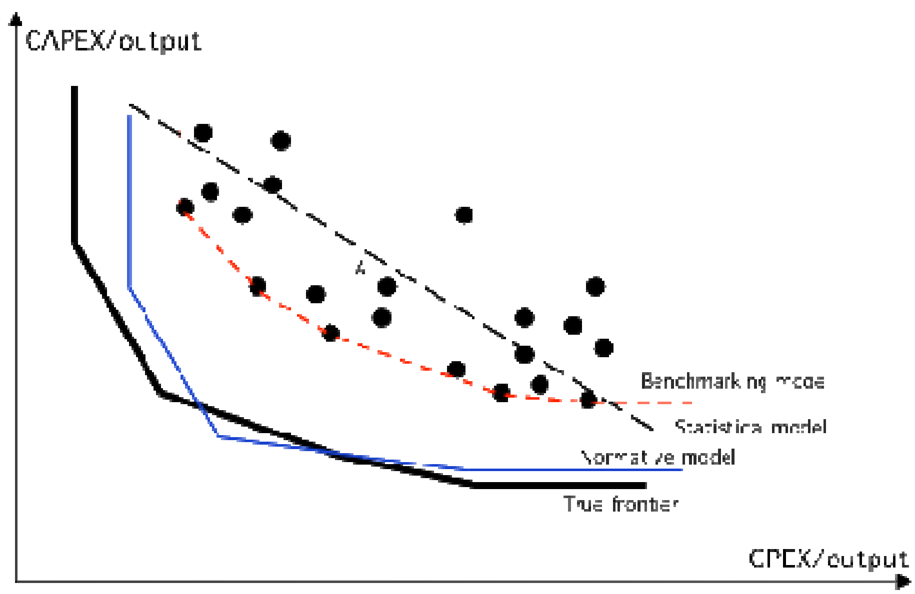

Figure 2-3. *Production space and normative, statistical and benchmarking models.*

In general, technical normative models are just special cases of engineering cost functions with varying level of information requirements. As such, they are used to prescribe rather than predict the optimal, or allowable, cost for a certain level of operation. Thus, the model’s estimate can be made feasible by *parameterization* and *construction*.

Conservative parameterization: One approach to achieve feasible cost estimates is to tune parameters and variables in the model unilaterally in more conservative direction. In case of doubt, capacities, times and lengths are rounded upwards, risks are exaggerated and costs overestimated. The resulting error is always positive for the regulated firm and can be seen as the cost of information imperfection in the model. The risk of system error is born by the regulator, since this maximizes the social welfare.

Construction: To assure feasibility with a minimum loss of cost efficiency, norm values may be deducted from a realization of a network in all detail. Less likely to result in a mathematical model, this approach requires considerable effort and industrial expertise. If the technical system can be fully parameterized, an exhaustive frontier may be construction, even for networks that have never existed. If the analysis is made on discrete examples, perhaps candidates for improvement, some assumption is necessary to form the frontier (if necessary).

In DSO regulation, only two countries use formalized technical normative models, Sweden and Spain, cf. Agrell and Bogetoft (2003b). Moreover, Sweden has recently abandoned the use of this model.

2.2.5 Menu of contracts

So far we have covered a series of classical regulation schemes. In reality, however, the task need not be to choose one of them. One can in principle allow a menu of multiple regulations that the DSOs can choose from. Also, having decided on a given class of regulation, say a revenue cap regulation, one can allow different variants of this, for example some with higher or lower base level and with larger or smaller catch-up requirements.

The idea of using a menu of contracts is to abandon a notion of one-size-fits-all. If we have one regulatory model that everyone shall be able to live with, we may have to make it rather lucrative. Therefore, a menu can be one way to reduce the information rent. That is, we can use a menu to solve adverse selection problems. This is the classical motivation in the theoretical literature, cf. e.g Laffont and Tirole (1993)

Another purpose of a using a menu is to adjust to local circumstances. It may not be relevant to strive for the same quality level for example in different DSOs since the marginal costs and benefits may differ. This is illustrated more detailed in Chapter 2.2.6.

Lastly, the use of a menu can be a way to protect the DSO against modeling uncertainty. If for example, we can measure capital costs in two ways and both have merits and drawbacks, one can make two models and let the DSOs be evaluated by a Best-of-Two approach. In this case, a DSO picks the one putting it in its best possible light. Such application of the menu idea was used early in Norway, to handle the problem of measuring capital. A more recent trend is to make both DEA and SFA model and to choose the best of these in the evaluation of individual DSOs. This has been used in for example Germany and Austria.

2.2.6 Quality regulation

Regulation in theory as well as in practice has mainly focused on the prices of goods and services, e.g. the prices for having electricity distributed. Price however is just one important parameter in the relationship between firms and customers. Quality is another. After all, it defines the good being exchanged and it makes little sense to set prices on ill-defined products. In this chapter, we outline some fundamental issues and challenges in quality regulation and we sketch some operational solutions.

Quality has traditionally been handled through the imposition of a system of compulsory and a system of suggestive minimum standards. Coupled with a tendency to rely on engineering reasoning, this has lead to relatively high quality standards in northern Europe. This, however, may neither be optimal nor the long run equilibrium. First, the cost of ensuring the present high quality level may exceed the benefits and the present quality level, although certainly high enough, may actually be too high and too costly. Second, any change in the regulatory approach will change the behavior of the agents. In particular, a movement towards a higher powered arms-length incentive regulation will induce the firms to focus more on cost minimization with a possible adverse effect on quality.

The basic underlying problem is to determine the optimal trade-off between the costs of producing higher quality and the benefits derived from it. This problem is illustrated in Figure 2-4. Here the cost function is the cost to the firm of changing its present quality level. The benefit function B(q) is similarly the gains to the consumers from changes in the quality level. The optimal level leads to the largest difference between costs and benefits.

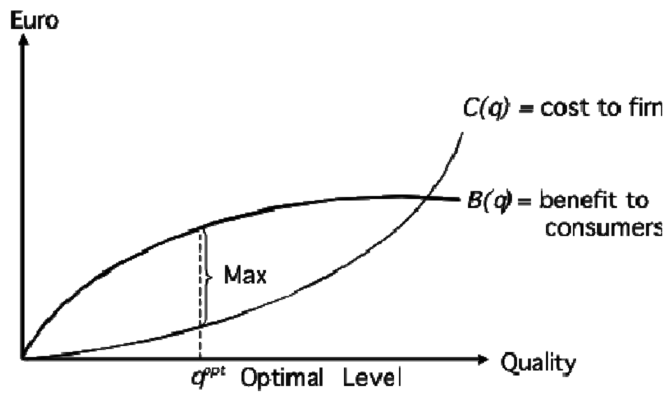

Figure 2-4. Optimal quality level.

Figure 2-5 illustrates an instance where there are significant differences in the demand for quality from different consumer groups and where it may therefore be worthwhile to introduce such variations depending of course on the costs.

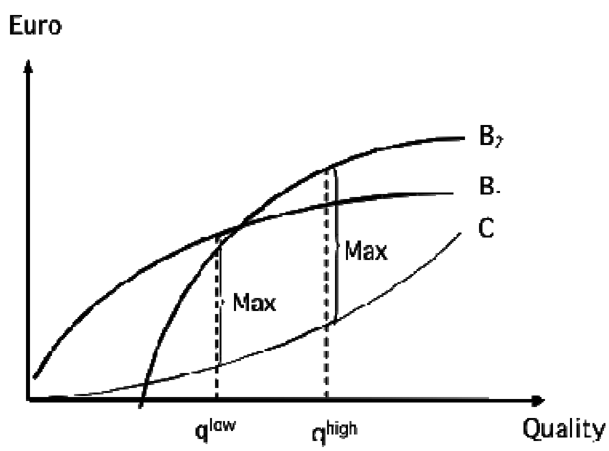

Figure 2-5. Different quality to different consumers.

All of what has been said above can – with obvious modifications – be repeated in an inquiry as to the desirability of allowing differentiated quality levels from different distributors.

We shall now outline four principal ways in which the DSO may be incentivized to adjust quality towards the socially optimal level, the q^{opt} in Figure 2-4. One possibility is to use a *generalized price plan* where the firm is reimbursed an amount R(q) equal to the consumers benefit B(q) minus a lump sum (quality independent) payment A:

$R(q) = -A + B(q)$

The lump sum amount A can be chosen as any value between 0 and $B(q^{opt})$-$C(q^{opt})$. High values means that all the gains from adoption to optimal quality goes to the consumers and low values means that the gains go the firm. This scheme is illustrated in Figure 2-6.

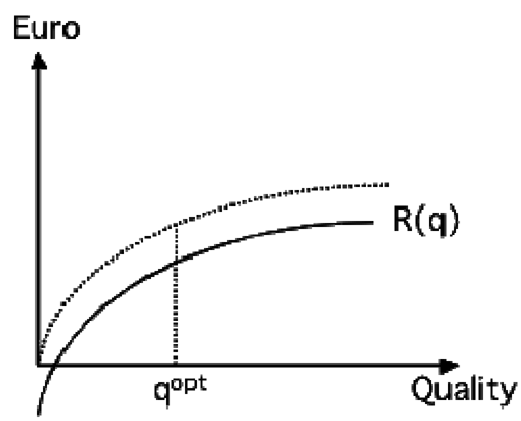

Figure 2-6. Generalized price plan.

The generalized scheme is advantageous by leading to optimal quality levels for all possible cost functions. The regulator do not need to know and constantly track changes in the costs function except to determine the exact range in which A can be chosen. On the other hand, the regulator needs considerable information about the benefit function. To collect such information, the regulator may undertake willingness to pay and consumer choice studies where a number of consumers are asked how much they are willing to pay for improved quality and how they would choose in some hypothetical choice experiments. There is a considerable literature on the design of such studies and a large body of practical experience, in part from the marketing science. Still, the collection of information about B(q) may be a non-trivial task. Moreover, it may be difficult to communicate especially in the multiple dimensional cases.

A second possibility is to use a so-called *two-price scheme* where the firm is paying a lump sum amount A for the right to make quality decisions plus a relative high price p_1 for quality improvements, when quality is low; and a small price p_1-p_2 for quality improvements when quality is higher:

$R(q) = -A + p_1 q - p_2 \max\{q-q^{opt},0\}$

This scheme is illustrated in Figure 2-7.

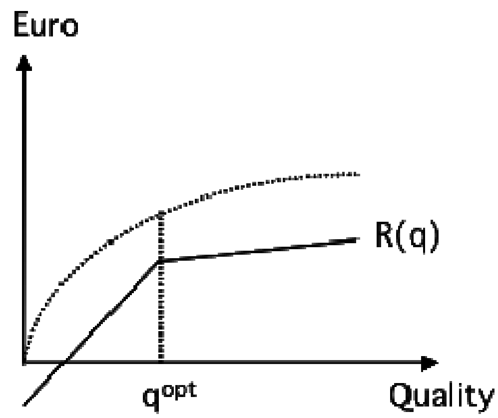

Figure 2-7. Two-price plan.

The advantage of this scheme is its relative simplicity making it easy to communicate and to adapt to. Also, the outcome is less sensitive to changes in costs and benefits than the restriction based approach.

A third possibility is to use a so-called *marginal-price scheme* where the firm is paid a lump sum amount A plus a relative small price for quality improvements equal to the marginal value to the consumers in optimum:

R(q) = A +pq

This scheme is illustrated in Figure 2-8.

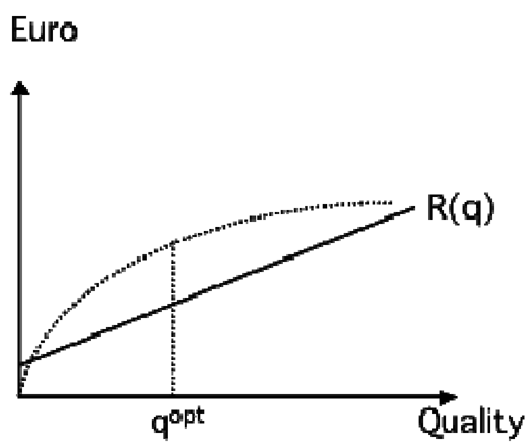

Figure 2-8. Marginal price scheme.

The advantage of this scheme is its relative simplicity making it easy to communicate and to adapt to. Also, the outcome is not too sensitive to changes in costs and benefits. On the other hand, the estimation of marginal value in optimum must be rather precise.

The final possibility we will consider here is to use a *restriction based plan* similar to the familiar minimal quality requirement approach in electricity distribution. In this scheme, the reimbursement to the firm equals A, if it complies with minimal standards and the penalty otherwise is very large

R(q) = A if q>=0 and very negative otherwise

Again, the lump sum amount A can be chosen as any value between 0 and $B(q^{opt})-C(q^{opt})$. High values mean that all the gains from adoption to optimal quality go to the firm and low values that the gains go the consumers. This scheme is illustrated in Figure 2-9.

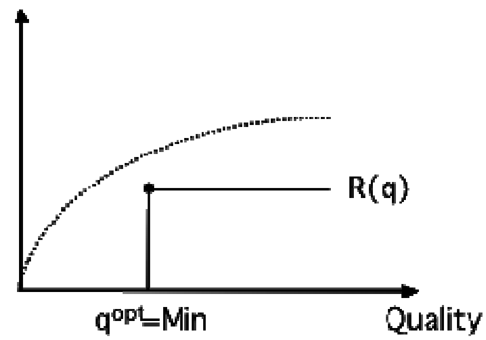

Figure 2-9. Restriction based scheme.

The advantage of this scheme is its simplicity making it easy to communicate and to adapt to. On the other hand, its optimality is extremely sensitive to variations in the cost and benefits function. It is therefore primarily useful in those cases, where the benefit or cost curves are linked with a sharp decrease in marginal value or a sharp increase in marginal costs at q^{opt}.

All the schemes sketched above involved some *lump sum* payment, denoted A. The size of this payment depends both on the way the non-quality revenue model is calibrated and on the way the gains from quality adjustments shall be distributed between DSOs and consumers. By and large, however, the incentive effects are not dependent on A and we shall therefore leave the problem of setting A for future more detailed studies. To illustrate the idea here, it suffices to note that if, for example, we assume that the reimbursement for the non-quality dimensions presumes a given minimal quality level, the quality payment schemes shall ideally be interpreted as penalty or bonuses for deviations from these minimum levels. This means that A shall be chosen such that the quality payments are 0 at the minimal levels.

All the schemes above require information about benefits and –except for the generalized payment plan – costs. Since such information is noisy at best, it is important in the choice of regime to consider the impact of having mis-specified costs and benefits – or to have changes in costs and benefits over time.

In DSO regulation, quality has usually been ignored initially. In a second or third regulation period, a quality incentive has then been added to the price regulation. The most common form is to use the marginal cost approach above. The Norwegian KILE system has been the model for much of the thinking about these issues (see Chapter 3.3.5).

3 Review on recent developments

3.1 Theoretical advances

Basically, all the tools used in the period 2005-2009 were already present at the outset of the period, but specific issues or timing had not yet permitted their application. Here, we highlight some important issues for research in energy network regulation.

3.1.1 Vertical unbundling

Prandini (2007) analysis of BETTA in UK, focuses at the role of vertical separation between transmission and generation for effective deregulation. This aspect came under major discussion in the preparation of the Third IEM Directive (2009). Research using both stylized and empirical models showed that vertical unbundling is a prerequisite for much of the market efficiency, and in the case of energy network regulation, an important condition for unbiased frontier yardstick design.

3.1.2 Decentralized generation and DSO regulation

The EU Green Paper (2008) and subsequent national implementations of the Kyoto targets for CO_2 reduction calls for a major restructuring of the European electricity generation; especially favouring massive integration of renewable energy resources. A substantial part of these investments concern distributed generation (DG) in form of cogeneration, small-scale wind or photovoltaic installations connected directly to the distribution layer (LV or MV) without much control or protective equipment. Prompted by the surging and heterogeneous flora of various support programs for the supply side, Ackerman (2007), de Joode (2009), Cossent et al. (2009), Bauknecht and Brunekreeft (2008) analyze the deficiencies in the current European network regulation to effectively accommodate these investments. The closest to a concluding result may be the summary of the EU-DEEP project, advocating a three-step analysis of the technological, economic and regulatory feasibility of a given technology in a jurisdiction.

3.1.3 Quality regulation

The widespread adoption of incentive regulation prompted for renewed analysis of quality regulation. Ajodhia and Haakwort (2005) as well as Giannakis et al. (2005) showed that quality and cost-efficiency are neither necessarily correlated, nor incentivized in current regulatory regimes. In distribution, postponement of preventive maintenance and downgrading equipment may show up as improvements of cost-efficiency in most models. Fumagalli et al. (2007) showed that in Italy, privatization in itself does not lead to lower service quality, but managerial dominance (i.e. weak public or private owners) does. These results complement other work showing that public firms may be less susceptible to incentive regulation, including incentivized quality regulation such as interruption compensation schemes. Quality regulation schemes exist at least since their introduction in Italy in 2000, in Norway and Ireland in 2001, in Great Britain in 2002, in Hungary and Portugal in 2003, in Sweden and the Netherlands in 2004, in Estonia in 2005, and in Finland in 2008. Germany has decided to implement quality regulation for both electricity and gas in 2011.

3.1.4 R&D in liberalized energy markets

A previously neglected issue, namely the drop of research and development activities in the regulated network industry was treated by Jamasb and Pollitt (2008). They showed significant cuts in budgets in R&D worldwide following deregulation and unbundling, suggesting that regulators should consider incentives to retain certain parts for process development in the interest of long-term cost. So far, only OFGEM has launched a concrete incentive scheme for R&D at DSO-level.

3.2 Advances in regulatory application

If the theoretical development was relatively calm, the period 2005-2009 was the more intensive in regulatory application development. Below are described some highlights:

3.2.1 Demise of technical norm models (Sweden, Spain, Germany)

Following the early adoption by Spain (following examples from South America) and Sweden of technical norm models for distribution systems, several countries investigated the feasibility of such in their jurisdictions (Norway: Agrell and Bogetoft, 2005, Germany: Agrell and Bogetoft, 2006). However, since Sweden decided to dismantle the unpopular model in 2008, Spain stays alone with a relatively unclear regulatory implementation of the output from the model(s). Some consensus has been reached that technical norm models are heavy and expensive instruments that shift managerial tasks to the regulator without any advantage in information access.

3.2.2 Operational launch of large-scale frontier-based yardstick regimes (Germany)

Unexpectedly, Germany under the lead of the newly instituted Bundesnetzagentur (2006) designed, politically endorsed and implemented a full-scale frontier-yardstick regime (DEA-SFA) for both electricity and gas distribution and regional transmission. All in all some 800 firms are subject to annual information collection and bi-annual revenue-caps fully determined by a set of mathematical models. In spite of heavy industry resistance, the incentive regulation in Germany seems to withstand the legal and political turmoil in 2008/2009 (first decisions). The Ordinance is also the first to explicitly determine that outlier detection should be used in frontier analysis (including which methods that are prescribed). The regulation in Germany from 2009 must be considered as the state-of-the-art in regulatory design, a source of inspiration for many regulators. However, the regime has still not implemented the quality element and the division in federal and regional competences in regulation limit the effectiveness and fairness of the model.

3.2.3 Revival of parametric techniques (SFA) in regulation (Germany, Portugal, Finland)

Whereas non-parametric methods (DEA) have been in operation since 1994 (Kittelsen, 1994), stochastic frontier analysis only came into use in the last years. Portugal (ERSE) performed a SFA for DSO regulation in 2007 with internal resources. Finland commissioned complementary analyses of SFA models to previous DEA models with two different applications. Germany has a full-scale hybrid approach where the same model specification is estimated using both SFA and DEA and the highest (most favourable to the firm) estimate is used in regulation. The German model (Agrell and Bogetoft,

2006) is relatively complex and introduces several challenges in terms of model interpretation, as well as a likely infeasibility for smaller datasets.

3.2.4 Franchise auctions for network expansion (UK, offshore transmission)

A classic idea since Demsetz, the franchise auction for network operation licenses saw a European implementation through the OFGEM program for offshore transmission. Following a well-prepared analysis of investment incentives, providership competition and the synergies of joint operation, OFGEM introduces an original system that may provide necessary capacity at optimal long-term cost for this particular type of radical network expansions. An interesting question for research is whether this approach can be applied to some other aspects of network provision as well.

3.2.5 Menus in regulation (UK, DSO capex and system operations, NGET)

Another theoretical result, the menu approach from Laffont and Tirole (1993) as a solution to the adverse selection problem, came into application through OFGEM in two fields. Firstly, the CAPEX part for the DSO is reimbursed through a menu approach that combined reward and risk (CEPA, 2007). Secondly, the system operations regulation for National Grid Electricity Transmission (NGET) is its quality of TSO by OFGEM 2006. NGET may opt ex ante for either high-powered targets (with full risk/reward) or a cost-plus model (with low mark-up and no risk). The choices by NGET indicate that the menu is useful and informative. Once again, it is our assessment that OFGEM may be leading the way on something that might be applicable more generally (Agrell and Bogetoft, 2004).

3.2.6 International operational benchmarking of electricity transmission (e^3GRID, CEER)

The pre-2005 dream of large-scale international benchmarking with high-quality validated data and advanced methods became reality with the 2008 project for electricity TSO benchmarking (e^3GRID, Agrell and Bogetoft, 2009) with 22 TSO and 19 countries participating. Judging from the frequent use of its results and a CEER survey it was a success, 18 of 19 countries indicated interest to repeat a study in 2012/13. The methods used were DEA and unit cost (index number approach).

3.2.7 First application of bootstrapped scores in regulatory benchmarking (e^3GRID, CEER)

Finally, a new approach in frontier benchmarking saw its first application in regulatory contexts: bootstrapping (Simar and Wilson, 2000) in e^3GRID (Agrell and Bogetoft, 2009). Bootstrapping is method to address the bias that occurs in DEA with small sample sizes due to unequal "competition" along the frontier. Using a distribution, new frontiers may be simulated to create statistical estimates for the robustness of any score. Although promising and likely to become a standard instrument for analysis, bootstrapping is currently not a method that can replace SFA or DEA due to some informational issues (technical parameters influencing, complexity and heavy reliance on external expert consultants).

***

Clearly, the theory and practice of incentive regulation have advanced considerably in the last five years and must be considered a relatively uncontested element of European network regulation. However, it should be mentioned that some seemingly elementary problems still await scientifically published answers, e.g. questions related to the derivation of model specifications for DEA models from statistical data, scientifically sound capital base normalization methods or the limits for model dimensionality with respect to sample size.

3.3 Detailed review of selected publications

The detailed review focuses on selected publications of alternative regulation models. After a more general ERGEC's position paper (ERGEC, 2009), we firstly look at the future plans of Ofgem's RPI-X based model (OFGEM, 2010), and thereafter, on a yardstick based model suggested in NEMESYS project for Pan-Nordic regulation (NEMESYS, 2005a-d). Furthermore, papers on stipulated settlements in Florida (Littlechild, 2007) and a theoretical study on simple menu of contracts (Kopsakangas-Savolainen et al. 2009) are reviewed. Finally, also a paper on quality incentive scheme in Norway (Growitsch et al. 2009) is presented.

3.3.1 ERGEC's Position Paper on Smart Grids

Much attention is focused on increasing zero and low-carbon electricity generation. There is a growing consensus that today's networks will not be able to integrate this generation effectively into a coherent system including effective demand response. An overall view is that more intelligence is needed in the future grids, but there is no specific knowledge as to what are the cost-efficient solutions to achieve this (ERGEC, 2009).

While maintaining the existing objectives of high security, quality and economic efficiency of electricity supply, there are also new objectives for electricity network operators. The main indirect driver of the new requirements is legislation, especially the 20/20/20 objectives[1] of the European Union. The three core objectives of the European Energy Policy are: sustainability, security of supply and competitiveness (see Figure 3-1).

[1] The objectives are: cutting greenhouse gas emissions by at least 20% with respect to 1990 (30% if other developed countries commit to comparable cuts); increasing to 20% the share of renewable energies (wind, solar, biomass, etc) in overallenergy consumption (currently about 8.5%); and saving 20% of the projected energy consumption by improving energy efficiency

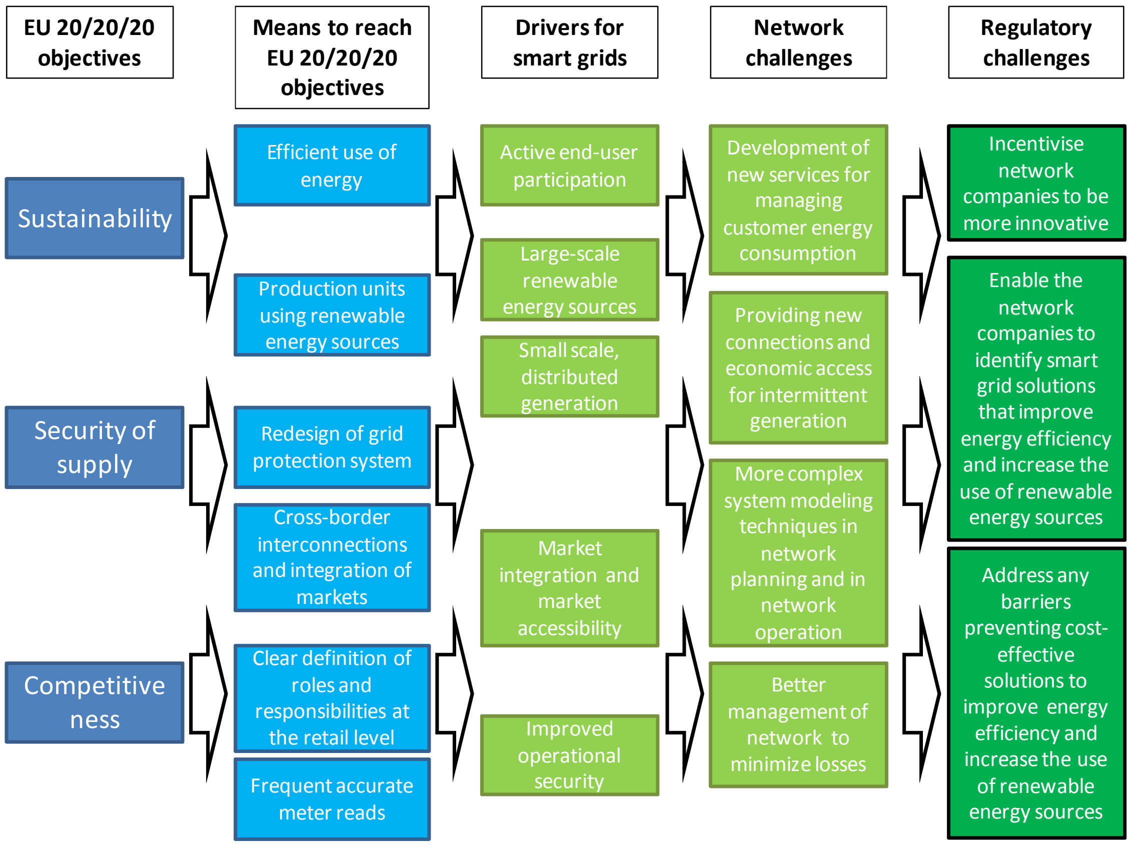

Figure 3-1.Implications of EU's 20/20/20 objectives to electricity distribution network regulation.

ERGEG lists the means to achieve these objectives and states that these means lead to the following drivers for smart grids from a technical perspective:

- Large-scale renewable energy sources including intermittent generation
- Distributed generation including small-scale renewable energy sources
- Active end-user participation
- Market integration and market accessibility
- Improved operational security at all voltage levels

In the future, there are new services needed by generators, "prosumers" and especially small customers. From the network operator perspective, these lead to new challenges. Smart grid solutions need to deal with more complex system modelling techniques in network planning and in network operation. In addition, new services need to be developed for managing customer energy consumption and better management of network needs to be done to minimize losses.

The overarching or macro challenge of the regulator is to find ways to incentivise network companies to be more innovative. The second challenge is to enable the network companies to identify and prioritise specific smart grid solutions that can more efficiently meet network users' needs and incentivize them to be deployed. Finally, regulators have a legal obligation to identify and address any barriers that could prevent cost-effective solutions from being adopted which would benefit network users, taking particular account of environmental issues. ERGEG states that the regulatory framework should enable the integration of the new services in the electricity network, sharing the possible extra costs in a fair way among those shareholders who incur them. At the same time, any unnecessary barrier to the renewable sources of generation or more efficient use of energy should be avoided. ERGEG also states that the volume of energy supplied should be decoupled from companies' profits in new regulatory model.

It is stated that regulation should concentrate on the outputs of the regulated entity and the effects of a given activity or service. No barriers for technology development or solutions in the grid should be created. In regulation, tight benchmarking of cost/performance might become a drawback, as it could favour the postponement by grid operators of innovative solutions in favour of traditional solutions. Hence, it might be necessary to complement the incentive regulation of "smartness" by encouraging innovation. Potential indicators for promoting smartness of networks are listed in Appendix 1.

3.3.2 Ofgem's RPI-X@20

RPI-X@20 is Ofgem's detailed comprehensive, two-year review of how we regulate energy network companies (OFGEM, 2010). The current Ofgem's regulatory framework has served customers well over the last 20 years but it was designed for a different era. RPI-X regulation was not designed to meet the challenges of moving to a more sustainable energy sector. It needs to change to be fit to deliver government policy in the future.

Ofgem is currently considering how best to regulate energy network companies to enable them to meet the challenges and opportunities of delivering a sustainable, low carbon energy sector whilst continuing to facilitate competition in energy supply. There is considerable uncertainty about how best to meet these challenges whilst maintaining value for money for existing and future consumers.

Ofgem has started a wide consultation process in order to get balanced view to its emerging thinking related to new regulation framework. The authority will take its final decisions in summer 2010, and any new framework would first be applied in the next transmission price control reviews in 2013. The regulatory framework would encourage the network companies to change by:

- Putting much greater focus on the delivery of outcomes and outputs related to safe, secure, high quality and sustainable network services at value for money;
- Retaining and, where appropriate, strengthening incentives on companies to constrain costs but with much greater focus on the long-term cost of delivery and considering different (and new) approaches;
- Extending at least part of the regulatory package to more than five years;
- Providing a separate time-limited innovation stimulus common to all the energy networks and open to a range of parties, including non-networks;
- Taking a proportionate approach to the regulatory process, with the depth of our scrutiny of each company's plans depending on their track record for delivering;
- Aligning incentives between industry participants focused on delivering a low carbon energy sector; and
- Setting clear principles for ensuring network companies earn appropriate returns (on a defined regulatory asset value) for their performance and the level of risk they face, but not bailing out inefficient companies.

In addition, larger and discrete network outputs and investments could be opened up to greater competition through tendering where there was strong evidence that this would drive innovation and long-term efficiency, but only where it would not threaten timely delivery of the challenging emission reduction (or renewable) targets or the integrity of the way the networks are operated.

The new regulatory framework would continue to be an ex ante price control framework. The price control would be set using the building block approach familiar to all involved with RPI-X regulation. That is, it would be determined by assessing expected efficient costs of delivery, depreciation allowances and an allowed return on the regulatory asset value. An inflation index would be applied to the control. When working up the detail of the framework, Ofgem will examine whether the retail price index (RPI) remains the appropriate index to use for revenue allowances and for specific aspects of the control (for example the regulatory asset value) or whether other indices (such as the consumer price index (CPI) used by the Bank of England when setting monetary policy) would be more appropriate.

The new regulatory framework would put sustainable development and more effective engagement alongside consumers at the heart of what network companies do. The price control will be outcome led. Outcomes would be reflected in outputs relating to reliability (of network services and the wider energy system); safety; environmental targets, particularly delivery of low carbon energy services; conditions for connecting to network services; customer satisfaction; and network-related social obligations. Where outcomes cannot be defined by clear quantitative outputs, there would be a qualitative understanding of what network companies need to deliver (see Figure 3-2). In addition, network companies submit business plans with longer-term focus, demonstrating how they intend to deliver outputs and what the expected total cost of delivery is.

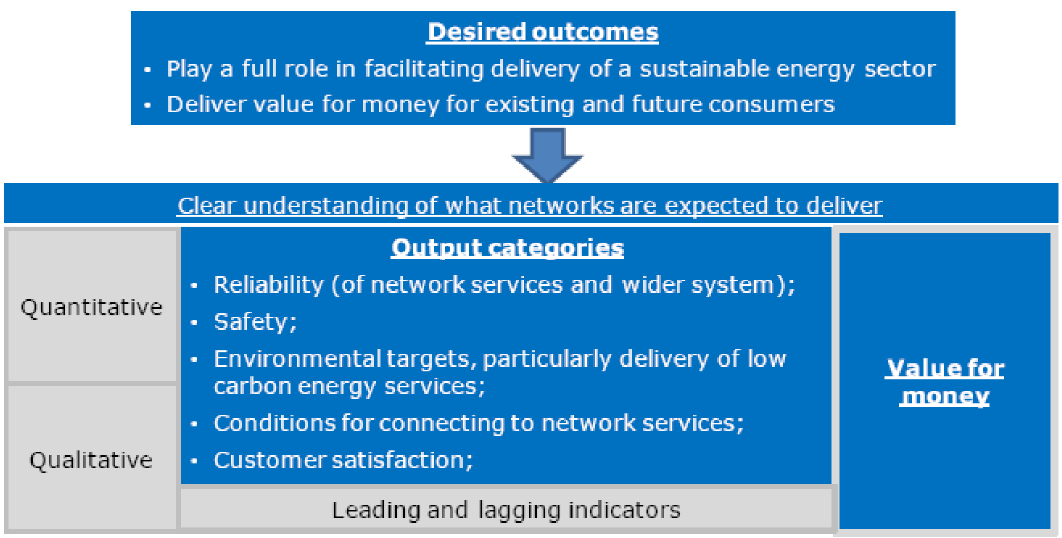

Figure 3-2. Relationship between outcomes and outputs in Ofgem's new regulation framework.

3.3.3 Pan-Nordic Regulation – NEMESYS project

The NEMESYS project was carried out already in 2005 but it is worth to analyse because of ambitious target trying to develop a common regulation model for electricity distribution in the Nordic region based on a revenue yardstick model and a quality incentive scheme. The proposed yardstick model is presented here while the details of the quality incentive scheme can be found in NEMESYS reports (NEMESYS 2005a-d).

The NEMESYS 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. This is done by invoking a two year delay which enables 1) the DSOs to do their financial accounting in the usual way, 2) the regulator to have time to collect and process tariff and service data, and 3) the consumers to know tariffs a priori.

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 but the one in question (superefficiency evaluation). The (benchmarked) DSO charges in period t-2, C(t-2), may deviate from the yardstick revenue. If the 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 interests.

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

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

The parameter α is the two-period borrowing interest rate in period t-2 and β = α+δ is a lending rate that exceeds the two period costs of borrowing with some extra penalty δ>0. In the following, we shall think of a period as one year. The sum of the revenue base and the carry forward defines the revenue target for period t

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

This revenue target is indicative. 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. 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

$$AC(t)$$

The actual charges will however reflect not only the costs and profits to the DSO in period t but also the need to repay a negative and the right and obligation to collect a positive carry forward. Therefore, the real in period DSO charges in period t, the benchmarked charges BC(t) is

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

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

The benchmarking model is the engine in the yardstick model to determine C* for any kind of DSO; rural or urban, with any kind of service profile, mix of high voltage/low voltage. 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, non-distribution tasks and taxes.

On the output or services side, the NEMESYS study notes that 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 covered 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 covered by proxies for capacity such as installed transformer power or peak power. Contextual conditions can be covered by network length, delivery area, climate zone or other proxies, cf. NEMESYS (2005c).

Concerning the type of model, the NEMESYS study (in particular subproject C), draws on the economic optimality and international experience of the Data Envelopment Analysis (DEA) model for network regulation, already in regulatory use in Norway, Sweden and Finland. 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 Stochastic Frontier Analysis (SFA). Although frontier models as DEA appear as more complex than e.g. average cost functions, the consequences of the simplicity on firm revenue in a multi-output service can be considerable, both up and down.

3.3.4 Stipulated Settlements in Florida

The development of network regulation in Florida, where stipulated settlements between the utilities and interested parties has been increasingly used as a regulation method has been reviewed by Littlechild (2007). Office of Public Counsel (OPC, the consumer advocate) has been the main driver supported by other intervenor groups in the electricity sector stipulations. Traditionally, hearings and litigation before the Public Services Commission has been the regulation method in use. In 2001, the Public service commission regulated five electric companies in Florida. The stipulations were used for the regulation of a base rate. Base rates cover the costs of building and operating generation plant, and transmission and distribution lines. Base rates exclude fuel costs.

Initially, settlements were seen as a means of speeding up decisions and reducing costs and uncertainty. In practice, the cost savings achieved by a stipulation process are of the order of a quarter of the total costs of litigating a case. More recently there is a recognition that settlements may achieve more than this by reflecting more accurately the views of the parties, and allowing more innovative and creative solutions that the regulatory commissions may not be able to achieve by litigation. For all parties, the purpose of settlement is to get something different and better than what litigation would yield, not to get the same outcome at slightly lower cost.

In the reviewed period, OPC was responsible for opening or reopening cases that accounted for $1.4 billion of customer benefits measured in terms of electricity rate reductions and refunds, constituting around 40 per cent of the total of such benefits. Littlechild concludes that OPC had a significant impact in achieving these reductions. The rate changes slightly favored industrial customers, but residential customers were also better off as a result of the stipulations.

The utilities, OPC and other parties all agree to stipulations for essentially the same reason: they believe they can negotiate more from the stipulation than the full FPSC hearing process would deliver. It seems that the OPC and other parties can offer concessions to the utility that are within their own control but beyond the remit of the FPSC. In addition, it may be that the OPC and other parties are willing to make concessions that FPSC is able but unwilling or unlikely to make.

Commitments by the parties to act or not to act in a specified way are something that the parties can deliver that the FPSC cannot. The parties typically commit not to undermine the agreement by later action. Thus both parties have security of the rate level for a longer period. It is normally beyond the power of a regulatory commission to preclude a utility from making a request to increase rates, or a consumer group from requesting a rate review or decrease.

Over the years, stipulations have often prescribed accounting policy for the utilities, notably with respect to depreciation and reserves, which in many cases have been less onerous, or allowed greater flexibility to the utility, than FPSC's rather conservative policy. This has often facilitated refunds, rate freezes or reductions that would otherwise not have been possible. At first, FSPC objected to those stipulations that went beyond conventional treatment of economic assets, but later accepted this. FPSC was willing to accept a more flexible policy if that secured the significant refunds and rate reductions that customers appeared to want.

Some other changes brought about by stipulations, have included a shift from regulation based on ROE to a focus on rates and other outputs of the regulatory decision. In addition, there has been a development of revenue-sharing instead of earnings-sharing incentive plans. This was because OPC wanted to have a more objective scheme that was less subject to manipulation of costs. In some cases, the stipulations have lengthened the use of existing rate schedules and in some cases they have resulted in introducing new rate schedules.

It can be concluded that the stipulations is seen as a satisfactory process, as all parties have not been willing to use the old litigation process. Also FSPC encouraged stipulated settlements as a more effective method of regulation. It was clear that it could not secure a more attractive deal for customers in the time available.

3.3.5 Theoretical study on menu of contracts in regulation

In most cases the regulated company has more information about its costs and other factors and accordingly, the regulated company may use its information advantage strategically in the regulatory process to increase its profits. This creates a disadvantage for consumers. Kopsakangas-Savolainen et al. have studied menu of contracts in DSO regulation as an option to solve this problem (Kopsakangas-Savolainen et al. 2009)

The rate of return or cost of service regulation is a relatively simple method to limit monopoly pricing. However, the method does not provide incentives for cost-savings and efficiency improvements. It may also give an incentive for overinvestment. If the regulation is based on a cost-of-service, a moral hazard problem is created. This means that the loss of the opportunity for the company to earn extra profits reduces managerial effort and consequently less managerial effort increases the company's realized costs.

The moral hazard problem may be solved by some form of incentive regulation (e.g. price cap regulation, revenue cap regulation or yardstick competition), but then full costs of adverse selection problem are incurred. Adverse selection problem arises when all network companies are regulated based on the same principles. As other companies operate more efficiently, they will be able to earn higher profits. In addition, the regulator will have to collect the company information and this also causes costs.

In the purest form of price cap regulation, the price or price path is fixed. Therefore, the regulated company has full incentive to reduce costs because it can keep all the benefits from cost reduction. The disadvantages of the price cap regulation include the uncertainty about the service quality and the impact that companies may have on setting the price limit. Also, in regulating the companies by setting a price cap for each year based on the Retail Price Index and an efficiency factor X ("RPI-X model"), there are possible problems related to the service quality and the rules on how to determine the X parameter.

The task of the regulator is to find such a mechanism that takes the social costs of adverse selection and moral hazard into account. It has been argued (Laffont and Tirole 1986, 1993 and Joskow 2006) that perhaps the optimal regulatory mechanism will lie somewhere between the two extremes of pure cost of service (or rate of return) and pure price regulation. The basic idea of the optimal incentive scheme is to make it profitable for a company with low cost opportunities to choose relatively high powered incentive scheme (e.g. price or revenue cap regulation) and a company with high cost opportunities a relatively low powered scheme (e.g. rate of return or cost of service regulation).

The theory of a menu of cost-contingent regulatory contracts with different cost sharing provisions requires detailed understanding of the companies' operations and complex mathematics. Therefore, the model has not been widely used in practice. Kopsakangas-Savolainen et al. state that a simple menu of contracts can capture a substantial share of the benefits with lower informational requirements. When the regulation is based on the simple menu of contracts, the company's allowed price P is determined based on the following equation:

$$P_{i,t} = aC^{*}_{t-1} + (1-a)C_{i,t-1},$$

where *C** is the efficient costs, *C* is the company's realised costs and a is the sharing parameter that defines the responsiveness of the company's allowed price to the realised costs, *t* refers to time and *i* to the company in question. If the true efficient costs of the company are high, it would choose *a* equal to zero. The price would then be based on the true costs of the company and it would earn zero profits. If the true efficient costs of the company would be less than the defined efficient costs *C**, it would choose *a* equal to 1.

Kopsakangas-Savolainen et al. have estimated the total welfare effects of each regulatory method with four different techniques based on Stochastic Frontier Analysis. The analysis is based on 76 electricity distribution utilities in Finland. In changing from cost of service regulation to price cap, menu of contracts or a simple menu of contracts a significant welfare improvement is created. Total welfare is increased most in menu of contracts regulation. However, if the regulator is interested more on consumer welfare and wishes to see lower overall prices it should set the regulation according to the simple menu of contract

3.3.6 Quality of Supply in Norway

When moving form cost-plus to incentive regulation of DSOs, there is a risk of creating an incentive that leads to decreased quality of supply (Growitsch et al. 2009). In order to tackle this trade-off, some regulatory regimes have introduced incentive-based regulation schemes that also include quality of supply. The objective is to include the costs of (poor) quality in the profit optimisation calculus of DSO.

The challenges of the regulator are to create financial incentives for quality and to adequately quantify these. Modern regulatory practice creates the incentive by including the external cost of energy not supplied (CENS) into the network operators decision making. In Figure 3-3 the total costs of the network owner (TOTEX) are depicted by CAPEX and maintenance cost. CENS is based on energy not supplied (ENS) and customer willingness to pay (WTP) for network reliability. CENS and TOTEX together form the social cost of network provision (SOTEX). At least in theory, the companies will reach an optimal quality level where the sum of CENS and TOTEX is smallest as illustrated in figure below.

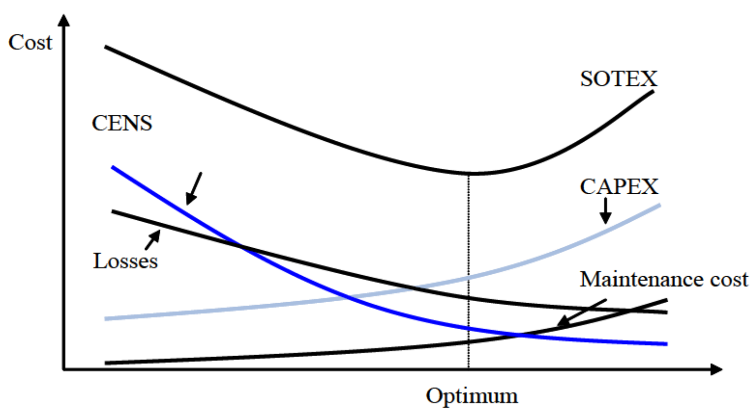

Figure 3-3. Trade off between CENS and TOTEX

The outage costs incurred for the customers can be determined based on indirect or direct approaches. The indirect approaches are not used in regulation of network companies, because they only provide aggregated data. The direct approaches include estimating the customers' WTP based on insurance premiums, estimating the real costs incurred during an outage, contingent valuation and conjoint analysis. Insurance premiums have been used by network companies to give an indicator for how to prioritize investments. For regulatory purposes, contingent valuation and conjoint analysis are most commonly used.

Both contingent valuation and conjoint analysis are based on surveys. Contingent valuation uses hypothetical scenarios that must be monetarily valued by respondents. In conjoint analysis, respondents do not have to choose a binding and certain option or state concrete values. Instead they have to give relative assessments when comparing different options. Conjoint analysis attempts to measure the value of a service by estimating the value of its parameters. In both cases, the outcome of the survey crucially depends on the appropriate design of the questionnaire.

In Norway, quality was included in the regulatory formula to determine the revenue cap for the second regulatory period, 2001-2006, but the data collection has been started already in 1995. The cost of energy not supplied included planned and unplanned interruptions longer than three minutes and the specific outage costs for each customer group were specified based on a survey. Therefore in theory, a profit maximising network operator would also maximise the social welfare by taking into account the cost of energy not supplied for the customer.

It is stated that the implementation of the quality regulation system has sensitised the Norwegian network operators to outage costs incurred by their customers. However, according to an analysis based on DEA technique about the efficiency of network operators for the years 2001-2004, external cost for quality has not played a major role in the current regulatory regime in Norway. This may be due to the high quality level prior to the implementation of the quality regulation or to the fact that there is a time lag between the introduction of quality regulation and its impact on the investment decisions of network operators.

3.4 Projected future trends

In addition to new objectives in the regulation framework, there are trends that will affect regulation models to be utilised in the future. The expected themes in future regulation are (Pollitt, 2009)

- More use of negotiation
- Extension of auctions
- Attention to access terms
- Innovation in/across networks
- Role of unbundling and ownership

Negotiations have been considered a success in network regulation in many countries. There are still many uncertainties related to the result of the negotiation process. In using negotiations, the main challenge is to create a buy side for network services. As explained in Chapter 3.3.4 above for Florida, an organisation representing the customers has achieved larger and earlier rate reductions than would have been possible by the unbiased regulator. Even there, however, the question remains as who has the right to speak for the consumers, how to include future consumers in the negotiations, and how to achieve fair pricing for industry and residential customers.

Using negotiations requires flexibility in regulation. In addition, some changes in the market structure are likely to be necessary. In the beginning, there would most likely be some difficulties in finding the right triggers for sensible and timely negotiations. An unsolved question is also, what happens when the parties fail to agree. In practice, negotiation is may a laborious regulation method if the number of companies is high.

Auctioning has been widely used for constructing transport systems and arranging public services. It has also been used successfully in Argentina for electricity transmission. The benefit of auctioning is that it would minimise the cost of building and could also induce new entrants as well as innovation in the market. When using auctioning, the risk of failure in construction projects or operation may increase. Hence there should be incentives for risk management included in the regulation. In some cases, there may be a challenge with too few participants in the auction. In addition, auctioning relies on high quality of competition policy.

In the future, there should be more attention put into access of electricity production to electricity network as the distributed generation increases. Important issues are how to encourage efficient new connections and how to eliminate barriers to experimentation. According to Pollitt, new unbundled products would also encourage innovation.

In modifying the access terms, there is a balance between simplicity and efficiency. Theoretically a comprehensive nodal pricing would be efficient, but in practice it would be complicated to establish. A pricing model based on location, may increase the risks for small entrants and it may be politically difficult to increase the differentiation in prices. However, there is a need to handle the impact of large investments required for new entrants.

There is a need to increase innovation in the electricity network business especially related to increasing the energy efficiency of the whole electricity system. In telecommunication, innovation has increased successfully and new business models have been created. In electricity networks, more R&D and piloting is required and a shift from valuing transmitted energy to also taking into account the information provided may be necessary.

In the UK, there has been a Low Carbon Network Fund[2] set up to support projects sponsored by the distribution network operators to try out new technology, operating and commercial arrangements. The objective of the project is to increase the understanding of the network companies on how to achieve security of supply cost efficiently when shifting to a low carbon economy. Innovation is partly limited by the absence of clear legislation on who owns the customer information. Before the legislation is clear, there is a risk for companies to create technological solutions or new business models relying on the smart meter information delivered to other parties.

As there are many new challenges related to the electricity business, the question remains, what is an optimal degree of integration? Unbundling of electricity production and transmission has been successful (Pollitt, 2008). In some cases, also the unbundling of ownership has been considered necessary. One question to be considered is who should own the data of smart meters. Could there be more innovative solutions and new services developed, if the smart meters (or measuring) would be unbundled from the network operator; especially in markets, where electricity network companies and selling companies are owned by the same owner?

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[2] http://www.ofgem.gov.uk/Networks/ElecDist/lcnf/Pages/lcnf.aspx

In general, the environmental emphasis seems the most important new aspect, and in turn, this is likely to require new ways to integrate the thinking about distribution and transmission tasks. Smart grids and decentralized generation give the DSO systems operation obligations much like a TSO. It also raises new questions as to cost allocations – how to allocate the costs of new network and production activities using for example deep or shallow charges. Moreover, it challenges the separation of generation and distribution tasks since investments herein may sometimes substitute each others, sometime complement each others, and to get cost minimal solutions.

4 Incentive analysis

4.1 Development of regulation objectives

In principle, the objective of the regulator is to maximize social welfare. Traditionally, the main objectives in regulating electricity distribution monopolies have been economical – typically focused on price or cost control in order to provide moderate tariffs for customers as well as enhance competitiveness in the electricity market. The price and revenue cap models has tackled well this objective and many countries have a good track record of applying these models successfully.[3] Thus, the economical factors are expected to remain in the core of the regulation also in the future.

Beside price control issues, also security of supply and quality issues has gained increasing interest in regulation regimes during the recent years as the whole society has become more dependent on electricity supply. The objective has been to find optimal balance between costs and quality. Thus, these issues have been studied already in 1990's and introduced mainly in 2000's to regulation regimes in many countries (see Chapter 3.1.3). Very recently, regulation has been seen as a tool for fulfilling EU's 20/20/20 objectives and to enhance energy sector to change towards low carbon economy (see Chapters 3.3.1 and 3.3.2).

The development of regulation objectives in time is roughly described in Figure 4-1. It shows that the traditional base of the regulation is economical - targeting low price for customers. Thereafter other themes, such as quality and security of supply as well as sustainability issue have been introduced to regulation regimes. Although new themes have appeared, the economical issues remain strongly in the base of regulation regime. For example, Ofgem introduced its RPI-X based regulation framework already in 1984 – and they are planning to continue with this model by adding quality and sustainability elements to it. Especially, the object is to enhance development towards low carbon economy, which has been seen as a target to increase social welfare – the ultimate objective of the regulation.

[3] E.g. Ofgem has reported that since privatisation, allowed revenues have declined (until 20109 by 60 per cent in electricity distribution, 30 per cent in electricity transmission and by approximately 45 per cent in gas distribution and transmission (Source: Ofgem's Emerging Thinking consultation document, January 2010).

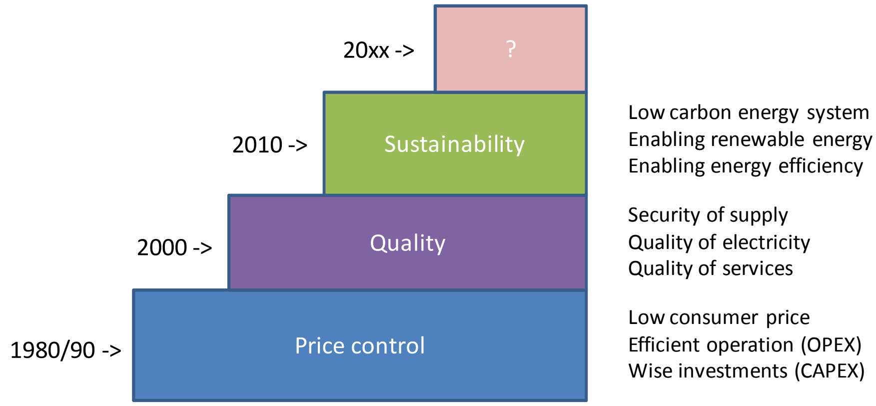

Figure 4-1. Development of regulation objectives in electricity distribution business.

4.2 Framework for incentive analysis

The framework of the incentive analysis is based on the objectives of the future regulation, i.e. price control, quality and sustainability issues (see Figure 4-2). The price control is targeted to low consumer prices and low costs. The main elements of low costs are low operational costs (OPEX), low capital costs (CAPEX) with reasonable investments as well as rational R&D costs that may enhance efficient operation in the future by developing more efficient methods and services. Concerning the smart grid related R&D activities, ERGEG has stated that supporting the transition process from R&D over demonstration to full deployment of smart solutions, when it is profitable from the point of view of the whole society, while incentivising only economical and technologically efficient technologies, should also be one of the future tasks for the NRA. The participation of regulators in this process could reduce the risk of having duplication of costs and financial burden for the final customers in the RD&DD chain (ERGEC, 2009).

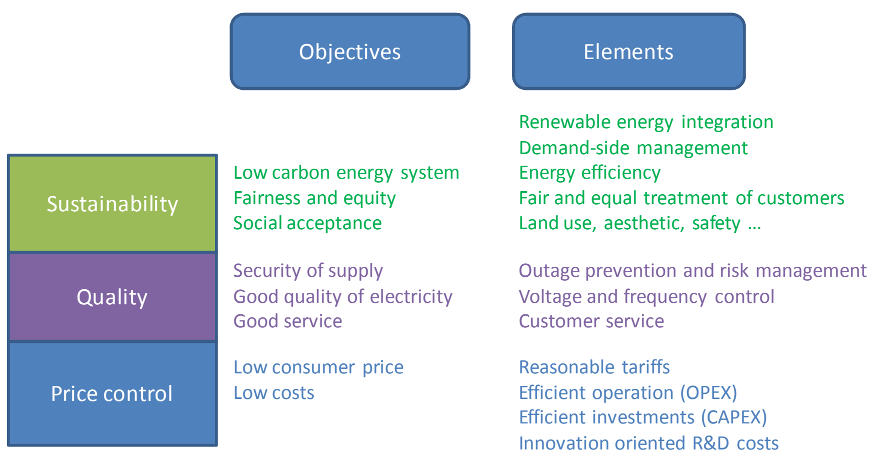

Figure 4-2. Objectives and elements of regulation.

The quality issues cover security of supply - especially preventing outages as well as good quality of electricity. This includes, at least, voltage and frequency control. Furthermore, good customer service covering, e.g., quick response times, efficient communication and guidance is an important quality issue.

The sustainability issues cover primarily elements that enhance low carbon energy systems, including integration of renewable energy sources, demand-side management and energy efficiency solutions. These issues are heavily linked to smart grid technology development and deployment. According to ERGEG's point of view, regulators should further support increasing efforts and international cooperation in R&D in the field of smart grids and promote their effectiveness. Regulators should also support the link between R&D projects and demonstration & initial deployment of selected promising solutions (ERGEC, 2009).

In addition to low carbon issues, also fairness and equity between customer segments and geographical areas are inherently related to sustainability. Also social acceptance, such as land use, aesthetic, safety, is a part of the sustainability objectives even though the integration of such issues is not straightforward.

In the next Chapter, we will study how effectively each type of regulation model can tackle each objective? The framework for the analysis is given in Figure 4-3 including the objectives and alternative models to be studied. In the beginning of the analysis, the main regulatory objectives are studied separately in Chapter 4.3. Thereafter, all the models are compared against each other in Chapter 4.4.

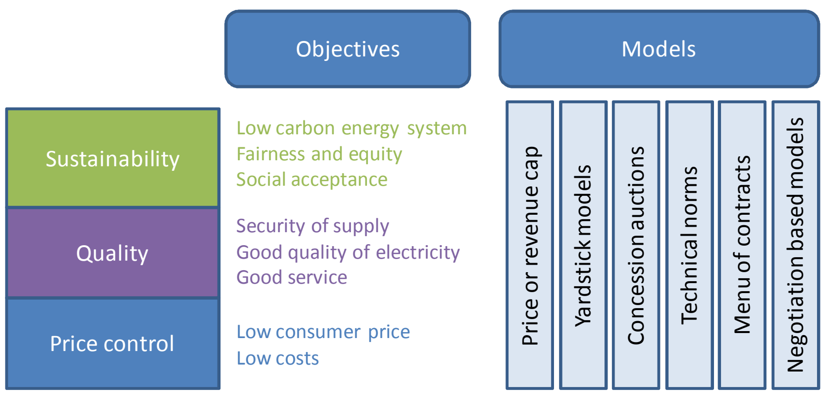

Figure 4-3. Regulation objectives and models to be studied.

4.3 Analysis of various incentives

4.3.1 Price control incentives

Price and revenue cap models have inherently clear incentives to decrease customer price. In practice, as the price or revenue is capped, there is also incentive to cut costs because the company gets full benefit of cost cutting. However, in price and revenue cap schemes regulator usually has limited information on company's actual efficiency and ability to cut costs – either CAPEX or OPEX. This may limit to get full advantage of price or revenue cap model in practice. In case of the contract of menus, in turn, regulator may offer different options, and by choosing one option, the regulated company reveals partly its actual ability to improve its efficiency. In a longer term, as the understanding of the regulator increases, it can be more precise to set price or revenue targets.

In yardstick models, a company is compared to other companies and it is possible to identify efficient companies that can be used as an efficient benchmark. Thus, regulator has more information on company's actual efficiency, and the target setting can be done more precisely. In a long term, this makes possible to force the company towards efficient operation and also low consumer price by cutting costs that cause inefficiency. Yardstick models are especially feasible when the number of companies is high, which makes the model more reliable and precise.

Concession auctions are, in theory, very efficient ways to decrease price and cost as the minimum bid is accepted. The concession auction offers perfect adjustment to heterogeneity, since prices may vary across franchises. As described in Chapter 2.2.3, problems occur in limited markets with high concentration that bidding may be collusive, that excessive informational rents may be extracted and that competition may be hampered by asymmetric information among incumbents and entrants.

Technical normative models are special cases of engineering cost functions with varying level of information requirements as described in Chapter 2.2.4. In theory, they should be very efficient models for cost cutting as the efficient frontier defined by technical norm is closer to actual frontier compared to statistically or benchmark-build frontiers. However, in practice this may not be the case, if the regulator is very conservative in parameterization.

Negotiation based models offer the regulator possibility to understand better company's actual performance. Thus in longer term, negotiation based models can be efficient for cost cutting and price control, if the regulator manage to remove asymmetry of information during the negotiation process. In practice, this may take many years and may be a costly process for the regulator.

Regarding to R&D costs that may facilitate efficient operation in longer term, pure price or revenue cap models has no incentives as these costs are just similar costs as the other costs. In yardstick models R&D costs can be seen as a positive output, but on the other hand, it is difficult to categorise which R&D costs are beneficial to customers in a long term? In negotiation based models, these can be discussed more precisely.

4.3.2 Quality incentives

The price or revenue cap models do not have any incentive for improving quality and security of supply because all the extra costs reduce their profit. Thus, the quality regimes have been build separately and integrated to these models. Detailed description of various ways to do it has been described in Chapter 2.2.6.

In yardstick regimes quality issues can be included to models (e.g. as an output in DEA models) or they can be integrated to models in a similar way as described above in the case of price and revenue cap models. In concession auctions, the regulator can beforehand set e.g. minimum requirements for quality and security of supply as well as define sanctions, if these limits are not achieved. In negotiation based models, there is a good opportunity to negotiate what is the socially optimal quality level, and thus, these issues can be easily integrated to these kinds of regimes.

In a case of menu of contracts, the situation is close to price or revenue cap model. Thus, the menu of contracts does not have incentives to improve quality and security of supply. However, offering the company selection opportunities, the company can choose the alternative it considers to be the best for the company taking into account also the quality issues. In practise, this is not necessarily the case, because the company is not necessarily capable to make this kind of analysis.

Quality of customer service can be included into regulation models as a separate module or it can be included in e.g. DEA models as an output. However, measuring of the quality of customer service is a tricky question. Firstly, the quality of customer service is based on subjective experiences of customers, and customer's opinion can be biased. For example, customers may not be able to separate the role of electricity distribution and selling businesses. Secondly, the measurement method must be same for all the distribution companies and the parameters must be clearly defined. Also data must be collected for many years before it can be reliably integrated into regulation scheme. One option could be that regulator collects customer service data outside the regulation model. By publishing this data, the companies with poor customer service performance would have pressure to improve their performance. Later, if the method had been proved to be reliable and effective, the customer service with real economical incentives could be integrated into regulation model.

In current regulation schemes, customer satisfaction (or lack of) seems typically to be dealt with via complaints to the regulator, minimum standards etc. Some directly identifiable customer services may also be dealt with on a cost-pass-through basis, i.e. all such costs are kept out of the incentive regulation. Some companies have internal incentive schemes for managers that reward customer service performance. Such internal incentive schemes and the applied measures may be an interesting starting point for the development of service incentives.

4.3.3 Incentives for sustainability

In its smart grid report, ERGEG states that the regulatory framework should enable the integration of the new services in the electricity network, sharing the possible extra costs in a fair way among those shareholders who incur them (ERGEC, 2009). At the same time, any unnecessary barrier to the renewable sources of generation or more efficient use of energy should be avoided. ERGEG also states that the volume of energy supplied should be coupled from companies' profits in new regulatory model.

Currently, most regulation regimes do not have much incentive for integrating renewable sources of generation or more efficient use of energy. In case of price or revenue cap models, integration of renewable energy sources usually increases cost that, in turn, cut the profit of the company. Thus, there is actually a negative incentive. The models based on menu of contracts are not able to remove this barrier. In yardstick regimes, the low carbon issues can be taken into account, e.g. if DEA models are used. For example, the number of renewable energy generation units connected into grid can be put as an output of the model. However, there is still little practical evidence how this could work. In the new benchmarking model used to regulate German DSOs, the amount of decentralized generation is an explicit cost driver.

Concession auctions are suitable for promote sustainable incentives because in auction documents regulator can define requirements for renewable energy integration and energy efficiency. Also concession auctions can be used, e.g., for large offshore wind power projects, if there is no transmission and/or distribution network at all.

Negotiation based models are also suitable for creating incentives as the regulator and the company can negotiate what is the optimal way to reach social welfare in a balanced way. However, the negotiation process may be laborious. Furthermore, the values of the regulator and the company may be different that makes the negotiation process even more challenging.

In any case, independently on regulation model, it is most critical from sustainability point of view that transmission and distribution companies are really unbundled from electricity production and selling business. This could be done so that the regulation incentives are created so that it is beneficial for the distribution company to decrease energy consumption as well as increase distributed electricity production.

Regarding the other dimensions of sustainability such as fairness and equity as well as social acceptance, the alternative regulation models, per se, do not offer practical solutions – except concession auctions and negotiation based models, in which these issues can be explicitly included. In practice, issues like equity of customer types and customers in different geographical areas should be taken into account in model details and parameters. This highlights the need of addressing cost allocations more carefully in the future.

4.4 Comparison of alternative regulation models

The comparison of incentives of the alternative regulation models have been summarised in Table 4-1. All the models studied are able to create incentives to low consumer prices and low costs. Especially concession auctions leads to low price as the lowest bid is accepted. In yardstick models, the targeted price or cost level is based on comparison of companies, while in price or revenue cap models it is usually based on historical performance, effectiveness of which is unknown. Thus, by using the yardstick models, regulator can get more information of the actual performance of the company. By using menus of contracts or negotiation models, regulator can also get more information in time, and thus, these models can be considered to be more effective than pure price or revenue cap models.

Table 4-1. Indicative incentives of alternative regulation models (+ is positive incentive, ++ is very positive, - is negative and o neutral, + in parentheses means potentially positive incentive, if model is adjusted accordingly)

	Price or revenue cap	Yardstick models	Concession auctions	Technical Norms	Menu of contracts	Negotiation based models
Low consumer price	+	+(+)	++	+(+)	+(+)	+(+)
Low costs	+	+(+)	+	++	+(+)	+(+)
Security of supply	-	+	+	-	(+)	+
Quality of electricity	-	+	+	-	(+)	+
Customer service	-	+	+	-	(+)	+
Low carbon energy system	-	(+)	+	-	-	+
Fairness and equity	o	o	+	o	o	+
Social acceptance	o	o	+	o	o	+

The quality issues can be inherently integrated to yardstick models as well as concession auctions and negotiation based models. Indirectly, these issues can be taken into consideration in menus of contracts by offering the company alternative options. Pure price and revenue cap models does not have quality incentives, but separate quality models can be integrated also to these models.

The most difficult situation concerns sustainability. Only concession auctions and negotiation based models can easily take into account these elements. The yardstick models can also cover low carbon elements as an output but the fairness, equity and social acceptance are hard to implement to these models. Price or revenue cap, menu of contracts and technical norms are practically incapable to create incentives for sustainability.

The administrative requirements of alternative regulation models vary significantly (see Table 4-2). The cost and resource needs for regulation are highest in negotiation based models, in which separate negotiations with companies are needed. In negotiation based models, also know-how requirements are high. Compared to price or revenue cap regulation yardstick models and menu of contract based models are more laborious but, in general, they need less administrative efforts than concession auctions and negotiation based models. Generally, the administrative requirements are lowest in price and revenue cap models. Naturally, the number of companies and the differences between companies has effect on the administrative efforts. This issue, relevant to Finnish environment, is considered more closely in Chapter 5.3.

Table 4-2. Indicative administrative requirements of alternative regulation models.

	Price or revenue cap	Yardstick models	Concession auctions	Technical Norms	Menu of contracts	Negotiation based models
Cost of regulation	Low	Modest	High	Modest	Modest	High
Resources needed	Low	Modest	High	Modest	Modest	High
Know-how requirements	Modest	High	Very high	High	High	Very high
Data collection requirements	Modest	Modest	High	High	Modest	High

It is also important to understand that costs, resources, know-how and data collection costs are present not only at the regulator but at the regulated companies as well. The regulator may reduce his costs by pushing costs to the companies. The auction mechanism illustrates this. It may be relatively easy to specify the auction conditions, but the companies may have to spend considerable resources preparing their bids.

5 Regulation in Finnish environment

5.1 Characteristics of Finnish regulatory environment

The Finnish regulatory environment has some unique characteristics that must be taken into account when designing regulatory model. In Finland there are about one hundred network companies[4] which is very high number of companies from regulatory perspective. In addition, the size of the distribution companies varies significantly (see Figure 5-1). In 2008, 2 companies had distribution volume for consumers less than 10 GWh/yr; 40 companies less than 100 GWh/yr; and 8 companies more than 1000 GWh/yr.

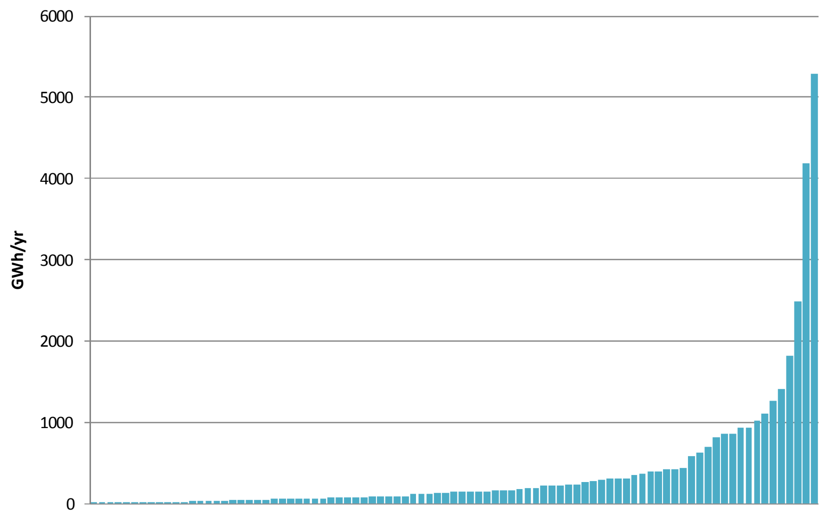

Figure 5-1. The size of Finnish distribution companies based on the amount of electricity distributed to consumers.

Furthermore, the geographical location of distribution network companies varies from coastal to inland companies; also some companies are purely urban companies while some companies operates mainly in rural areas. Thus, the companies have inherently different operation conditions. From the regulation point of view, this means that the regulation model to be utilised must be able to manage these differences in a fair and equal way.

[4] 88 distribution network companies, 12 regional transmission companies and 1 national transimsission company, Energy market authority www.energiamarkkinavirasto.fi, visited 12.4.2010.

5.2 Analysis of incentives in Finnish regulatory environment

5.2.1 Price control

All the alternative regulation models presented in this study are capable to create incentives for lower consumer price and lower cost. Thus, there is no theoretical basis to prefer any of the above mentioned models. However, compared to price and revenue cap models, the yardstick models as well as the models based on the menus of contracts are more efficient as the actual performance of each company is better revealed by these models. Thus, these models can be considered as an improvement to classical price and revenue cap models.

The negotiation based models are flexible and they can be utilised effectively to set targets for price control. However, applying these models broadly seems to be too laborious in Finnish environment due to the number of companies. Negotiations may however be useful to handle exceptions. Rather than striving for a general model that can cover all companies, a regulation can be designed to cover 95% of the DSOs with the understanding that the last 5% are handled on a negotiation basis.

Likewise, concession auctions are too radical change to current situation, and thus, they can be ruled out as a solution to regulate whole distribution network system. Only in the case of major new installations, e.g. connections to wind-parks, do they seem relevant in the Finish context.

The current regulation model, based on the WACC[5] model, is practically a revenue cap model, which allows the company increase revenues as it increase investments. The model does not have any mechanism to evaluate rationality of investments but, in practice, the company has incentives to make such investments that decrease OPEX and improve quality because there are different modules for OPEX and quality targets. From the price control point of view the weakest point of the current model is that over-investments may lead to unnecessary high price. This can be avoided either creating a mechanism to evaluate effectiveness of CAPEX (similarly to OPEX) or turning into a yardstick model that cover both CAPEX and OPEX, and potentially all the other relevant costs.

5.2.2 Quality and security of supply

The quality issues have been taken into account in the current Finnish regulation model by a separate quality incentive model based on the disadvantage to electricity consumers caused by an outage. For each company, a company specific quality target is set and the company has economical incentive to meet the target. If the performance is better than the target, the company is allowed to get extra revenue. On the other hand, poorer performance is punished in a similar way. The maximum benefit or punishment can be 10 % of the annual allowed revenue. However, if the quality level of the company is so high that maximum achievable revenue is less than 10 % (in case that there are no outages at all), the maximum punishment is limited accordingly.

In practice, the quality and security issues can be taken into account by a separate quality incentive model as in Finland. The other alternative is to include these quality issues directly into regulation

[5] Weighted Average Capital Cost

models. This may lead to a very complicated model whether it is yardstick model or some other model. From practical point of view, there is no evidence that separate model should not work properly. An integrated model may be more satisfactory from a theoretical point of view, but in reality, it raises some intricate problems of how to integrate quality to overall model. Including quality as separate costs drives along side for example the number of connections, km of lines etc., it is usually not appropriate since quality is a property of the other service dimensions. Theoretical solutions to this problem will vastly increase the number of dimensions – or require a multiplicatively separable structure with quality separated from the other service dimensions. In practice, therefore, these theoretical solutions are not obviously better than the present approach.

5.2.3 Low carbon energy system

Concerning network companies, the two main topics related to low carbon energy systems are the integration of renewable electricity production into electricity network and the demand-side management to enhance energy saving and consumption peak levelling.

Currently, the Finnish legislation and regulation do not create real incentives for distribution companies to connect renewable electricity production in the grid. The 0.07 c/kWh price cap for average annual transmission fee for electricity production connected into distribution network (less than 110 kV) is an advantage for renewable energy producer, but not for the distribution company as the costs related to this service may be higher than incomes limited by this price cap. The distribution company can actually charge CAPEX associated to this service from the electricity consumers within the same distribution network, but not OPEX because they are limited by the company specific OPEX target. This also leads to situation, in which different geographical areas are treated unequally because, e.g., wind energy production locates in areas where wind conditions are excellent, i.e., costal areas. Thus, it would be important that the regulation model will be revised to reward the distribution company to integrate new renewable electricity into grid. However, if the equal treatment of consumer geographically is precondition, there may be a need to develop some kind of nationwide method to share the costs of renewable electricity integration between companies.

In cases of large wind parks, typically connected to high voltage (110 kV or more) network, one option could be concession auction, i.e., distribution companies could make offers for transmission service from the wind park to the national transmission network. In this case, the regulator could state requirements related to, e.g., quality and other relevant issues, and the lowest bid fulfilling these requirements would win. However, this could be suitable option for limited number of very large wind parks.

Concerning the demand-side management, the current WACC based model is neutral or actual a slightly positive in some cases. As the revenue of the company is practically based on the value of the network of the company, any investments related to demand-side management or smartness of the grid can be charged from the consumers (e.g. smart metering investments). On the other hand, the excess OPEX related to new demand-side management services is covered by the company itself due to separate OPEX incentive model. Thus, the company must balance currently between CAPEX and OPEX related to demand-side management issues. This may lead to peculiar situation that it may be beneficial to make investments but not use them. Thus, it would be beneficial to develop the regulation model in such way, that there is clear advantage of provide demand-side management services, not only make investments.

5.3 Regulatory challenges

The main regulatory challenge in the future is how to balance with three dimensions of future regulation needs, i.e., price control, quality and low carbon energy system. Naturally, the price control is a basis of regulation but the other elements must be taken in the account in a balanced way. Should these elements to be integrated to in one comprehensive model or should these elements to be treated separately? Perhaps the most convenient way is to have an economical model (e.g. yardstick or revenue cap model) and link quality and sustainability issues to this model with clear economical incentives – better quality, more renewable electricity connected to network and more energy saving services would provide better revenue for the company.

The quality issues can be taken into account, e.g., in a similar way that it has been utilised currently in Finnish regulation environment or it can have some benchmarking elements to set the targets. The targets related to low carbon energy system are more challenging. How to set the targets and how to convert the performance of companies into economical incentives? The renewable electricity feed into grid can be measured but how to measure or evaluate emission reductions achieved by demand-side management solutions? How to ensure equal treatment of consumers and network companies in the situation when renewable electricity production is geographically unevenly distributed? All these questions need careful consideration, and thus, more studies related to these issues are needed.

One regulatory challenge is related to administrative issues, such as cost of regulation and resource requirements as described in Chapter 4.4. Furthermore collecting of data and reliability of data must be taken into consideration. Based on the past experience (e.g. introduction of the quality incentive model in Finland), it may take several years to get reliable data in such way that it can be utilised in the regulation model either for setting target levels based on historical performance or for benchmarking purposes. Thus, it would be beneficial to define required data to evaluate sustainability or low carbon performance of distribution companies, and start to collect the data as soon as possible.

6 Conclusions and recommendations

The theory and practice of incentive regulation have advanced considerably in the last five years and must be considered a relatively uncontested element of European network regulation. However, it should be noted that some elementary problems still await scientifically published answers. Furthermore, practical experiences of new regulatory approaches and evaluations of their effectiveness are still needed. Especially, sustainability and low carbon issues have appeared to regulation targets in many countries during the last few years but there are still very few practical experiences on the regulatory applications in this field.

In this study, alternative regulation models and especially their capability create incentives for 1) low consumer price, 2) good quality and 3) low carbon energy system were studied. Theoretically, negotiation based regulation models as well as concession auction based models are able to take into account practically all the necessary elements that the regulator wants. Based on the experiences from other countries, negotiation based regulation models have demonstrated several advantages. However, they are administratively laborious. Thus, they may not be very practical to be used widely in Finnish business environment, where the number of distribution companies is close to one hundred. One option, however, could be to limit the negotiation based model only for big companies while the majority of the small companies could be regulated by the current-like regulation model. However, this would lead to situation where companies are not equally regulated, which may be legislative difficult. Concerning the auction based models; they could be suitable for new electricity networks, such as transmission lines for large-scale wind parks.

Menu of contract based models offer a gradual improvement compared to price or revenue cap model as it makes companies to reveal their actual capability to improve their performance. However, this process may take several years, and it is also more laborious to implement than pure price or revenue cap model; especially when the number of companies is high as in the case of Finland. Thus, the overall advantage compared to present situation is somewhat limited.

Yardstick models are rather efficient and practical as they reveal the ineffectiveness of companies by comparing their performance against each other. Furthermore, yardstick models can cover more than economical issues, and create incentives to quality improvement and help to meet low carbon targets. For example, integration of renewable electricity can be considered as a cost driver in a benchmarking model. Thus, yardstick models can provide interesting option for future regulation, in which quality and sustainability issues may play more important role than today.

The yardstick model can include all the targeted elements in one model, or it can focus on economical elements, while the quality and sustainability elements are integrated to this model by separate modules that convert the quality and sustainability performance to economical value. Even though one comprehensive model would be theoretically interesting, by using separate models for quality and sustainability, the total regulation scheme can be kept more understandable.

Although the yardstick models have some advantages, the traditional RPI-X model can also be basis for future regulation as has been decided in Great Britain. In this case, other required elements, such as quality and low carbon targets, must be integrated in the total model as separate modules that create economical incentives.

Based on the observations of this study, it is recommended that future regulation will be based either on yardstick model or further development of current-like revenue cap model. In case of current-like revenue cap model, low carbon incentives must be taken into account in a similar way than the quality issues in the current model. To keep the overall regulation model understandable, it is recommended that the quality and low carbon issues are covered by separate modules that are integrated into overall model in terms of economical incentives. It is important that the future regulation scheme creates real incentives for deployment of low carbon solutions, such as integration of renewable electricity production as well as energy efficiency and demand-side management solutions. It should be also beneficial to ensure that the investments in the future will support these targets while unnecessary over-investments for networks that do not enhance quality or sustainability are avoided.

Regardless of the theoretical regulation model to be used, the main challenge of the future regulation is how to take into account the low carbon energy system targets? Many practical question are still open and further studies are needed in order to ensure effectiveness of the potential planned actions.

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Appendix 1: Potential performance indicators to promote smartness

Benefit	Potential performance indicators[16]
(1) Increased sustainability	Quantified reduction of carbon emissions
(2) Adequate capacity of transmission and distribution grids for "collecting" and bringing electricity to consumers	Hosting capacity for distributed energy resources ('DER hosting capacity') in distribution grids Allowable maximum injection of power without congestion risks in transmission networks Energy not withdrawn from renewable sources due to congestion and/or security risks
(3) Uniform grid connection and access for all kind of grid users	Benefit (3) could be partly assessed by: - first connection charges for generators, prosumers and customers - grid tariffs for generators, prosumers and customers - methods adopted to calculate charges and tariffs - time to connect a new user
(4) Higher security and quality of supply	Ratio of reliably available generation capacity and peak demand Share of electrical energy produced by renewable sources Duration and frequency of interruptions per customer Voltage quality performance of electricity grids (e.g. voltage dips, voltage and frequency deviations)
(5) Enhanced efficiency and better service in electricity supply and grid operation	Level of losses in transmission and in distribution networks (absolute or percentage)[17] Ratio between minimum and maximum electricity demand within a defined time period (e.g. one day, one week)[18] Demand side participation in electricity markets and in energy efficiency measures Availability of network components (related to planned and unplanned maintenance) and its impact on network performances Actual availability of network capacity with respect to its standard value (e.g. net transfer capacity in transmission grids, DER hosting capacity in distribution grids)
(6) Effective support of trans-national electricity markets by load-flow control to alleviate loop-flows and increased interconnection capacities	Ratio between interconnection capacity of one country/region and its electricity demand Exploitation of interconnection capacity (ratio between mono-directional energy transfers and net transfer capacity), particularly related to maximisation of capacity according to the Regulation on electricity cross-border exchanges and the congestion management guidelines Congestion rents across interconnections
(7) Coordinated grid development through common European, regional and local grid planning to optimise transmission grid infrastructure	Benefit (7) could be partly assessed by: - impact of congestion on outcomes and prices of national/regional markets - societal benefit/cost ratio of a proposed infrastructure investment - overall welfare increase, i.e. always running the cheapest generators to supply the actual demand) → this is also an indicator for benefit (6) above.

Source: Position Paper on Smart Grids, An ERGEG Public Consultation Paper, Ref: E09-EQS-30-04, 10 December 2009.

Appendix 2: Example of Nemesys yardstick model

To illustrate the mechanics of Nemesys model, consider a case with three DSOs that have so far in each and every period charged 100. Let the interest rate is α=5% and the penalty rate δ=5%. The development in underlying minimal costs is illustrated in italics and the chosen DSO charges are illustrated in bold in the table below. We see that DSO Two faces idiosyncratic extra costs of 10 in Period 2 and that DSO Three tries to use its relatively low costs to get extraordinary profits.

The example not only illustrates the formula. 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 that covers all costs, including capital costs.

		Period 1	**Period 2**	**Period 3**	**Period 4**	**Period 5**
DSO One						
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
DSO Two						
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
DSO Three						
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)	100	100	90	90	90
Extraordinary Profit	AC(t)-c(t)	0	10	0	-11.5	0

Source: Pan-Nordic Regulation of Distribution System Operations, NEMESYS White Paper, 2005, Sumicsid AB.