EFFECTS OF BENCHMARKING OF ELECTRICITY DISTRIBUTION COMPANIES IN NORDIC COUNTRIES – COMPARISON BETWEEN DIFFERENT BENCHMARKING METHODS

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ABSTRACT

This paper describes the different benchmarking methods used in benchmarking of electricity distribution companies in Finland, Sweden and Norway. Data Envelopment Analysis (DEA) is used in benchmarking in Norway and Finland. Network Performance Assessment Model (NPAM) is used in benchmarking in Sweden. Theory of these methods is presented briefly. Main focus is on the comparison of these two very different methods.

INTRODUCTION

DEA (Data Envelopment Analysis) and many other benchmarking methods have been developed for benchmarking of non-commercial units like schools and hospitals. In these cases the results of benchmarking do not usually have economical effects. These benchmarking methods have then been adapted to benchmarking of electricity distribution companies. When benchmarking is used as a regulatory tool it has direct effects to companies profits. Therefore benchmarking methods have very high demands on correctness and fairness.

Benchmarking of electricity distribution companies differs significantly from benchmarking of any other industries. For example the operational environments of companies vary greatly from one company to other. The costs of electricity distribution vary greatly depending on geographic and demographic issues. Even companies, which seem to have similar operational environments, could have very different costs structures.

Correctness of benchmarking is strongly dependent on input parameters. If there are too few parameters, the differences in the operational environments of companies may not be taken correctly into account in the benchmarking. Efficiency of company may seem to be poor if reference companies operate in different environments with smaller cost requirements. In the other hand, if number of parameters is too large the benchmarking may not find true inefficiencies.

BENCHMARKING METHODS

Companies, which operate in state of monopoly, do not have pressure from the markets to keep prices and costs at reasonable level. Therefore regulator must supervise the prices of electricity and costs of companies. Reasonable level of costs is usually determined with efficiency benchmarking. Most of benchmarking methods use the most efficient companies to form an efficiency frontier in which all the companies are compared to; these methods are called frontier methods. One of most used frontier method is Data Envelopment Analysis. Other benchmarking philosophy is to use company itself as a reference in benchmarking. The efficient cost-level of company is calculated with efficient fictive network built today in the same area. This is the main idea of Network Performance Assessment Model (NPAM). There is also one major difference between DEA and NPAM, which should be taken on account when comparing these two methods. DEA is only a benchmarking tool, which is used as one part of regulation. NPAM is a regulation tool, including benchmarking and regulation.

Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a method for benchmarking Decision Making Units (DMU). These units can be non-commercial units, companies, business units of one company etc. DEA is a linear programming application where the goal is to maximize the ratio of weighted outputs to weighted inputs. Only constraints are that weights must be positive and weights of one company must not provide efficiency score larger than 1 to any other company. Input oriented DEA method with variable returns on scale is very commonly used in benchmarking of electricity distribution companies. Theory of this method is presented in equations (1) – (4). Theory of DEA can be found more detailed in (Cooper et al. 2002).

$$\text{Max} \quad h_0 = \frac{\sum_{j=1}^{n} u_j y_{j0} + c_0}{\sum_{i=1}^{m} v_i x_{i0}} \qquad (1)$$

s.t.

$$\frac{\sum_{j=1}^{n} u_j y_{jk} + c_0}{\sum_{i=1}^{m} v_i x_{ik}} \leq 1 \qquad ;k = 1,\ldots,K \qquad (2)$$

$$u_j, v_i \geq \varepsilon \qquad ;i = 1,\ldots,m; \ j = 1,\ldots,n \qquad (3)$$

$$c_0 \text{ unrestricted} \qquad (4)$$

Where

h	= efficiency score	u	= weight of output
v	= weight of input	y	= output
x	= input	m	= number of inputs
n	= number of outputs	K	= number of DMUs
ε	= small positive constraint		

DEA-model, as any linear programming problem, can be presented in 2-dimension figure when there are only 1 input and 1 output. The graphical example of DEA is shown in fig. 1.

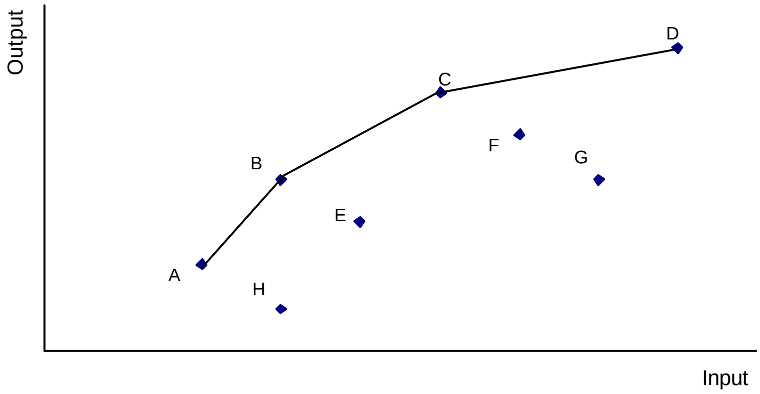

Figure 1 Example of efficiency frontier in 1 input 1 output case.

The inputs and outputs of 8 (A…H) companies are plotted in figure 1, inputs in x- axis and outputs in y- axis. Companies A, B, C and D have been founded to be efficient since those companies have best output to input ratio. These efficient companies forms efficient frontier, which "envelops" points plotted in the figure. Therefore the name of method is Data Envelopment Analysis.

DEA in benchmarking of electricity distribution companies

There are few features in the DEA model, which should be considered when using this method as benchmarking tool. The number of utilities must be large enough for reliable results. If there are too few utilities in benchmarking, similar reference companies may not be found for every company. Because of this DEA model could be unsuitable for benchmarking method in countries where number of distribution companies is very small.

Input and output parameters have obviously very strong effect to correctness of benchmarking. In input oriented DEA model the input parameters are only parameters, which are considered to be controllable from companies' point of view. Therefore environmental and output parameters are treated same way in the model. The number of parameters have direct effect to number of efficient companies, more parameters more efficient companies.

Weights of each parameter are chosen to show the company in the best possible light. Therefore, weight of some parameters may be very small and changes in these parameters do not affect to efficiency score. This kind of situation can be problematic when there is some output parameter that has to have influence on efficiency of company. That parameter could be for example power quality.

The smallest and largest companies are founded as efficient in all cases. In figure 1 company A is utilising least amount of input. Therefore it is founded as efficient, no matter how much output it is producing. The same way company D is founded as efficient since it produce largest amount of output. Efficiency of company D remains the same, no matter how much inputs it uses. Company D is said to be "superefficient" company. The superefficient companies are problematic, since true efficiencies of such companies cannot be estimated with DEA.

Network Performance Assessment Model

Network Performance Assessment Model (NPAM) is a combination of rate of return and revenue cap regulation. Reasonable level of revenues is based on costs of fictive network. Fundamentals of NPAM are shown in fig. 2.

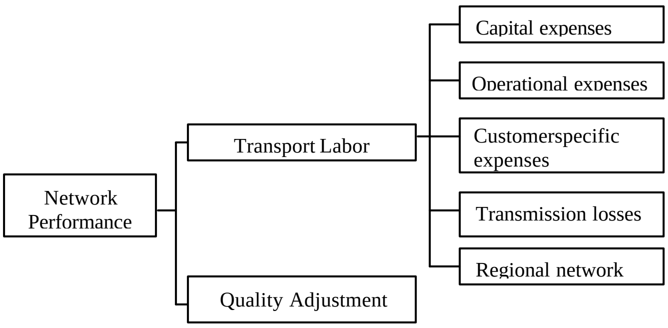

Figure 2 Fundamentals of NPAM.

The basic idea of NPAM is to determine reasonable revenue for each company based on costs of fictive network. This reasonable level of revenue is called network performance, which reflects the price level customers are willing to pay.

Input parameters of model are geographical position, energy consumption, voltage level and yearly income from every customer and every boundary points. Fictive network is constructed based on this information. Fictive network is radial network, which reflects the optimum network built today. Fictive network has 4 voltage level and there is only 1 conductor type used in each voltage level. Lines are routed directly form one point to other, without any bends. Actual network cannot be built directly since there are buildings, routes etc. on the way. This is taken account on length of fictive network with geometrical adjustment factor.

Network performance is calculated based on repurchase value of fictive network. Repurchase value of fictive network is based on amount of components in fictive network and unit costs of components, determined with cost function. The cost function used in NPAM is shown in equation (5).

$$C = \left(k_1 + k_2 * \tanh\left(k_3 * \left(x - k_4\right)\right)\right)^{k_0} \qquad (5)$$

Where

$k_0 \ldots k_4$ = constants 0…4

x = density of customer (length of line / customer)

This cost function, with different constants, is used to calculate the costs of lines, costs of transformers, area costs of substations, network losses, outage cost parameters, reserve capacity needed, expected outage costs and geometrical adjustment factor. Cost function of medium voltage line is presented in fig. 3. Cost function of distribution transformer is presented in fig. 4.

Figure 3 Cost of medium voltage line in NPAM.

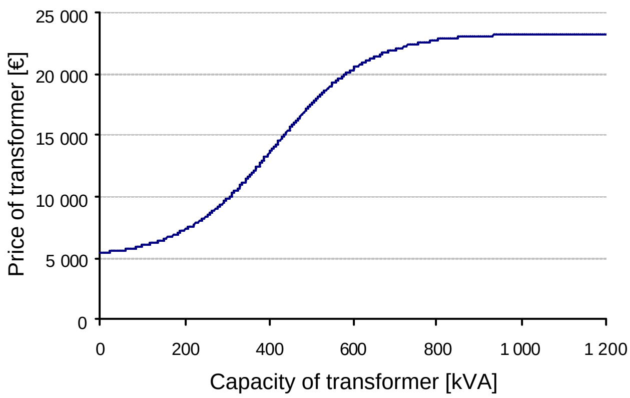

Figure 4 Cost of distribution transformer in NPAM.

Quality adjustment in NPAM is calculated with equation (6).

$$QA = \textit{Costs of reserve capacity} - (\textit{Reported outage costs} - \textit{Expected outage costs}) \qquad (6)$$

Capital cost is calculated with certain interest rate, which consists of risk-free interest and risk supplement, and 40 years depreciation time. Operational costs are 1 percent of repurchase value for lines and 2 percent for transformers. Customer specific costs are fixed and depend only on voltage level of customer. (Larsson 2004)

NPAM in benchmarking of electricity distribution companies

There are some main characteristics in NPAM, which should be taken on account when using it as a regulation tool. The fictive network is used as regulatory asset base in NPAM and the existing network is totally ignored. The actual network could be oversized because of historical investments. For example growth of population in certain area could be overestimated and network could then be oversized. However, company should be able to maintain network once built to retain good level of reliability of supply.

Most of parameters in NPAM are calculated with cost function, which is dependent only on customer density. Therefore the total costs of fictive network determined with NPAM are very sensitive to changes in customer density. It should be noted that customer density is determined with length of fictive network. The actual density of population in same area could differ significantly from that. Customer density is also dependent on design parameters of fictive network, for example maximum length of low voltage network.

BENCHMARKING IN NORDIC COUNTRIES

Although Nordic countries have somewhat similar geographic and demographic circumstances, benchmarking methods used in Finland, Sweden and Norway are different. Finland and Norway are using DEA with different parameters in benchmarking. Sweden has developed NPAM for regulation and benchmarking.

Benchmarking of electricity distribution companies in Finland

Finnish regulator Energy Market Authority has been chosen DEA for benchmarking method to be used in regulation. The input parameter is operational costs, output parameters are value of delivered energy and power quality and environmental parameters are length of network lines and number of customers. Parameters of benchmarking are shown in table 1. (Korhonen et al. 2000)

Table 1. Parameters of benchmarking in Finland.

Input	Output	Environmental factor
OPEX	Power quality	Length of network
	Value of delivered energy	Number of customers

Original idea was that the results of efficiency benchmarking have direct effect to reasonable return on capital. Since some inaccuracy in the DEA benchmarking was noticed, the error marginal of 0,1 was included in efficiency requirement. The reasonable level of operational costs (RC) was then be determined with DEA-score as shown in equation (7). (EMA 2002)

$$RC = (DEA\text{-}score + 0{,}1)*OPEX \tag{7}$$

Where

RC = Reasonable operational costs

$OPEX$ = Actual operational costs

However, Energy Market Authority has considered that it is not reasonable to decrease inefficient company's reasonable level of return on capital afterwards, when company was not informed it's inefficiency and effects of inefficiency. Therefore the authority has decided to use DEA-scores only for rewarding companies, not for punishment. (EMA 2003) The problem is that DEA-score of each company is calculated and informed to company afterwards, but reasonable level of operational costs should be known in advance for pricing and planning of business.

The new regulation model comes into use at beginning of 2005. In new model, there is not individual efficiency requirement, only the general efficiency requirement. However, individual efficiency requirement is probably coming to use to second regulatory period (years 2008 – 2012). The efficiency requirement will most likely be based on benchmarking done by DEA.

Benchmarking of electricity distribution companies in Norway

Norway has been a pioneer in the deregulation of electricity markets. Therefore Norwegian regulator has great experience of regulation and benchmarking of electricity distribution companies. Regulation method in Norway is revenue cap and benchmarking method is DEA. The X-factors, which have direct impact on revenue cap, are based on benchmarking of each company and general efficiency requirement. Parameters of benchmarking are shown in table 2. (Gammeltvedt 2003)

Table 2. Parameters of benchmarking in Norway.

Input	Output	Environmental factor
Network assets	Number of customers	Length of network
Number of man-labour years	Delivered energy	Normalised interruption time
Interruption time		
Network losses		
OPEX		

Different age profiles for different grids influence to companies book values. Therefore NVE has decided to use two different versions of benchmarking, one with book values and other with replacement values. The X-factor is based on most favourable result for each company. (Gammeltvedt 2003)

Benchmarking of electricity distribution companies in Sweden

Swedish Energy Agency (STEM) has been developing the Network Performance Assessment Model since 1998. There have been many pilot tests with model and the final version is most likely coming to use during 2004. In the regulation, the revenue of company is compared to network performance and that ratio is called Relative Billing Ratio. If Relative Billing Ratio is higher than 1 the company is overcharging the customers. STEM has informed that it is using NPAM to find out certain companies, which has too high Relative Billing Ratio. Pricing of these companies will then be investigated more closely. However, method of closer investigation has not been published yet. (Gammelgård et al. 2003)

COMPARISON OF DIFFERENT BENCHMARKING METHODS

The methods presented above, DEA and NPAM seem to be very different but both methods are used in evaluating the cost-efficiency of electricity distribution companies. The methods have totally different philosophy of benchmarking and also different directing effects.

Benchmarking philosophy

In the DEA-model companies are benchmarked against the efficient frontier, which is constructed by efficient companies. In the other words companies are benchmarked against other companies, which operates in similar operating environment. How similar reference companies are is dependent on parameters of DEA. In Finland environmental parameters are length of network lines and number of customers.

In NPAM all companies are benchmarked against a hypothetical company which has costs based on fictive network. This is major difference between DEA and NPAM. In DEA companies are benchmarked against other companies and parameters of benchmarking are based on existing network. In NPAM every company is benchmarked against a hypothetical company with fictive costs. The existing network is totally ignored in the benchmarking made with NPAM.

The costs of fictive network are strongly dependent on density of customers, which describes is company operating in city or rural area. However, density of customers is only parameter that has effect on costs of fictive network. The companies operating in different kind of rural areas are assumed to have similar operating environments. In practice the companies, which have similar density of customers, could have very different cost structure. It should be advised that density of customer is based on fictive network and could differ significantly from actual density.

Costs of outages

The price of outage is very clear directing parameter, which is used as one cost component in network planning. If price of outage is very high, the network is developed to be as reliable as possible. In this case the power quality is good, but also price of electricity becomes very high. In the other hand, if price of outage is zero, the reliability could be ignored in the development of network.

Effects of benchmarking of electricity distribution companies in Finland has been analysed in (Lassila et al. 2002). It is shown out that if power quality is treated as technically non-controllable factor, it's effect to efficiency score vary significantly from one company to other. The dependences between power quality and efficiency score can be analysed with sensitivity analysis. If efficiency score has direct effect to company's return on capital, the cost of outage can also be calculated. The results of analysis was that the price of outage varied between 0 and 600 €/customer,h depending on company as shown in fig. 5. Prices of outages varied also between two years. It should be noticed that unit of these outage costs is [€/customer,h]. Therefore the actual price of non-delivered energy [€/kWh] is higher for smaller customers. For example, if price of outage is 100 €/customer,h, the price of non-delivered energy is 50 €/kWh for domestic user with average effect of 2 kW and 2,5 €/kWh for industrial user with average effect of 40 kW.

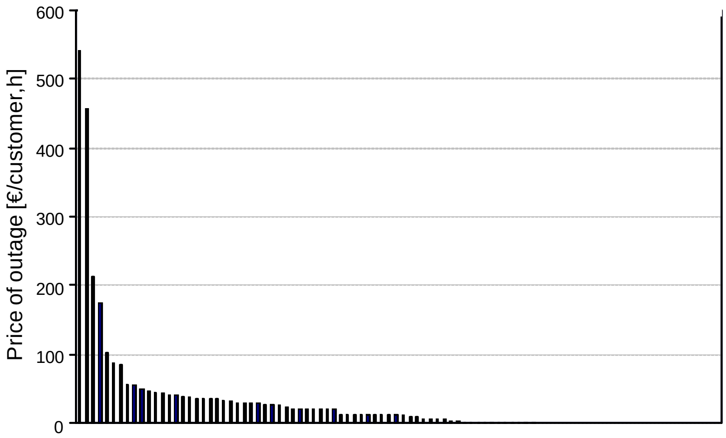

Figure 5 Prices of outages of 94 Finnish electricity distribution companies determined with DEA benchmarking. Price of outage is 0 €/customer,h for 26 companies. (Lassila et al. 2003)

The proposal to fix this problem in Finnish benchmarking model has been made in (Lassila et al. 2003). In the developed benchmarking model power quality was measured as interruption costs, and operational costs and interruption costs was added together as input parameter of DEA.

In Finland power quality affects to revenue of company through efficiency benchmarking. In Norway and Sweden power quality has direct effect to revenue, calculated by similar method in both countries. The expected outage cost is determined for every company and if actual outage cost is larger than expected the revenue is decreased. In Norway interruption time is also one input parameter in the benchmarking. However, power quality has only minor effect to revenue through efficiency benchmarking compared to direct effects to revenue.

In the Swedish model the cost of outage is function of customer density as shown in fig. 6. In Norway cost of non-delivered energy vary between 1 and 12 €/kWh depending on customer type as shown in fig. 7.

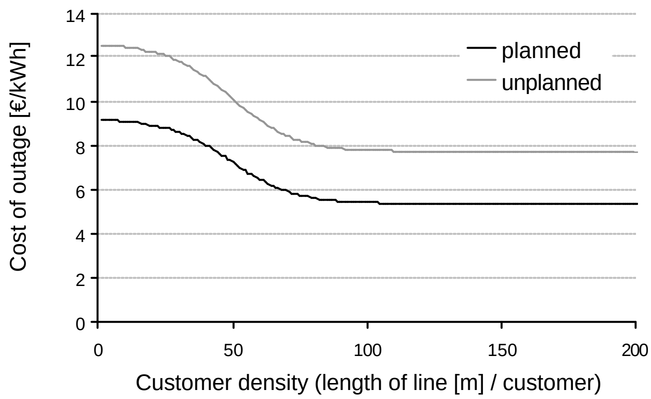

Figure 6 Cost of outage in NPAM. (Larsson 2004)

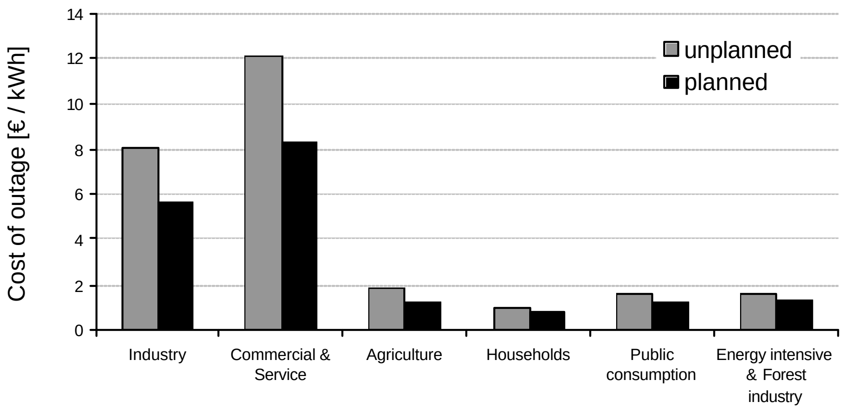

Figure 7. Cost of outage in Norwegian regulation. (NVE 2004)

Effects of benchmarking on network development

When using costs of fictive network as a reference in benchmarking, the growth of loads could become a major problem. In NPAM the fictive network is designed to be an optimal network for current loads. The actual electricity distribution networks are designed with 20 - 30 years time scale and design criteria has been to minimise total costs (capital costs, operational costs, losses and outage costs) during whole operating time of network. The growing loads have been taken into account during the planning and developing of the network. Therefore actual network seems to be oversized for current loads and costs needed for maintain actual network could be significantly higher than costs provided by NPAM. Reliability of network could lower if there is not enough incentives for maintain and develop the existing network.

CONCLUSIONS

Benchmarking of electricity distribution companies is very challenging due to great varying in operational environments. The accurate efficiency of each company could not be achieved with any benchmarking method. Therefore results of benchmarking should use carefully in the regulation. Efficiency requirements should be reasonable from view of every interest group. Reasonable cost levels must provide companies enough incentives for maintaining and developing the network. Constant developing of the network is only way to maintain good level of power quality. From customers' point of view, the efficiency of electricity distribution means that power quality is good and price of electricity is low. The price and reliability of electricity distribution should be balanced to get socio-economically optimal solution.

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