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Abstract

This study examines the feasibility and applicability of the Self-Organizing Map (SOM) as a complementary efficiency benchmarking approach, in the context of the Finnish electricity distribution sector. A SOM-model has been built based on Finnish Energy Market Authority (EMA) data for the period of 2001-2004, which consist of the electricity distribution operators' (DSOs) operational indicators and their efficiency scores. Through cluster analysis and benchmarking of the most efficient performers, it is shown that the proposed SOM-model is potent in visually displaying the different operating circumstances in which the different DSOs operate. The distinct characteristics of the DSOs within one cluster and the interrelations between clusters and amongst efficiency measurements can be easily interpreted from the trained maps. Additionally, the SOM-model raises a number of potential focuses concerning efficiency improvement for particular companies (e.g., most of the DSOs in Cluster F) and the regulatory authority. The study provides evidence that the application of the SOM has promising benefits in terms of electricity distribution regulation and efficiency benchmarking.

Keywords: Efficiency Benchmarking, Self-Organizing Maps, Electricity Distribution Regulation

TUCS Laboratory
Data Mining and Knowledge Management

1. INTRODUCTION

Energy efficiency has become an increasingly important topic today. As a matter of fact, the electricity distribution sector's efficiency has always been under scrutiny due to the fact that electricity distribution is considered to be a natural monopoly. Benchmarking has been widely adopted as a regulatory tool in electricity distribution. The benchmarked target is the cost-efficiency or technical efficiency of electricity distribution system operators (DSOs). Efficiency benchmarking aims to close the gap between inefficient companies and the best performers.

Despite the fact that there are different incentive regulation schemes[1], the benchmarking methods adopted in this field are mainly frontier-based approaches, e.g., Data Envelopment Analysis (DEA), Corrected Ordinary Least Square method (COLS), Stochastic Frontier Analysis (SFA), and the so-called 'Network Performance Assessment Model' (Jamasb and Pollitt 2003; Honkapuro et al. 2004)[2].

The Finnish practice in electricity distribution regulation and benchmarking has drawn special attention because the Finnish Energy Market Authority (EMA) has implemented a controversial regulatory scheme – the rate of return (ROR) – which is considered to lack incentives for cost-cutting. Arguably, however, Finland has still achieved a more efficient electricity distribution system relative to many other European countries (Edvardsen and Førsund 2003; Kinnunen 2006). The Finnish energy authority has combined the DEA benchmarking method with the ROR scheme since 2000. Consisting of the variables *Operating Costs, Amount of Distributed Energy, Customers' Total Interruption Time, Total Network Length, and Number of Users* as indicators that describe the electricity distribution business, the Finnish DEA-model is acknowledged as sophisticated for efficiency comparison (Edvardsen and Førsund 2003; Jamasb and Pollitt 2002).

Nevertheless, the direct outcome of the Finnish DEA-model is the efficiency score for each DSO in a given regulatory year in the form of the scale of 0 to 1, with the most efficient DSOs receiving a score of 1. It cannot provide in-depth information about the relations between the indicators and efficiency, and the dependency between multivariate indicators. In other words, the DEA-model only indicates which DSO performed efficiently or inefficiently, but does not display the real operating characteristics of efficient / less efficient DSOs in terms of the selected indicators (i.e., Operating Cost, Distributed Energy, Interruption Time, Network Length, Number of Users, etc.). If one wants to investigate the actual reasons when comparing inefficient DSOs to efficient ones, the DEA-model is not capable of providing such information. Moreover, the circumstances in which the Finnish DSOs operate vary significantly. The geographic and environmental characteristics determine, for instance, that the line types (overhead vs. underground) as well as the corresponding installation and maintenance expenses for companies operating in the sparsely populated Lapland area must differ from those either operating in populous urban areas, or delivering power to archipelagos. Again, the Finnish DEA-model cannot explicitly reflect such differences caused by the variations in operating circumstances. Hence, there is room for a complementary method(s) to fill this gap.

Self-Organizing Maps (SOM), as one major category of Artificial Neural Networks (ANNs), have been extensively examined and successfully implemented for both discovering hidden knowledge and benchmarking in business (Back et al. 1994, 1998; Deboeck and Kohonen 1998; Eklund et al. 2003; Karlsson 2002). Knowledge discovery has been acknowledged by ever-growing domains as the key leading to success, while benchmarking is broadly seen as a means towards competitive advantage and continuous improvement (Camp 1989; McNair and Leibfried 1992). Based on these foundations, this study seeks to apply the SOM in the field of electricity distribution benchmarking, specifically in the Finnish context. As an exploratory data analysis, the purpose of this study is to examine the applicability of the SOM as a complementary approach in this specific domain, as well as to explore what insights and added value the SOM-model can offer in light of Finnish DEA benchmarking. To our knowledge, the SOM has not been previously applied in this specific domain.

By visualizing and clustering Finnish electricity DSOs with the SOM, this experimental study intends to achieve the following goals: 1) *to identify the characteristics of DSOs in clusters, in terms of the differences in operating circumstances;* 2) *to examine the relation and dependency between DSO clusters and the chosen indicators;* 3) *to identify any added value of using the SOM as a complementary tool*.

This study will use publicly available data. The examined period is from 2001 to 2004, because the DEA benchmarking method in Finland was introduced in 2000 and since 2005 the EMA has started a new regulatory period in accordance with European Union (EU) legislation. It needs to be noted that the proposed SOM-model is not attempting to challenge the current DEA-model and the implemented regulatory principle. Rather, it is used in order to provide a complementary approach to efficiency benchmarking. The research in this study follows a design science approach (Hevner et al., 2004; Järvinen 2004; March and Smith 1995) in which a model is created and then evaluated by domain experts. It thus follows the traditional build-evaluate cycle of design science. This study builds upon the findings in Liu (2008).

The rest of the paper is organized as follows. In the following section, the SOM algorithm and the DEA method will be briefly presented. The current benchmarking practice in Finland will also be briefly presented. The construction of the SOM-model is described in Section 3. In Section 4, the results will be displayed and analyzed. In the final part of this study, conclusions will be drawn and topics of future research are addressed.

2. BACKGROUND

2.1 The Self-Organizing Map (SOM)

Artificial Neural Networks (ANNs) are artificial intelligence tools that employ learning techniques modeled after those of the human nervous system. Similar to a human who learns to model relationships from seeing a few examples, ANNs can be trained to recognize similarity and regularity, in order to extract relations within superficially irrelevant data. This makes ANNs suitable for knowledge discovery applications where little *a priori* knowledge is available, and where formulating hypotheses for testing may be unnecessarily restrictive or difficult. ANNs can be categorized based on connection topologies (e.g., feed-forward vs. partially or fully recurrent networks), learning methods (e.g., supervised vs. unsupervised), and learning algorithms (e.g., backpropagation vs. competitive learning) (Bigus 1996; Deboeck and Kohonen 1998; Haykin 1999; Kohonen 2001).

As one type of feed-forward and unsupervised-learning neural network, the SOM consists of two layers, i.e., one input layer and one output layer, in which each input node is fully connected to each output node. Since it uses an unsupervised learning approach, the SOM needs no knowledge about the desired output, i.e., target values are not required. The fundamental idea of the SOM is through a process called *self-organization* to map high dimensional data onto a spatial map (usually in the form of a two-dimensional lattice of hexagonal nodes). Unlike the supervised learning method used in *multi-layered feed-forward backpropagation neural networks*, the SOM uses the *competitive learning* algorithm (unsupervised), meaning that the nodes on the output layer compete with each other to be the best matching node (i.e., the winner) whose connection weights to the input pattern are the closest in terms of the *Euclidian distance*. At the same time, the SOM algorithm allows the output nodes in the neighborhood of the winner to adjust their weights accordingly. Theoretically, all the nodes on the output layer are the projection of the input data items. As such, the intrinsic patterns of input data in the multivariate space are reflected on the feature maps, i.e., visual clustering is performed (Back et al. 1998; Bigus 1996; Deboeck and Kohonen 1998; Eklund 2004; Haykin 1999; Kohonen 2001). Here, a 'cluster' refers to a group of observations that are close to each other in geometric terms, while clusters themselves can be discriminated (Bigus 1996; Wang and Wang 2002). Readers are referred to Kohonen (2001) for a more detailed description of the SOM algorithm.

In this study, the Viscovery SOMine v.4.0 software is used. SOMine is an advanced and easy to use commercial SOM software package, developed by Eudaptics Software GmbH in Austria (http://www.eudaptics.com/). SOMine uses an expanding map size and the batch training algorithm (Kohonen, 2001), allowing for very rapid training of maps (Deboeck and Kohonen 1998). Ward's clustering method is also used to identify clusters on the map, eliminating the need for subjective identification of clusters.

2.2 Data Envelopment Analysis (DEA)

As mentioned above, the DEA method, which has been adopted by the Finnish energy regulatory authority (EMA) in electricity distribution benchmarking, is a non-parametric frontier-based technique. The principle of the DEA method lies in using piecewise linear programming to calculate the best input-output ratio (i.e., the best practice) in a multiple input and output case. In terms of electricity distribution benchmarking, the efficient firms with the best input to output ratio will form a frontier, which envelops the inefficient firms. Each firm's efficiency is represented by an efficiency score on the scale of 0 to 1, with the most efficient firms receiving the score of 1 (Jamasb and Pollitt 2003, Korhonen and Syrjänen 2003, Honkapuro et al. 2004).

In practice, the variables selected as inputs and outputs vary within the European countries who have implemented the DEA method as an electricity distribution benchmarking tool (Tahvanainen et al. 2004). In Finland, the EMA has adopted *Operating Costs* as input, while such factors as *Customers' Total Interruption Time* and *Amount of Distributed Energy* consist of outputs, alongside two environmental factors (*Total Network Length* and *Number of Users*). One reason for selecting the input/output in this way is that the DSOs are unable to control the amount of energy distributed and the environmental factors. Another reason is due to the EMA wants to use the DEA-model as a part of the monitoring system in regulation of distribution pricing (Korhonen and Syrjänen 2003).

3. THE SOM-MODEL

3.1 Data and Datasets

The data used in this study are derived from the Finnish Energy Market Authority (EMA) data sources Tehokkuusluvut 2001-2004 (publicly available from http://www.energiamarkkinavirasto.fi/), which consist of the distribution companies' (DSOs) operational indicators and their efficiency scores. The use of the EMA data provides the best possible reliability and comparability across the examined years.

The Investigated DSOs

The number of DSOs varies across the examined period. In order to preserve the original data structure, we try to include as many of the DSOs as possible in the SOM training. Therefore, there are in total 356 DSOs included in the experiment, with 94 in 2001, 90 in 2002, 86 in 2003 and 2004 respectively. The list of the investigated companies' codes, names, and respective efficiency scores can be seen in Appendix I.

The Variables in the SOM-model

The variables in the SOM-model replicate the measurements used in the Finnish DEA-model, in order to make the two models compatible. There are five numerical indicators included in the Finnish DEA-model, as explained following Korhonen and Syrjänen (2003):

Operating Costs – the amount of operating costs (teuro), controlled by the company;
Interruption Time – three year average of customers' total interruption time (h /year);
Distributed Energy – the amount of distributed energy weighted by the average national voltage-level-based distribution prices (teuro);
Network Length – the total network length of the different voltage levels (km);
Number of Users – the total number of customers.

These five indicators are referred to as efficiency measurements in the following paragraphs.

Dataset in the Experiment

The dataset, which includes 356 samples with 5 variables, is used to train the map. The resulting map is called E01-04. Then, the most efficient DSOs according to the DEA-model (i.e., DSOs that had efficiency scores of 1) are mapped onto the trained map year by year, for the purpose of benchmarking.

3.2 Training the Network

During the experiment, hundreds of maps were created. In the first phase, the different sizes of map (i.e., number of nodes = 2000, 500, 200, respectively), three values of tension (0.5, 0.3, and 0.02), and three options for transformation of the data (none, sigmoid, and logarithmic [3]) were tested. The scaling is always 'by default', i.e., either *Variance* or *Rang* [4]. Moreover, the examined variables are treated as equally important in this study, meaning that no priority factor is assigned. The 'automatic' [5] map ratio is used. In turn, the trained maps were compared in terms of clusters, visual interpretability, and average quantization error, in order to select suitable training parameters. Only one parameter was changed at each time, while keeping other settings fixed to simplify comparison. For each set of parameter combinations several runs were repeated.

Finally, the map size of 2000 nodes and the tension of 0.3 were selected, combined with 'automatic' map ratio and 'by default' scaling as the uniform training parameters. Additionally, the transformation method used is 'sigmoid' transformation, with which the satisfactory clustering and the reasonable average quantization error can be achieved. The final average quantization error of the map was 1.773E-007.

4. RESULTS AND ANALYSIS

4.1 Identifying the Clusters on the Map

The final map E01-04 results in eight clusters, as shown in Figure 1.

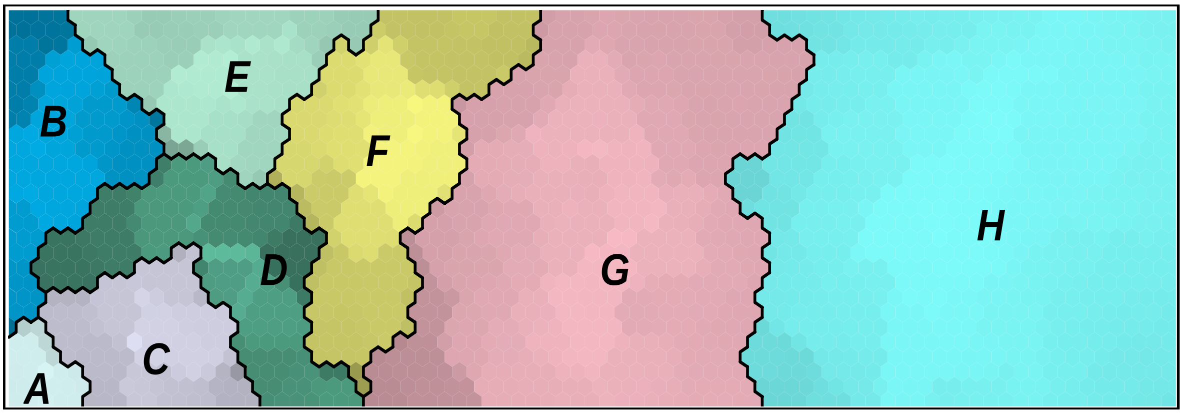

Fig. 1 Clusters in E01-04

The characteristics of each cluster can be identified using the feature planes (Figure 2), as summarized in the U-matrix of E01-04 (Figure 3):

Cluster A has the highest values in *Operating Cost, Interruption Time, Distributed Energy, Network Length,* and *Number of Users*.
Cluster B has medium to high values in *Operating Cost, Distributed Energy*, and *Number of Users*, while the value of *Interruption Time* and *Network Length* are medium.
Cluster C has medium to high values in *Interruption Time* and *Network Length*, and the remaining three are medium.
In **Cluster D**, the values of the five efficiency measurements are medium to low.
Clusters E and **F** have slightly low values in *Operating Cost, Distributed Energy*, and *Number of Users*, and lower values in *Interruption Time* and *Network Length*. In comparison, clusters E and F have similar characteristics as cluster B.
Cluster G has very low values in all five measurements, while **Cluster H** has the lowest.

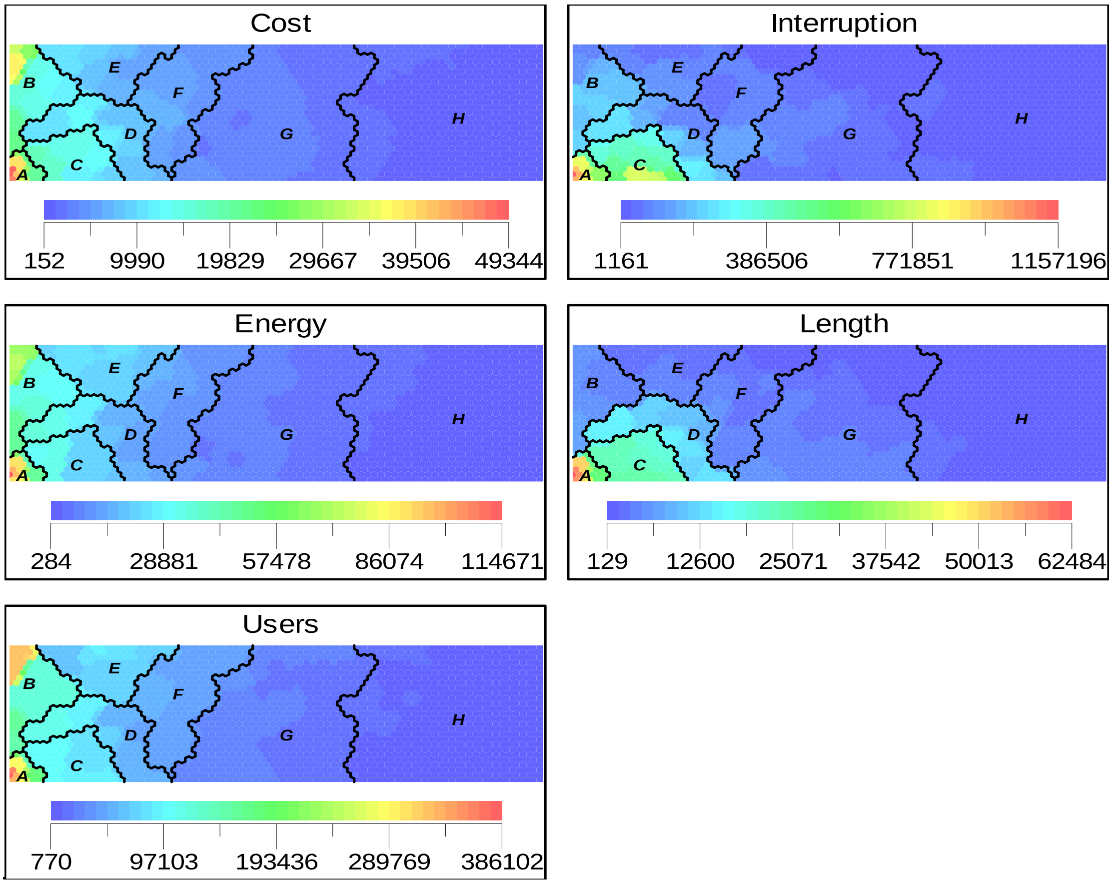

Fig. 2 Feature Planes of E01-04

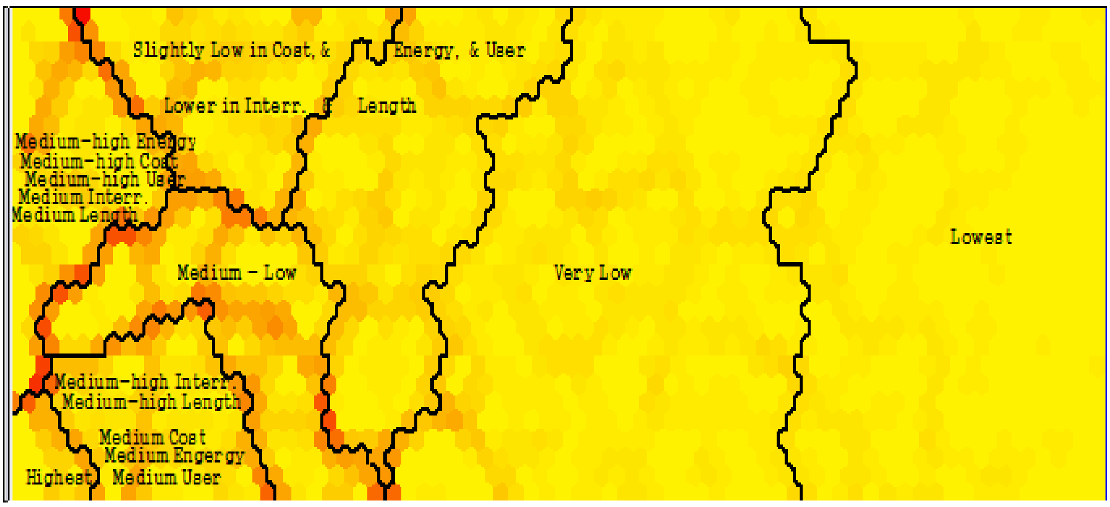

Fig. 3 Characteristics of Clusters in E01-04

As most of the Finnish electricity distribution network operators are municipal-based, their respective operational coverage is most likely amid the municipalities they belong to. Therefore, the company names are simplified according to this character. The compositions of each cluster are as follows:

Cluster A consists of Fortum and Vattenfall, which are two large, multiregional Finnish electricity distribution operators.
Cluster B is made up of Helsinki, Espoo / E.ON, and Tampere, which are situated in the metropolis area in Finland.
Cluster C has Savon / Atro, Pohjois-Karjala, and Järvi-Suomi, which are located in the lake area of Finland.
Cluster D is composed of Kainuu / Graning Kainuu, Kymenlaakso, and Uudenmaa, which are regional firms.
Clusters E and **F** also consist of urban operators, with Turku, Vantaa, Oulu, and Lahti in cluster E, while Jyväskylä, Kuopio, Pori, Kouvola / KSS, Vaasa, and Lappeenrata -- relatively small cities -- are in cluster F.
Clusters G and **H** have most rural and small operators. Cluster G consists of 22 DSOs, and cluster H has 46 DSOs.

The numbers of samples and DSOs in each cluster are summarized in Table 1:

Clusters	No. of samples	No. of DSOs
A	8	2
B	12	3
C	12	3
D	12	5 (NB: Uudenmaa only exists in 2001 and 2002. Revo and Keski-Suomi merged with Vattenfall after 2001)
E	16	4
F	24	6
G	86	22
H	186	46

Table1. Distribution of Samples and DSOs in E01-04

4.2 Benchmarking against the Finnish DEA-model Efficiency Scores

According to the calculated efficiency scores in the DEA-model, we picked out the most efficient DSOs which have a score equal to 1. The numbers of the most efficient DSOs also vary across years, with 19 DSOs in 2001, 29 DSOs in 2002 and 2003 respectively, and 35 DSOs in 2004. The codes and names of the most efficient DSOs during 2001-2004 can be found in Appendix II. When importing the most efficient DSOs for each year into the trained map E01-04, it is apparent that they are spread out across the clusters, as in Figure 4-7 [6]. The distribution of the most efficient DSOs from 2001 to 2004 is summarized in Table 2.

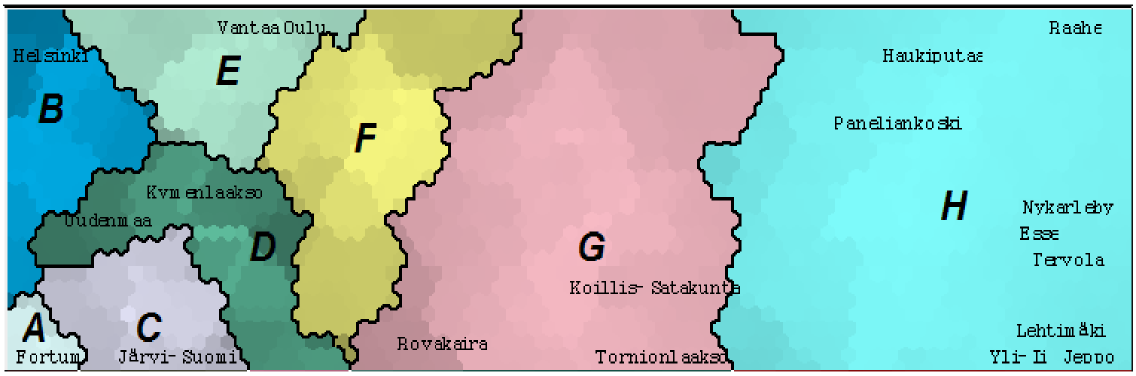

Fig.4 the Most Efficient DSOs in 2001

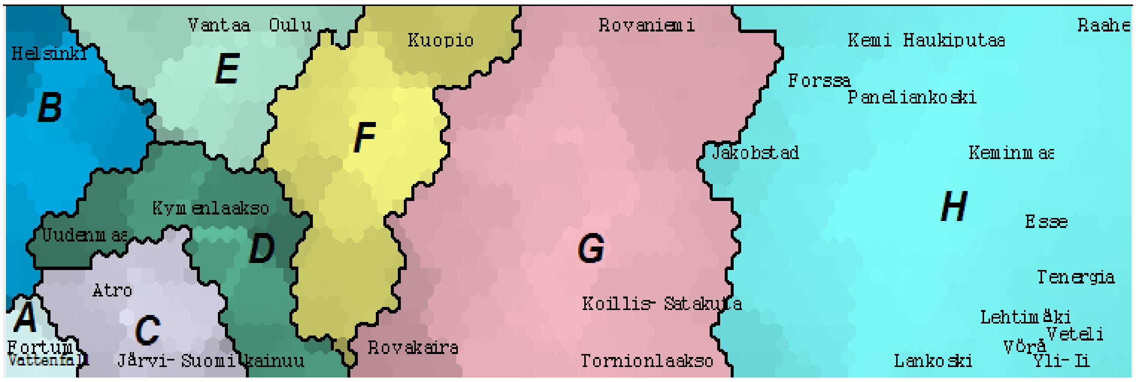

Fig. 5 the Most Efficient DSOs in 2002

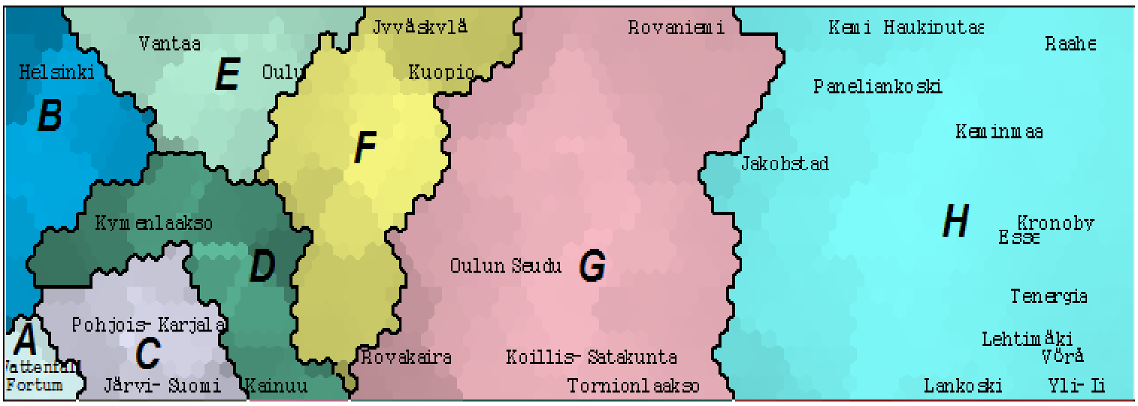

Fig. 6 the Most Efficient DSOs in 2003

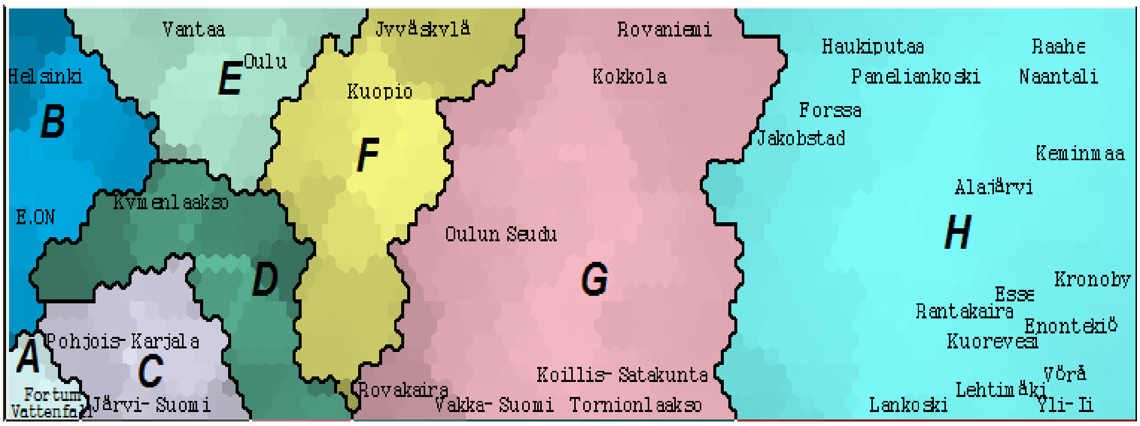

Fig. 7 the Most Efficient DSOs in 2004

4.3 Discussion of the Results

As was stated before, the purpose of this study is to visually investigate Finnish electricity DSOs in the attempt to perform benchmarking. As an exploratory study, the experimental results offer us new perspectives for looking at the Finnish electricity distribution sector.

Firstly, the eight clusters reflect the geographical character of each group. From the resulting maps, we can infer the different operating circumstances for urbanized groups (i.e., clusters B, E & F), the group operating in the lake area (i.e., cluster C), and the rurally based groups (i.e., clusters G & H). Also, this clustering result highlights two conglomerates in the Finnish electricity market, which are grouped in one cluster (i.e., cluster A). The two DSOs (Fortum and Vattenfall) presumably have similar operational circumstances. In addition, the SOM-model distinguishes the three regional players in the Finnish electricity distribution sector, i.e., Kymenlaakso, Kainuu, and Savo / Atro, which are in cluster D. Such a grouping allows us to compare the relative efficiency performance of DSOs based upon operating circumstances.

The SOM-model also reveals the distinctive characteristics of each cluster in terms of the efficiency measurements. It highlights the opposing attributes of the urbanized clusters B, E, & F and the lake area cluster C, where *Operating Cost*, *Distributed Energy*, and *Number of Users* have a negative correlation against *Interruption Time* and *Network Length*.

Secondly, the SOM-model presents a general picture of the best performance of the Finnish DSOs over the examined years. For example, the maps with the most efficient DSOs (Fig. 4-7) demonstrate that a great number of DSOs performed stably efficiently across 2001-2004, such as Fortum in cluster A, Helsinki in cluster B, Järvi-Suomi in cluster C, Kymenlaakso in cluster D, Vantaa and Oulu in cluster E, Koillis-Satakunta, Rovakaira, and Tornionlaakso in cluster G, as well as Esse, Haukiputaa, Lehtimäki, Paneliankoski, Raahe, and Yli-Ii in cluster H.

DSOs	*2001*	*2002*	*2003*	*2004*
Cluster A	Fortum	Fortum Vattenfall	Fortum Vattenfall	Fortum Vattenfall
Cluster B	Helsinki	Helsinki	Helsinki	Helsinki E.ON
Cluster C	Järvi-Suomi	Järvi-Suomi Savo / Atro	Järvi-Suomi Pohjois-Karjala	Järvi-Suomi Pohjois-Karjala
Cluster D	Kymenlaakso Uudenmaa	Kymenlaakso Uudenmaa Kainuu	Kymenlaakso Kainuu	Kymenlaakso
Cluster E	Vantaa Oulu	Vantaa Oulu	Vantaa Oulu	Vantaa Oulu
Cluster F	N/A	Kuopio	Jyväskylä Kuopio	Jyväskylä Kuopio
Cluster G	Koillis-Satakunta Rovakaira Tornionlaakso	Koillis-Satakunta Rovakaira Rovaniemi Tornionlaakso	Koillis-Satakunta Oulun Seudu Rovakaira Rovaniemi Tornionlaakso	Kokkola Koillis-Satakunta Oulun Seudu Rovakaira Rovaniemi Tornionlaakso Vakka-Suomi
Cluster H	Esse Haukiputaa Jeppo Lehtimäki Nykarleby Paneliankoski Raahe Tervola Yli-Ii	Esse Forssa Haukiputaa Jakobstad Kemi Keminmaa Lankoski Lehtimäki Paneliankoski Raahe Tenergia Veteli Vörå Yli-Ii	Esse Haukiputaa Jakobstad Kemi Keminmaa Kronoby Lankoski Lehtimäki Paneliankoski Raahe Tenergia Vörå Yli-Ii	Alajärvi Enontekiö Esse Forssa Haukiputaa Jakobstad Kemi Keminmaa Kronoby Kuorevesi Lankoski Lehtimäki Naantali Paneliankoski Raahe Vörå Yli-Ii
Total	19	29	29	35

Table 2. Distribution of the Most Efficient DSOs in 2001-2004

Moreover, these maps illustrate the changes in each cluster over the examined period with more and more DSOs joining the efficient ones. This implies that there has been a considerable improvement in efficiency within the Finnish electricity distribution sector. Also, via these maps one can identify which particular DSO(s) improved their efficiency through cost-cutting (e.g., E.ON, Jyväskylä, Rovaniemi, Jakobstad, Kemi, etc.).

The maps also reflect the unstable performance of certain DSOs. For instance, Atro from cluster C (2002) and Kainuu from cluster D (2002 and 2003) respectively appear among the most efficient players, but only for these years.

Specifically, one can interpret and compare the best practices from cluster to cluster. The maps visualize the occurrences of most efficient DSOs for each cluster in a single year, as summarized in Table 3.

Cluster	**Occurrences of the Most Efficient DSOs**					**No. of Records** *2001-2004*	**Efficient Proportion**
	2001	*2002*	*2003*	*2004*	*Σ*		
A	1	2	2	2	7	8	87.5%
B	1	1	1	2	5	12	41.7%
C	1	2	2	2	7	12	58.3%
D	2	3	2	1	8	12	66.7%
E	2	2	2	2	8	16	50%
F	0	1	2	2	5	24	20.8%
G	3	4	5	7	19	86	22.1%
H	9	14	13	17	53	186	28.5%
Total	19	29	29	35	112	356	31.5%

Table 3. Occurrences of the Most Efficient DSOs in Each Cluster

When comparing the occurrences of the most efficient DSOs for each cluster over the years to their respective samples in each cluster, the calculation indicates that cluster A with 87.5% counts for the best performing cluster, followed by cluster D and cluster C with 66.7% and 58.3%, respectively. On the contrary, cluster F is the least efficient group with a ratio of 20.8%.

Furthermore, the calculation shows that the most efficient DSOs during 2001-2004 account for 31.5% as a whole. If we take this ratio as average performance across 2001-2004, it implies that the relative-small-city group (cluster F) and the rurally based group (clusters G & H) performed far below the average level, with 20.8%, 22.1%, and 28.5%, respectively. It is evidence that the suburb- and rural-characterized DSOs have big potential to close their efficiency gap towards the best performers.

When comparing the general performance between the urbanized clusters B, E, & F, one can conclude that the DSOs in the medium-sized municipalities in cluster E performed more efficiently than those in the metropolis area and much more than those in relatively small-sized cities, i.e., clusters B and F. To some extent, it provides indicators for the Finnish electricity regulator to leverage the operator-specific variations within the urban DSOs. This also raises questions of why the DSOs in relatively small-sized cities performed poorly and what can be done to close the gap.

4.4 Implications of the Results

Based on the experimental process and aforementioned discussion, several implications can be gained.

Firstly, we can assume that the trained maps represent and reflect the properties of the given data since one can draw regularities from the clustering. Due to the fact that the SOM technique itself does not provide measures for validating the clustering results (Wang and Wang 2002), the evaluation in this study is mainly expert-based – that is, the validation of the SOM-model result is via domain experts' empirical judgment (Järvinen 2004, pp. 98-114). To this end, it verified that the training method applied in this study is feasible.

Through cluster analysis, the characteristics of DSOs in a particular group can be discriminated. Not only are the similarities and differences between clusters visible, but the correlations between specific technical and financial measurements are also displayed. This implies the applicability of the SOM as a complementary analytical tool in electricity distribution benchmarking.

Secondly, when looking at the most efficient DSOs within the Finnish electricity distribution sector, the SOM-model provides additional information about the best performers (see Fig.4-7 and Table 2). Such additional information is what the DEA efficiency score is not able to offer. Even though these patterns are based on historical data, via visualization the SOM-model makes the changes and trends in terms of efficiency improvement in the Finnish context explicit. Furthermore, with respect to efficiency improvement and electricity distribution regulation, the SOM-model pinpoints the potential focus for particular companies and the regulatory authority. In short, these are added value in applying the SOM in electricity distribution benchmarking.

Due to the result that there are a great number of rural and small-sized DSOs concentrated in two clusters, it is also possible to perform further clustering based on the data derived from these two clusters. In other words, the SOM-model leads to a deeper knowledge of the specified domain than by using only the DEA-model.

On a related note, the SOM-model would in particular make regulatory sense in connection with the yardstick scheme [7]. In yardstick regulation the goal is to identify a reference performance for utilities comparable in terms of operating circumstances. The application of the SOM in the Finnish electricity distribution sector demonstrates its capability to identify the DSOs with similar operating circumstances. Therefore, yardstick regulation may benefit from the application of the SOM for clustering of DSOs.

5. CONCLUSION

Starting from the Finnish DEA-model, this study applied the SOM as a data mining tool in an attempt to extract hidden patterns from given data. The data investigated are derived from the EMA database for the period of 2001-2004. The variables inspected are in accordance with the DEA-model measurements. This makes the SOM-model comparable with the Finnish DEA-model.

The SOM benchmarking in this study differs from conventional benchmarking. On the one hand, it is from the perspective of exploratory data analysis, rather than that of regulation or competition. On the other hand, it is neither to work out the best practice frontier, nor to compete with the DEA-model. Instead, it is intended to discover implicit information and patterns via clustering and visualization. To this end, we can conclude that the SOM has the potential to act as a complementary approach in electricity distribution regulation and benchmarking. It would be beneficial to deepen the SOM application in this domain to a wider scope.

In conclusion, this study has fulfilled the initial objectives:

1) *to identify the characteristics of DSOs in clusters, in terms of the differences in operating circumstances*; 2) *to examine the relation and dependency between DSO clusters and the chosen indicators;*

With the proposed SOM-model, the resulting eight clusters reveal the distinct operating circumstances of the Finnish DSOs. Such clustering also indicates the respective characteristics of each group regarding the five DEA efficiency measurements, as shown in the feature planes and summarized in Figure 3. These are the insights which the SOM-model has offered.

3) *to identify any added value of using the SOM as a complementary tool.*

Through cluster analysis, the characteristics of the Finnish DSOs in a certain cluster, and the interrelations between clusters and amongst efficiency measurements can be easily interpreted from the trained maps. This information is visually presented in Figures 2 and 3. Information as such is difficult to extract from the DEA-model efficiency scores.

The study has shown that the SOM is feasible as a complementary approach in Finnish electricity distribution benchmarking. Through clustering and visual benchmarking, the

SOM-model not only presents the similarities and differences between the Finnish DSOs, but also illustrates the efficiency improvement of the Finnish electricity distribution sector over the examined years. Additionally, the SOM-model raises a number of potential focuses concerning the efficiency improvement for particular companies (e.g., most of the DSOs in Cluster F) and the regulatory authority. These are added value attained by applying the SOM in addition to the DEA-model in this domain.

FUTURE RESEARCH

From the results of this study, we can conclude that there are several topics for future research emerging from applying the SOM in the domain of electricity distribution benchmarking.

Firstly, the clustering results require further expert evaluation, which should be from both the regulatory authority and the industry itself, in order to validate the usefulness of the discovery and the applicability of the SOM.

Secondly, the established SOM-model in this experiment is entirely based on the DEA-model measurements. It does not take into account factors such as capital cost and investments. In fact, such factors have an important impact in connection with regulation, benchmarking, and business strategies. However, the currently implemented benchmarking methods are problematic when taking the capital cost or the investment into account. Therefore, it is necessary to include these factors in future research.

Thirdly, this study has focused on clustering analysis in terms of operating circumstances and benchmarking of the most efficient performers. In practice, it is also of interest to investigate the correlation between the efficiency score and specific efficiency measurement. For instance, the negative relationship between the Interruption Time and the efficiency score should be further investigated. Taking advantage of the visual properties of the SOM could be beneficial in examining such correlations.

Finally, this study has focused on the Finnish electricity distribution sector. The Finnish DSOs at large performed relatively efficiently. To some extent, it indicates that the observations are fairly homogeneous, which makes the data pre-processing process in this study relatively easily. Therefore, the applicability of the SOM in a highly heterogeneous energy market context needs further examination.

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ENDNOTES

1. See Joskow and Schmalensee (1986), Comnes et al. (1995), Hill (1995), Hall (2000), and Jamasb and Pollitt (2000) for further discussions about different incentive regulation models.
2. See Jamasb and Pollitt (2001), (2002); Korhonen and Syrjänen (2003); Honkapuro et al. (2004); Tahvanainen et al. (2004); Viljainen et al. (2004); Kinnunen (2005); Farsi et al. (2007) for thorough discussions about major electricity distribution benchmarking methods.
3. Two typical data transformation methods are logarithmic and sigmoid. The 'none' option refers to without applying any transformation.
4. Each variable is scaled by Variance if its range is smaller than 8 times the standard deviation (i.e. max(x) –min(x) < 8σ); otherwise, the scaling is by Range (Viscovery SOMine Manual).
5. Viscovery SOMine is capable of computing a suitable horizontal- vs. vertical- axis ratio based on the input data.
6. Fig. 4-7 are static illustrations of the SOM outcomes. The position of each company in Fig. 4-7 is approximate to respective original values. Some companies are overlapping due to their close proximity regarding the chosen variables. If examining the maps in Viscovery SOMine, the dynamic label mode will allow to discriminate the overlapping companies in real-time.
7. Sweden and Spain, for example, have applied the yardstick regulatory approach.

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APPENDIX I LIST OF FINNISH DSOs (2001-2004)

Year 2001:

Company ID	Company Name	Efficiency Score
134	Alajärven Sähkö Oy	0,778
661	Asikkalan Voima Oy	0,991
538	Ekenäs Energi	0,842
7	Enontekiön Sähkö Oy	0,620
511	Espoon Sähkö Oyj	0,730
98	Esse Elektro-Kraft Ab	1,000
292	Etelä-Savon Energia Oy	0,831
659	Etelä-Suomen Energia Oy	0,673
374	Forssan Energia Oy	0,741
733	Fortum Sähkönjakelu Oy *)	1,000
471	Haminan Energia Oy	0,910
45	Haukiputaan Sähköosuuskunta	1,000
403	Heinola Energia Oy	0,824
532	Helsingin Energia	1,000
78	Herrfors Oy Ab *)	0,606
92	Hiirikosken Energia Oy	0,911
371	Hämeenlinnan Energia Oy	0,619
43	Iin Energia Oy	0,542
418	Iitin Sähkö Oy	0,494
458	Imatran Seudun Sähkö Oy	0,588
6	Inergia Oy	0,636
77	Jakobstads Energiverk	0,485
80	Jeppo Kraft Andelslag	1,000
199	Joensuun Energia Oy	0,726
290	Joroisten Energialaitos	0,770
466	Joutsenon Energia Oy	0,598
107	Jylhän Sähköosuuskunta	0,811
165	Jyväskylän Energia Oy	0,804
657	Järvi-Suomen Energia Oy	1,000
74	Kainuun Sähkö Oyj	0,916
40	Kemin Energia Oy	0,928
28	Keminmaan Energia Oy	0,870
433	Keravan Energia Oy	0,732
168	Keski-Suomen Valo Oy	0,860
140	Keuruun Sähkö Oy	0,698
18	Koillis-Lapin Sähkö Oy	0,779
141	Koillis-Satakunnan Sähkö Oy	1,000
233	Kokemäen Sähkö Oy	0,681
75	Kokkolan energialaitos	0,832
108	Korpelan Voima Kuntayhtymä	0,832
473	Kotkan Energia Oy	0,780
567	Kouvolan Seudun Sähkö Oy	0,459
97	Kronoby Elverk	0,849
178	Kuopion Energia	0,781

To be continued

Company ID	Company Name	Efficiency Score
244	Kuoreveden Sähkö Oy	0,714
448	Kymenlaakson Sähköosakeyhtiö	1,000
317	Köyliön-Säkylän Sähkö Oy	0,843
413	Lahti Energia Oy *)	0,947
122	Laihian Sähkö Oy	0,793
229	Lammaisten Sähkö Oy	0,746
206	Lankosken Sähkö Oy	0,941
465	Lappeenrannan Energia *)	0,749
135	Lehtimäen Sähkö Oy	1,000
212	Leppäkosken Sähkö Oy	0,670
10	Muonion Sähköosuuskunta	0,891
427	Mäntsälän Sähkö Oy	0,640
330	Naantalin Energia Oy	0,866
399	Nurmijärven Sähkö Oy	0,699
79	Nykarleby Affärsverk	1,000
50	Oulun Energia	1,000
52	Oulun Seudun Sähkö Keskusosuuskunta	0,847
195	Outokummun Energia Oy	0,758
341	Oy Turku Energia - Åbo Energi Ab	0,677
231	Paneliankosken Voima Oy	1,000
307	Parikkalan Valo Oy	0,615
201	Pohjois-Karjalan Sähkö Oy *)	0,847
221	Pori Energia	0,604
436	Porvoon Energia Oy-Borgå Energi Ab *)	0,814
58	Raahen Energia Oy *)	1,000
41	Rantakairan Sähkö Oy	0,707
314	Rauman Energia Oy	0,623
61	Revon Sähkö Oy	0,884
36	Rovakaira Oy	1,000
34	Rovaniemen Energia	0,959
321	Sallilan Sähkölaitos Oy	0,690
190	Savon Voima Oyj	0,877
127	Seinäjoen Energia Oy	0,613
265	Tampereen Sähkölaitos	0,845
101	Tervolan kunnan sähkölaitos	1,000
24	Tornion kaupungin energialaitos	0,943
29	Tornionlaakson Sähkö Oy *)	1,000
1	Utsjoen Sähköosuuskunta	0,887
694	Uudenmaan Sähköverkko Oy *)	1,000
88	Vaasan Sähkö Oy	0,778
320	Vakka-Suomen Voima Oy	0,694
272	Valkeakosken Energia Oy	0,611
501	Vantaan Energia Oy	1,000
208	Vatajankosken Sähkö Oy	0,750
734	Vattenfall Siirto Oy *)	0,965
102	Vetelin Sähkölaitos Oy	0,586
106	Vimpelin Voima Oy	0,762
89	Vörå Elektricitetsverk Ab	0,778
42	Yli-Iin Sähkö Oy	1,000
152	Ääneseudun Energia Oy	0,769

Year 2002:

Company ID	Company Name	Efficiency Score
134	Alajärven Sähkö Oy	0,855
661	Asikkalan Voima Oy	0,833
190	Atro Oyj	1,000
538	Ekenäs Energi	0,932
7	Enontekiön Sähkö Oy	0,799
511	Espoon Sähkö Oyj	0,924
98	Esse Elektro-Kraft Ab	1,000
292	Etelä-Savon Energia Oy	0,895
659	Etelä-Suomen Energia Oy	0,699
374	Forssan Energia Oy	1,000
733	Fortum Sähkönsiirto Oy *)	1,000
74	Graninge Kainuu Oy	1,000
471	Haminan Energia Oy	0,888
45	Haukiputaan Sähköosuuskunta	1,000
532	Helsingin Energia	1,000
78	Herrfors Oy Ab *)	0,723
92	Hiirikosken Energia Oy	0,831
371	Hämeenlinnan Energia Oy	0,991
43	Iin Energia Oy	0,743
418	Iitin Sähkö Oy	0,620
458	Imatran Seudun Sähkö Oy	0,717
6	Inergia Oy	0,796
77	Jakobstads Energiverk	1,000
199	Joensuun Energia Oy	0,977
290	Joroisten Energialaitos	0,822
466	Joutsenon Energia Oy	0,618
107	Jylhän Sähköosuuskunta	0,793
165	Jyväskylän Energia Oy	0,954
657	Järvi-Suomen Energia Oy	1,000
40	Kemin Energia Oy	1,000
28	Keminmaan Energia Oy	1,000
433	Keravan Energia Oy	0,798
140	Keuruun Sähkö Oy	0,723
18	Koillis-Lapin Sähkö Oy	0,662
141	Koillis-Satakunnan Sähkö Oy	1,000
233	Kokemäen Sähkö Oy	0,716
75	Kokkolan energialaitos	0,638
108	Korpelan Voima Kuntayhtymä	0,818
473	Kotkan Energia Oy	0,877
567	Kouvolan Seudun Sähkö Oy	0,704
97	Kronoby Elverk	0,878
178	Kuopion Energia	1,000
244	Kuoreveden Sähkö Oy	0,669
448	Kymenlaakson Sähköosakeyhtiö	1,000
317	Köyliön-Säkylän Sähkö Oy	0,980
413	Lahti Energia Oy *)	0,816
122	Laihian Sähkö Oy	0,815
	To be continued	

Company ID	Company Name	Efficiency Score
229	Lammaisten Sähkö Oy	0,589
206	Lankosken Sähkö Oy	1,000
465	Lappeenrannan Energia Oy *)	0,734
135	Lehtimäen Sähkö Oy	1,000
212	Leppäkosken Sähkö Oy	0,855
10	Muonion Sähköosuuskunta	0,916
427	Mäntsälän Sähkö Oy	0,824
330	Naantalin Energia Oy	0,948
399	Nurmijärven Sähkö Oy	0,863
79	Nykarleby Affärsverk	0,939
50	Oulun Energia	1,000
52	Oulun Seudun Sähkö Keskusosuuskunta	0,807
195	Outokummun Energia Oy	0,937
341	Oy Turku Energia - Åbo Energi Ab	0,718
231	Paneliankosken Voima Oy	1,000
307	Parikkalan Valo Oy	0,742
201	Pohjois-Karjalan Sähkö Oy *)	0,904
221	Pori Energia	0,687
436	Porvoon Energia Oy-Borgå Energi Ab *)	0,804
58	Raahen Energia Oy	1,000
41	Rantakairan Sähkö Oy	0,948
314	Rauman Energia Oy	0,655
36	Rovakaira Oy	1,000
34	Rovaniemen Energia	1,000
321	Sallilan Sähkölaitos Oy	0,818
127	Seinäjoen Energia Oy	0,661
265	Tampereen Sähkölaitos	0,854
101	Tenergia Oy	1,000
24	Tornion kaupungin energialaitos	0,829
29	Tornionlaakson Sähkö Oy *)	1,000
1	Utsjoen Sähköosuuskunta	0,977
694	Uudenmaan Sähköverkko Oy *)	1,000
88	Vaasan Sähkö Oy	0,852
320	Vakka-Suomen Voima Oy	0,763
272	Valkeakosken Energia Oy	0,667
501	Vantaan Energia Oy	1,000
208	Vatajankosken Sähkö Oy	0,743
734	Vattenfall Verkko Oy *)	1,000
102	Vetelin Sähkölaitos Oy	1,000
106	Vimpelin Voima Oy	0,791
89	Vörå Elektricitetsverk Ab	1,000
42	Yli-Iin Sähkö Oy	1,000
152	Ääneseudun Energia Oy	0,726

Year 2003:

Company ID	Company Name	Efficiency Score
134	Alajärven Sähkö Oy	0,850
661	Asikkalan Voima Oy	0,780
190	Atro Oyj	0,980
538	Ekenäs Energi	0,940
7	Enontekiön Sähkö Oy	0,890
511	E.ON Finland Oyj *)	0,940
98	Esse Elektro-Kraft Ab	1,000
292	Etelä-Savon Energia Oy	0,970
659	Etelä-Suomen Energia Oy	0,790
374	Forssan Energia Oy	0,990
733	Fortum Sähkönsiirto Oy*)	1,000
74	Graninge Kainuu Oy	1,000
471	Haminan Energia Oy	0,770
45	Haukiputaan Sähköosuuskunta	1,000
532	Helsingin Energia	1,000
78	Herrfors Oy Ab*)	0,690
92	Hiirikosken Energia Oy	0,730
43	Iin Energia Oy	0,820
418	Iitin Sähkö Oy	0,690
458	Imatran Seudun Sähkö Oy	0,720
6	Inergia Oy	0,810
77	Jakobstads Energiverk	1,000
290	Joroisten Energialaitos	0,770
466	Joutsenon Energia Oy	0,840
107	Jylhän Sähköosuuskunta	0,830
165	Jyväskylän Energia Oy	1,000
657	Järvi-Suomen Energia Oy	1,000
40	Kemin Energia Oy	1,000
28	Keminmaan Energia Oy	1,000
433	Keravan Energia Oy	0,740
140	Keuruun Sähkö Oy	0,700
18	Koillis-Lapin Sähkö Oy	0,690
141	Koillis-Satakunnan Sähkö Oy	1,000
233	Kokemäen Sähkö Oy	0,910
75	Kokkolan Energia	0,860
108	Korpelan Voima Kuntayhtymä	0,940
567	KSS Energia Oy	0,790
97	Kronoby Elverk	1,000
178	Kuopion Energia	1,000
244	Kuoreveden Sähkö Oy	0,990
448	Kymenlaakson Sähkö Oy *)	1,000
317	Köyliön-Säkylän Sähkö Oy	0,850
413	Lahti Energia Oy*)	0,910
122	Laihian Sähkö Oy	0,830
229	Lammaisten Sähkö Oy	0,650

To be continued

Company ID	Company Name	Efficiency Score
206	Lankosken Sähkö Oy	1,000
465	Lappeenrannan Energia Oy*)	0,740
135	Lehtimäen Sähkö Oy	1,000
212	Leppäkosken Sähkö Oy	0,880
10	Muonion Sähköosuuskunta	0,700
427	Mäntsälän Sähkö Oy	0,720
330	Naantalin Energia Oy	0,900
399	Nurmijärven Sähkö Oy	0,910
79	Nykarleby Affärsverk	0,910
50	Oulun Energia	1,000
52	Oulun Seudun Sähkö Keskusosuuskunta	1,000
195	Outokummun Energia Oy	0,900
341	Oy Turku Energia - Åbo Energi Ab	0,840
231	Paneliankosken Voima Oy	1,000
307	Parikkalan Valo Oy	0,760
201	Pohjois-Karjalan Sähkö Oy*)	1,000
221	Pori Energia	0,830
436	Porvoon Energia Oy-Borgå Energi Ab*)	0,800
58	Raahen Energia Oy	1,000
41	Rantakairan Sähkö Oy	0,970
314	Rauman Energia Oy	0,820
36	Rovakaira Oy	1,000
34	Rovaniemen Energia*)	1,000
321	Sallilan Energia Oy	0,910
127	Seinäjoen Energia Oy	0,740
265	Tampereen Sähkölaitos	0,830
101	Tenergia Oy	1,000
24	Tornion Energia Oy	0,770
29	Tornionlaakson Sähkö Oy *)	1,000
1	Utsjoen Sähköosuuskunta	0,940
88	Vaasan Sähkö Oy	0,900
320	Vakka-Suomen Voima Oy	0,870
272	Valkeakosken Energia Oy	0,770
501	Vantaan Energia Oy	1,000
208	Vatajankosken Sähkö Oy	0,780
734	Vattenfall Verkko Oy *)	1,000
102	Vetelin Sähkölaitos Oy	0,910
106	Vimpelin Voima Oy	0,820
89	Vörå Elektricitetsverk Ab	1,000
42	Yli-Iin Sähkö Oy	1,000
152	Ääneseudun Energia Oy	0,880

Year 2004:

Company ID	Company Name	Efficiency Score
134	Alajärven Sähkö Oy	1,000
661	Asikkalan Voima Oy	0,870
190	Atro Oyj	0,880
511	E.ON Finland Oyj*	1,000
538	Ekenäs Energi	0,840
7	Enontekiön Sähkö Oy	1,000
759	ESE-Verkko Oy	0,960
98	Esse Elektro-Kraft Ab	1,000
659	Etelä-Suomen Energia Oy	0,570
374	Forssan Energia Oy	1,000
733	Fortum Sähkönsiirto Oy*	1,000
471	Haminan Energia Oy	0,860
45	Haukiputaan Sähköosuuskunta	1,000
532	Helsingin Energia	1,000
78	Herrfors Oy Ab*	0,830
92	Hiirikosken Energia Oy	0,830
43	Iin Energia Oy	0,900
418	Iitin Sähkö Oy	0,720
458	Imatran Seudun Sähkö Oy	0,690
6	Inergia Oy	0,770
77	Jakobstads Energiverk	1,000
290	Joroisten Energialaitos	0,820
466	Joutsenon Energia Oy	0,780
107	Jylhän Sähköosuuskunta	0,970
165	Jyväskylän Energia Oy	1,000
657	Järvi-Suomen Energia Oy	1,000
74	Kainuun Energia Oy	0,890
40	Kemin Energia Oy	0,870
28	Keminmaan Energia Oy	1,000
433	Keravan Energia Oy	0,760
140	Keuruun Sähkö Oy	0,800
18	Koillis-Lapin Sähkö Oy	0,650
141	Koillis-Satakunnan Sähkö Oy	1,000
233	Kokemäen Sähkö Oy	0,810
75	Kokkolan Energia	1,000
108	Korpelan Voima Kuntayhtymä	0,910
97	Kronoby Elverk	1,000
567	KSS Energia Oy	0,740
178	Kuopion Energia	1,000
244	Kuoreveden Sähkö Oy	1,000
448	Kymenlaakson Sähkö Oy*	1,000
317	Köyliön-Säkylän Sähkö Oy	0,840
413	Lahti Energia Oy	0,940
122	Laihian Sähkö Oy	0,880
229	Lammaisten Energia Oy	0,710

To be continued

Company ID	Company Name	Efficiency Score
206	Lankosken Sähkö Oy	1,000
465	Lappeenrannan Energia Oy	0,700
135	Lehtimäen Sähkö Oy	1,000
212	Leppäkosken Sähkö Oy	0,870
10	Muonion Sähköosuuskunta	0,790
427	Mäntsälän Sähkö Oy	0,780
330	Naantalin Energia Oy	1,000
399	Nurmijärven Sähkö Oy	0,870
79	Nykarleby Affärsverk	0,790
50	Oulun Energia	1,000
52	Oulun Seudun Sähkö Keskusosuuskunta	1,000
195	Outokummun Energia Oy	0,900
341	Oy Turku Energia - Åbo Energi Ab	0,970
231	Paneliankosken Voima Oy	1,000
307	Parikkalan Valo Oy	0,740
201	Pohjois-Karjalan Sähkö Oy	1,000
221	Pori Energia	0,900
436	Porvoon Energia Oy - Borgå Energi Ab*	0,880
58	Raahen Energia Oy	1,000
41	Rantakairan Sähkö Oy	1,000
314	Rauman Energia Oy	0,790
36	Rovakaira Oy	1,000
34	Rovaniemen Energia Oy	1,000
321	Sallila Energia Oy	0,880
127	Seinäjoen Energia Oy	0,720
774	Tampereen Sähköverkko Oy	0,870
101	Tenergia Oy	0,870
24	Tornion Energia Oy	0,770
29	Tornionlaakson Sähkö Oy*	1,000
1	Utsjoen Sähköosuuskunta	0,910
88	Vaasan Sähkö Oy	0,980
320	Vakka-Suomen Voima Oy	1,000
272	Valkeakosken Energia Oy	0,620
501	Vantaan Energia Oy	1,000
208	Vatajankosken Sähkö Oy	0,820
734	Vattenfall Verkko Oy*	1,000
102	Vetelin Sähkölaitos Oy	0,790
106	Vimpelin Voima Oy	0,800
89	Vörå Elektricitetsverk Ab	1,000
42	Yli-Iin Sähkö Oy	1,000
152	Ääneseudun Energia Oy	0,730

Note: *) and * denote that there is merge or acquisition.

APPENDIX II LIST OF THE MOST EFFICIENT FINNISH DSOs (2001-2004)

Company ID	Company Name
	Year 2001
98	Esse Elektro-Kraft Ab
733	Fortum Sähkönjakelu Oy *)
45	Haukiputaan Sähköosuuskunta
532	Helsingin Energia
80	Jeppo Kraft Andelslag
657	Järvi-Suomen Energia Oy
141	Koillis-Satakunnan Sähkö Oy
448	Kymenlaakson Sähköosakeyhtiö
135	Lehtimäen Sähkö Oy
79	Nykarleby Affärsverk
50	Oulun Energia
231	Paneliankosken Voima Oy
58	Raahen Energia Oy *)
36	Rovakaira Oy
101	Tervolan kunnan sähkölaitos
29	Tornionlaakson Sähkö Oy *)
694	Uudenmaan Sähköverkko Oy *)
501	Vantaan Energia Oy
42	Yli-Iin Sähkö Oy
	Year 2002
190	Atro Oyj
98	Esse Elektro-Kraft Ab
374	Forssan Energia Oy
733	Fortum Sähkönsiirto Oy *)
74	Graninge Kainuu Oy
45	Haukiputaan Sähköosuuskunta
532	Helsingin Energia
77	Jakobstads Energiverk
657	Järvi-Suomen Energia Oy
40	Kemin Energia Oy
28	Keminmaan Energia Oy
141	Koillis-Satakunnan Sähkö Oy
178	Kuopion Energia
448	Kymenlaakson Sähköosakeyhtiö
206	Lankosken Sähkö Oy

To be continued

Company ID	Company Name
135	Lehtimäen Sähkö Oy
50	Oulun Energia
231	Paneliankosken Voima Oy
58	Raahen Energia Oy
36	Rovakaira Oy
34	Rovaniemen Energia
101	Tenergia Oy
29	Tornionlaakson Sähkö Oy *)
694	Uudenmaan Sähköverkko Oy *)
501	Vantaan Energia Oy
734	Vattenfall Verkko Oy *)
102	Vetelin Sähkölaitos Oy
89	Vörå Elektricitetsverk Ab
42	Yli-Iin Sähkö Oy
	Year 2003
98	Esse Elektro-Kraft Ab
733	Fortum Sähkönsiirto Oy*)
74	Graninge Kainuu Oy
45	Haukiputaan Sähköosuuskunta
532	Helsingin Energia
77	Jakobstads Energiverk
165	Jyväskylän Energia Oy
657	Järvi-Suomen Energia Oy
40	Kemin Energia Oy
28	Keminmaan Energia Oy
141	Koillis-Satakunnan Sähkö Oy
97	Kronoby Elverk
178	Kuopion Energia
448	Kymenlaakson Sähkö Oy *)
206	Lankosken Sähkö Oy
135	Lehtimäen Sähkö Oy
50	Oulun Energia
52	Oulun Seudun Sähkö Keskusosuuskunta
231	Paneliankosken Voima Oy
201	Pohjois-Karjalan Sähkö Oy*)
58	Raahen Energia Oy
36	Rovakaira Oy
34	Rovaniemen Energia*)
101	Tenergia Oy
29	Tornionlaakson Sähkö Oy *)
501	Vantaan Energia Oy

To be continued

Company ID	Company Name
734	Vattenfall Verkko Oy *)
89	Vörå Elektricitetsverk Ab
42	Yli-Iin Sähkö Oy
	Year 2004
134	Alajärven Sähkö Oy
511	E.ON Finland Oyj*
7	Enontekiön Sähkö Oy
98	Esse Elektro-Kraft Ab
374	Forssan Energia Oy
733	Fortum Sähkönsiirto Oy*
45	Haukiputaan Sähköosuuskunta
532	Helsingin Energia
77	Jakobstads Energiverk
165	Jyväskylän Energia Oy
657	Järvi-Suomen Energia Oy
28	Keminmaan Energia Oy
141	Koillis-Satakunnan Sähkö Oy
75	Kokkolan Energia
97	Kronoby Elverk
178	Kuopion Energia
244	Kuoreveden Sähkö Oy
448	Kymenlaakson Sähkö Oy*
206	Lankosken Sähkö Oy
135	Lehtimäen Sähkö Oy
330	Naantalin Energia Oy
50	Oulun Energia
52	Oulun Seudun Sähkö Keskusosuuskunta
231	Paneliankosken Voima Oy
201	Pohjois-Karjalan Sähkö Oy
58	Raahen Energia Oy
41	Rantakairan Sähkö Oy
36	Rovakaira Oy
34	Rovaniemen Energia Oy
29	Tornionlaakson Sähkö Oy*
320	Vakka-Suomen Voima Oy
501	Vantaan Energia Oy
734	Vattenfall Verkko Oy*
89	Vörå Elektricitetsverk Ab
42	Yli-Iin Sähkö Oy

Note: *) and * denote that there is merge or acquisition.

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