Benchmarking of security of supply in the Danish water sector

June 2022

Konkurrence- og Forbrugerstyrelsen

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Chapter 1 **Summary**

1.1 Introduction and key messages

Water companies are monopolists and their focus on efficient operations is therefore supported by economic regulation aimed at protecting consumers and undertakings from unnecessarily high water prices. Analyses show that economic regulation has led to significantly lower water prices to the benefit of households and undertakings.

Today, water companies' security of supply is supported by environmental regulation and, to a certain extent, by the general regulation of the water companies, e.g. green taxes. There are no indications that security of supply and water quality have been adversely affected by the current economic regulation.

This means that Denmark has water companies that generally provide good security of supply in the form of stable supply and high quality. To strengthen the security of supply in the water and waste water sector further by means of new economic incentives, a broad political majority decided in 2018 that security of supply is to be integrated in the future economic regulation of water companies.[1]

Against this background, the purpose of this analysis is to examine how security of supply can be integrated more directly in economic benchmarking, which is an important regulatory tool. The analysis also describes advantages and disadvantages of different methods for integration of security of supply in the benchmarking.

The conclusion is that it is possible to integrate security of supply in the economic benchmarking of the companies, and that this may have a positive effect on the security of supply in the water and waste water sector in Denmark.

Although no evidence has been found so far that regulation and benchmarking have had unintended effects on water quality, there may be benefits from such integration. This may provide an economic incentive for the water companies to maintain a high level or achieve an even higher level of security of supply in the future. In addition, it can strengthen the benchmarking model and thus contribute to more accurate efficiency requirements in the future, because security of supply costs can be taken into account to a greater extent than today.

[1] The political agreement from 2018: www.kfst.dk/media/54111/justeret-oekonomisk-regulering-af-vandsektoren-22112018.pdf (in Danish)

1.2 Background

Water companies are natural monopolists and are therefore not exposed to competition. Experience shows that this results in insufficient focus on efficient operations. Therefore, the water companies are subject to economic regulation, which contributes to ensuring that their costs and prices are not higher than necessary.[2]

In practice, the regulation takes the form of efficiency requirements for the water companies. To meet these requirements, they must, for example, keep up with the development in productivity and thus reduce their costs and prices on an ongoing basis in the same way as undertakings that face free competition. The efficiency requirements are implemented through reductions in the water companies' revenue caps. The revenue caps indicate the revenues that the water companies may generate through the price that households and undertakings pay for drinking water, climate adaptation and waste water discharges.

Parts of the efficiency requirement are determined on the basis of economic benchmarking of the companies' costs. Benchmarking is used to make an overall assessment of whether some companies have higher costs than other similar companies.

Benchmarking constitutes an essential element in the regulation of natural monopolies. If benchmarking is not done, it will, in effect, be very difficult for a regulator to assess whether there is a balance between the tasks of each individual company and its costs. Benchmarking is thus a systematised method that makes it possible to assess whether some companies have excessively high costs relative to the tasks they perform. Therefore, benchmarking is a widespread and recognised method among regulators in Denmark and a number of other countries.

However, the current economic benchmarking of the companies does not fully take into account the security of supply level in the different companies. This poses a risk that companies that incur costs for achieving a high security of supply appear as having 'too high' costs (being economically inefficient) relative to companies that do not have as high security of supply. This means that, in principle, the current benchmarking may make it less attractive for the companies to incur costs to improve their security of supply. However, analyses show that water quality and security of supply have not been negatively affected by the economic regulation and benchmarking so far.[3] So, even though, in principle, there is reason to be concerned that economic regulation puts companies with high security of supply in a relatively poor situation, there is no evidence that this has actually been the case.

Nevertheless, there may be good arguments for including security of supply in the future benchmarking. Firstly, this may provide an incentive for even higher security of supply. Secondly, it can result in truer and fairer benchmarking of the companies, which, in the final analysis, will lead to more accurate efficiency requirements for the various companies.

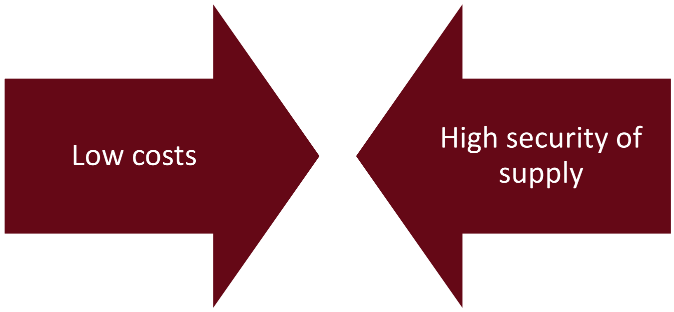
1.3 Low costs versus high security of supply

It is reasonable to assume that the water companies' customers – households and undertakings – want both low costs in the companies because this leads to lower water prices and a high degree of security of supply. It is therefore completely natural if the regulation contains a

[2] The Danish Competition and Consumer Authority (2022 A)
[3] The Danish Competition and Consumer Authority (2021 A) and The Danish Competition and Consumer Authority (2020 B)

weighing of the consideration for low costs against the consideration for high security of supply. If it is inexpensive to achieve a significant increase in security of supply, it will probably be advantageous. Conversely, there may also be investments in increased security of supply where the cost is not commensurate with the expected gain for consumers from the improvement in security of supply.

The economic regulation and thus also the method for including security of supply in benchmarking of the companies must continuously ensure a reasonable weighing between these two considerations. The fundamental challenge of integrating security of supply in the economic benchmarking of companies is to determine methods that involve an expedient weighting between low costs and high security of supply.



A good method for inclusion of security of supply must ensure an appropriate incentive for improving security of supply. At the same time, it must provide a true and fair assessment of the companies' efficiency, so that efficiency requirements for the companies are made as accurate as possible.

In addition, there are also other considerations involved in choosing a benchmarking method. The method must not be unnecessarily complex and nontransparent. The method applied must also be robust so that it can be used to include different security of supply indicators to ensure that the calculation can actually be done in practice.

The analysis compares different approaches to inclusion of security of supply in the current benchmarking. The assessment of the methods includes the following criteria:

» Appropriate incentive for security of supply
» True and fair assessment of the companies' efficiency
» Complexity and transparency
» Suitability for handling security of supply parameters

1.4 Advantages and disadvantages of different benchmarking methods

A comparison has been made of four different methods for including security of supply parameters, see Figure 1.1.

Overall, the first method (socio-economic cost) is assessed to be the method that best ensures a socio-economically optimal weighing between considerations for low costs and considerations for high security of supply. The method is also simple to apply. Furthermore, the method is already used in practice in the regulation of electricity grid companies in Norway. Conversely, this method can only be applied to those types of security of supply for which there are fairly accurate key figures for the socio-economic cost of failure in the type of security of supply in question.

The last method (security of supply as independent parameters) is also relatively simple to use. Conversely, there is nothing in this method that ensures a reasonable weighing between the consideration for low costs and the consideration for high security of supply. If this method is used, there is a risk that benchmarking either does not provide an incentive for the companies to improve their security of supply or does not provide an incentive for the companies to reduce their costs. This reflects the risk of corner solutions in benchmarking models with multiple independent output measures.

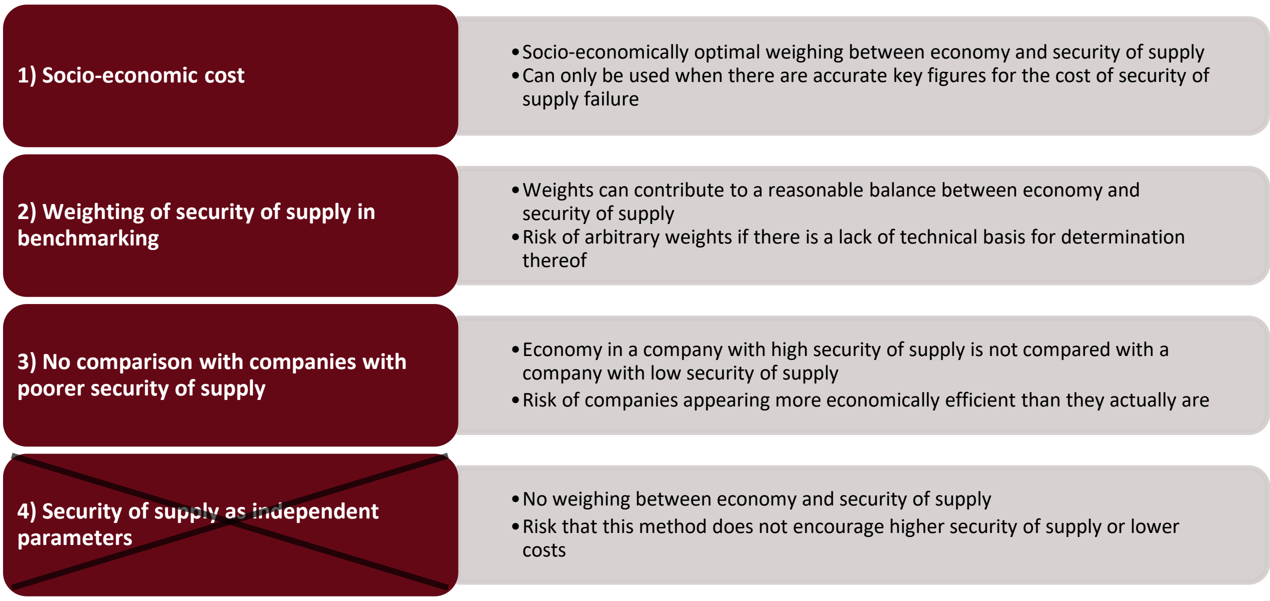
Therefore, it is *not* recommended to use the method of security of supply as independent parameters.

The second and third methods in Figure 1.1 are both more complicated to use than the first model with socio-economic costs, but overall they are assessed as useful methods for including security of supply in the benchmarking. In relation to the first method, these two methods can be used when there are no credible key figures for the socio-economic cost of security of supply failures. However, the methods may risk giving too positive an assessment of the companies' efficiency, although the risk thereof may be limited to a certain extent.

In addition to this, there are various advantages and disadvantages of the second and third method, which make it difficult to establish unequivocally whether one of the two methods is generally preferable to the other. Which of these two models works best in practice may also depend on data.

The four methods are briefly described below.

Figure 1.1 **Four methods for inclusion of security of supply in benchmarking**



Note: We recommend that model 4 should not be used to include security of supply in the benchmarking.

Source: Own production

Method 1: Socio-economic cost
This method takes into account the socio-economic cost of a lack of security of supply on an equal footing with the companies' ordinary costs. This entails that the benchmarking can be seen more as a broader socio-economic benchmarking of the companies rather than as a more narrow business economic benchmarking.[4]

This means that, through this benchmarking method, the companies are given an equally large incentive to reduce their own costs and to reduce the costs for consumers of security of supply failures. This consequently involves a socio-economically optimal weighing of considerations for low costs in the companies and for avoiding security of supply failures.

This benchmarking method is also the natural method to use if a system of economic sanctions and rewards is concurrently introduced for the water companies depending on whether the companies have a good or a less good security of supply level, see the political agreement from 2018. Overall, this will provide a consistent regulation, ensuring a coherent and uniform incentive structure for the companies through sanctions/rewards and in the benchmarking. The benchmarking thus provides a true and fair assessment of the efficiency of the companies given the scope of sanctions and rewards, see (Konkurrence- og Forbrugerstyrelsen, 2021 D).

This form of regulation and associated benchmarking has been implemented in the regulation of electricity grid companies in Norway with good results.

In relation to applying the model to regulation of water companies, it may, however, be a challenge that there are more different parameters for security of supply for water and waste water companies than there are for electricity grid companies.

In order to use the method, it is necessary to have fairly accurate key figures for the socio-economic cost of security of supply failures. There are currently no key figures for the socio-economic cost linked to all parameters for security of supply, and, for some security of supply parameters, it may be difficult to calculate related key figures for the socio-economic cost. For some security of supply dimensions, there may also be uncertainty connected with the calculation of the cost of security of supply failures.

This method is technically assessed to be the best method if there are fairly accurate key figures for the socio-economic cost of security of supply failures.

Method 2: Weighting of security of supply in benchmarking
This model uses so-called weight restrictions to ensure that the benchmarking entails a reasonable weighing of considerations for low costs and high security of supply.

As mentioned, the method, where parameters for security of supply are independent parameters, is not suitable because it entails a risk of corner solutions. In case of corner solutions, the benchmarking will not provide an encouragement to reduce costs or improve security of supply. The use of weight restrictions in the benchmarking model can be seen as a way to reduce the risk of corner solutions, so that there is a greater incentive to both reduce costs and increase security of supply.

[4] In addition to including the costs of security of supply failures, socio-economic benchmarking can also incorporate other external costs for the companies, such as the costs of their environmental impact.

The model with weight restrictions entails two challenges. One challenge is that the model is relatively complex. This may make the results less transparent and it will thus be more difficult for some companies to align their decision-making behaviour with the incentive in this benchmarking method. The second challenge is to find a technical basis for setting the weight restrictions. One option is to use key figures for the socio-economic cost of a lack of security of supply as a starting point when such figures are available (which is not always the case). Another option is to use as a basis estimate of how expensive it is for the companies to improve their security of supply.

Overall, the method may be relevant to use if there are significant security of supply parameters that are necessary to include in the economic benchmarking, but where there are no accurate key figures for the socio-economic cost of security of supply failures.

Method 3: No comparison with companies with poorer security of supply
The idea behind this method is basically that the costs in companies with good security of supply are not compared with the costs in companies with poor security of supply. The rationale for this is that a high security of supply level requires higher costs.

One challenge is that the method does not necessarily ensure a fair weighing between low costs and security of supply. Another challenge is that some companies will have to be compared with relatively few other companies. This entails a risk that some companies may unjustifiably appear to be efficient, so that they incorrectly appear to have low costs given their security of supply level. [5] The challenge increases with the number of different security of supply indicators, which may vary across the companies. This challenge can be partially addressed by easing the requirement that a company's costs must not be compared with those of other companies that, for example, have a slightly lower security of supply (to ensure that there are enough companies with which to make a comparison).

Overall, the method may be relevant to use if there are significant security of supply parameters that are necessary to include in the economic benchmarking, but where there are no fairly accurate key figures for the socio-economic cost of security of supply failures.

Method 4: Security of supply as independent output parameters
Finally, security of supply parameters can be included as independent output parameters in the benchmarking. As mentioned, this method entails a risk of corner solutions. In case of corner solutions, the benchmarking will not provide an encouragement to reduce costs or improve security of supply. There is consequently a risk that there will not be an expedient weighing between the consideration for low costs and the consideration for high security of supply. This reflects that some companies may appear as efficient simply because they have a high security of supply – regardless of whether they have high or low costs. Correspondingly, some companies may appear as efficient because they have low costs – irrespective of whether they have high or low security of supply.

[5] As a simplified example, assume that there is one water company that has higher security of supply than all other companies. The costs of this company therefore cannot be compared with those of other companies, as this would violate the principle of not making a comparison with costs in companies with poorer security of supply. Therefore, it is inherent in the method that one has to assume that the company with the highest security of supply operates efficiently, regardless of how high the costs are in the company in question. It should be noted that this is an illustrative example. In practice, there may be several companies that all have an equally high security of supply level. In any case, however, the method entails that some companies' costs are compared with relatively few companies. This will clearly entail the risk of some companies incorrectly appearing as efficient when, in reality, they have too high costs.

Such a model therefore does not ensure an expedient weighing between low costs and high security of supply and therefore cannot be recommended.

Some of the methods are combinable
As mentioned, the first method (socio-economic cost) can be used when there are key figures for the loss for consumers due to security of supply failures. The first method is combinable with one of the other methods in the same benchmarking model, making it possible to include security of supply measures both with and without key figures for the loss for consumers.

As the first method is assessed to be the one that best ensures a socio-economically optimal weighing between considerations for low costs and considerations for high security of supply, it is expedient that this is the method used to the greatest possible extent.

Technically, it is therefore recommended that work be continued with extension and validation of key figures for the socio-economic costs of security of supply failures, so that more accurate key figures are built up in this area. Furthermore, it may be expedient to improve the data quality for some security of supply parameters.

1.5 Methodology and correlation with previous analyses

The analysis in this report is based on a review of relevant parts of the benchmarking literature, own theoretical contributions and testing of the four different methods based on security of supply data and costs for the water companies. Against this background, theoretical and empirical opportunities and challenges of the different methods are reviewed.

The analysis is based on the models currently used for benchmarking of the water companies (Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA)). The methods described can also be used for waste water companies. For the waste water companies, the same opportunities and challenges generally apply as to the water companies.

This report should be seen as a non-technical and brief summary presentation of the opportunities and challenges of including security of supply in the benchmarking of the companies. A more technical presentation is available in a number of background analyses, articles, etc.[6]

This report on benchmarking and security of supply should also be seen in close correlation with two previous analysis reports on security of supply in the water sector. One of these reports presents models for how water companies can be given new economic incentives to maintain or increase their security of supply in the form of sanctions and rewards, which are known from other countries with positive effects on the security of supply. The report in question also describes how benchmarking with socio-economic costs (method 1) interacts with direct economic incentives for security of supply in the form of rewards and sanctions, see The Danish Competition and Consumer Authority (2021 D). The conclusion drawn in the report is that to achieve a consistent regulation, *both* sanctions/rewards should be used depending on the companies' level of security of supply *and* the socio-economic costs of a lack of security of supply should be included in the benchmarking of the companies. In this way, the consumers' cost of security of supply failures is considered on a completely equal footing with the companies' ordinary costs.

[6] The background analyses and articles are gathered here: https://www.kfst.dk/vandtilsyn/analyser/forsyningssikkerhed-okonomisk-regulering-og-benchmarking/

Finally, a previous analysis has calculated consumers' willingness to pay to achieve higher security of supply in the water sector, see The Danish Competition and Consumer Authority (2020 A). The analysis shows key figures for the loss incurred by consumers in the event of failures in some security of supply parameters. Such key figures are a prerequisite for being able to introduce both the benchmarking method with socio-economic costs and the proposed model for sanctions and rewards.

Chapter 2
Background and purpose

2.1 Background and purpose

Water and waste water companies are natural monopolists and are thus not exposed to competition. The water companies are therefore subject to economic regulation, the aim of which is to support that the companies' costs and prices are not higher than necessary.

The economic regulation consists in setting revenue caps that specify how much revenue the water companies may generate in charges from their customers. In this connection, the water companies are also subject to requirements that, like undertakings that are exposed to competition, they must improve their efficiency and productivity on an ongoing basis. In addition, extra requirements are made for companies that, based on economic benchmarking models, have higher costs than other companies of the same type, i.e. when differences in the companies' framework conditions (for example population density) have been taken into consideration.

Today, we have an economic regulation that has led to lower water prices (Konkurrence- og Forbrugerstyrelsen, 2022 A). The economic regulation of the companies focuses on efficient operations. However, economic regulation does not in itself provide a direct economic encouragement to ensure high security of supply. Instead, this is ensured through environmental regulation and, to a certain extent, by the general regulation of the water companies. We can show that, so far, economic regulation has not resulted in a lower security of supply in the water sector (Bjørner, Hansen, & Jakobsen, 2021).

Danish water companies generally provide a good security of supply in the form of stable supply and high quality. Today, economic regulation also interacts with a large number of other regulatory measures aimed at ensuring security of supply, where significant dimensions of security of supply are already subject to various rules and requirements, including green taxes, quotas, etc., through environmental regulation in the water sector.

To strengthen the economic incentives for security of supply also in the longer term, it was stated in the political agreement on adjusted economic regulation of the water sector from 2018 that "*security of supply and consumer satisfaction must be integrated into the future economic regulation. The Danish Water Regulatory Authority will therefore be able to make measurable and objective requirements for security of supply and for consumer satisfaction in the long-term economic regulation. The companies must therefore be rewarded or sanctioned according to whether they meet the targets set. This ensures that the companies provide both high service and quality while also meeting the ongoing requirements for efficiency improvement that ensure lower prices for consumers.*"

The purpose of this analysis is to highlight how it is possible to integrate security of supply in the economic benchmarking model. The benchmarking model is used in the economic regulation to encourage the water companies to become as efficient as the best operators in the sector. It is therefore obvious to identify how it is possible to prepare a benchmarking model that integrates security of supply to a greater extent than today and thereby encourages the companies to ensure a continued high level of security of supply combined with the continuing encouragement of efficient operations. We present specific proposals for security of supply and discuss the advantages and disadvantages of integrating them.

The Danish Ministry of Environment is responsible for defining security of supply in the water and waste water sector. The analysis is thus based on these definitions,[7] and security of supply data comes from the Danish Environmental Protection Agency's performance benchmarking.

2.2 Methodology and delimitations

The analysis work is based on the current economic benchmarking model, which has contributed to improving the economic efficiency of the water companies for a number of years. In the analysis, we map the theoretical opportunities and challenges of incorporating quality parameters in the economic benchmarking model.

Security of supply and economic benchmarking
It is theoretically possible to integrate non-economic parameters such as security of supply dimensions in an economic benchmarking model, and such integration may have positive effects. If security of supply is integrated in a transparent and true and fair manner, the integration can strengthen the incentive for water companies to provide high security of supply while also maintaining the necessary incentive for efficient operations.

The companies' different framework conditions are taken into account in the current benchmarking models through the use of statistical and mathematical tools. However, it is not taken into direct account that the companies provide different security of supply levels. This may be problematic if it is actually more expensive to provide a high security of supply in the supply area in question. However, the companies have other reasons for pursuing a high security of supply level than economic reasons, for example a good reputation, environmental regulatory requirements or municipal policy wishes. Furthermore, as mentioned, no empirical evidence has been found so far that regulation has weakened security of supply.

For a more technical and further theoretical basis for the analysis, see the background material on our website.[8] Here, we also review the two specific benchmarking theories, Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), on which the current benchmarking models are based.

Security of supply data
The opportunities for addressing security of supply in the benchmarking are greatly dependent on available high-quality security of supply data. As security of supply data have not previously been collected for the purpose of using them in economic regulation, the analysis has been preceded by large-scale work aimed at identifying possible security of supply parameters and assessing their quality and suitability.

Our analysis work is based on the benchmarking model for water companies and uses three parameters for security of supply of drinking water as examples. However, the results are general and can therefore be used with other parameters and also in benchmarking of, for example, waste water companies.

The background and considerations for the security of supply parameters and the data we have chosen to use are described in The Danish Competition and Consumer Authority (2021 C).

[7] The Danish Competition and Consumer Authority 2021 C
[8] www.kfst.dk/vandtilsyn/analyser/forsyningssikkerhed-okonomisk-regulering-og-benchmarking/

Delimitation

This analysis must be seen in the context of the analysis *Security of supply and regulation of the water sector* (Konkurrence- og Forbrugerstyrelsen, 2021 D). Here, an analysis is done of models that can provide incentives for optimal security of supply based on known socio-economic costs of security of supply failures. Benchmarking forms part of the above analysis as one of the key factors in creating these optimal incentives.

The present analysis will further elaborate on why benchmarking is crucial, even when the socio-economic costs are known, and also includes other methods for integration of security of supply, including when we do not know or use socio-economic costs.

The socio-economic costs have been estimated using, among other factors, the willingness to pay for various security of supply indicators. The present analysis does not go into further details on the basis for the willingness to pay on which the calculation of the socio-economic costs has been based. These have been found in connection with a separate analysis of consumers' willingness to pay.[9]

We continuously use technical concepts of economy, finances and benchmarking in the analysis. The most central concepts can be seen in Box 2.1.

[9] The Danish Competition and Consumer Authority, 2020. The analysis can be found here: https://www.kfst.dk/vandtilsyn/analyser/forbrugernes-betalingsvillighed/

Box 2.1
Central concepts

Benchmarking
Benchmarking is a generic term for comparison of, for example, companies. Here, the best performing company(ies) is/are set as the benchmark for the other companies. It is a relative comparison that takes into account various factors such as company size.

Benchmarking method and model
A benchmarking *method* is an overall classification of an approach to benchmarking. In turn, a benchmarking *model* is a specific design of a benchmarking method.

In the specific benchmarking *models* used in the economic regulation of the water sector, two benchmarking *methods;* Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), are used. The purpose of using two benchmarking methods in the benchmarking is to take into account the methodological uncertainties that may exist in using different benchmarking methods – for example whether the method takes noise into account.

Potential for efficiency improvement
The potential for efficiency improvement indicates by how much a company's revenue cap should be reduced in order for the company to become cost effective.

Efficiency score
An efficiency score is the companies' individual result of the benchmarking. The efficiency score shows how far a company is from being cost effective, i.e. how large its potential for efficiency improvement is.

Recovery rate and period
The recovery rate indicates how quickly the potential for efficiency improvement is to be recovered. Like recovery rate, recovery period is used to state the length of the period in which the potential for efficiency improvement is to be recovered. The recovery period is typically stated explicitly, for example as eight years, and can be specified based on the total costs or separately for operating and construction costs.

Individual efficiency requirement
Over time, the individual efficiency requirement reduces the potential for efficiency improvement, which some companies have through a gradual reduction of their revenue cap.

Revenue cap
A revenue cap sets a ceiling for a utility company's maximum permitted revenue.

Cost effective
Cost effectiveness is a term that indicates whether a company spends the least possible costs in its production. If this is the case, the company will be characterised as cost effective. If, on the other hand, a company has higher costs, it is not cost effective.

Framework conditions
A framework condition is a specific condition under which a company produces its goods or services. This may, for example, be geographical conditions, population density, etc.

Chapter 3
Costs for security of supply in current benchmarking

3.1 Introduction

Benchmarking models do not currently take security of supply costs into full account. The analysis shows that the benchmarking models may *theoretically* provide misleading incentives if security of supply is not taken separately into account in the benchmarking models to a greater extent than today. However, we cannot *empirically* demonstrate that the theoretical problem has, in practice, had a significant negative effect on the security of supply provided by the water companies today (Konkurrence- og Forbrugerstyrelsen, 2021 A).

The generally high security of supply level reflects that the companies' level of supply is regulated in other ways, in particular through environmental regulation. At the same time, security of supply is a core competence in the water companies and a natural part of the operations of a water company that often cannot be separated from the company's other activities – good and efficient general operations with ongoing maintenance often also lead to a high security of supply. In addition, water companies may have different types of incentives than economic ones when they make decisions. For example, the owners' wishes are not necessarily solely based on economic considerations or considerations for consumers. For a detailed discussion of the companies' other incentives, see The Danish Competition and Consumer Authority (2021 D).

In this analysis, we solely look at economic incentives in the benchmarking models.

3.2 How is security of supply currently included in the benchmarking?

In the economic regulation, the purpose of the benchmarking models is to create an incentive to keep up with the most effective companies in the sector. [10]

The current benchmarking models already take into account to some extent that the water companies must maintain a desired security of supply. For example, it is taken into account in the benchmarking that there may be additional costs connected with acquiring and operating a waterworks with a more complicated water treatment process that can ensure a higher security of supply. A water company that acquires a waterworks with complicated water treatment will appear with a larger production in the benchmarking. In this way, the additional costs of the complicated water treatment are already explained in the model through the company's production, and the additional costs will therefore not appear as economic inefficiency. In this case, a company will thus not be faced with greater efficiency requirements on the basis of higher security of supply costs.

This is the case for a large number of both water and waste water companies' assets and activities, which, to a greater or lesser extent, form part of the efforts to ensure a high security of

[10] A more detailed review of the benchmarking model can be found in The Danish Competition and Consumer Authority (undated)

supply. [11] However, there are also activities connected with ensuring a higher security of supply which do *not* result in a higher production volume for the company. This may, for example, be if a company acquires more expensive monitoring equipment of higher quality, or replaces pipes more frequently to reduce the risk of pipe rupture. In these cases, the benchmarking model cannot explain the additional costs connected with ensuring a higher security of supply because the output in question is not included in the benchmarking.

The additional costs connected with this will therefore appear as economic inefficiency, which may result in a higher efficiency requirement for the company. Where this is the case, this may provide the companies with an incentive to lower their security of supply level to avoid appearing ineffective in the benchmarking due to costs connected with a higher security of supply.

Overall, we can therefore distinguish between security of supply costs that have already been explained in the benchmarking models and costs that have not. When we review the problem of a lack of security of supply in the benchmarking in this Chapter and the following chapters, we are therefore referring specifically to additional costs connected with ensuring better security of supply, but which cannot already be explained in the current benchmarking model.

3.3 Current benchmarking of water companies' economic efficiency

The benchmarking models identify the sector's lowest level of unit costs for the supply of water etc. for the water companies and waste water discharges and climate adaptation management etc. for the waste water companies, respectively. As these are different services, they actually constitute two sectors – and therefore with different models for each sector. However, the models for each sector are based on fundamentally uniform principles.

The lowest level of unit costs in each sector is defined as the efficient level of costs. The difference between the actual unit costs of companies and the efficient level of costs indicates the companies' individual potential for efficiency improvement. The company is thus encouraged to recover the potential for efficiency improvement over time by gradually reducing its cost level to the efficient level. In practice, the potential for efficiency improvement is recovered by setting an individual efficiency requirement for the companies' revenue cap based on the result of the benchmarking, so that the revenue cap reflects the efficient cost level over time.

The calculation of the efficient cost level and the efficiency of the individual companies is done in the benchmarking models. A simplified illustration of a DEA benchmarking model is shown in Box 3.1.

[11] It has not been possible to analyse how much of the net volume measure can currently be attributed to security of supply or how much of the security of supply that is taken into account in the net volume measure. This is because the security of supply activities cannot be separated from other activities in the companies.

Box 3.1

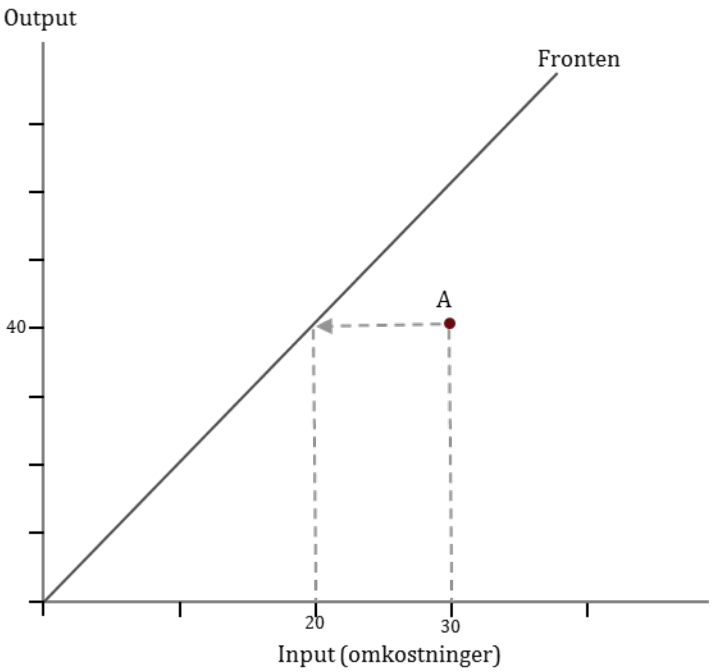
Benchmarking

The figure below shows a simple illustration of the intuition behind the benchmarking. In practice, there are variations in the calculation of the efficiency score, depending on whether the benchmarking is done using the Data Envelopment Analysis (DEA) or Stochastic Frontier Analysis (SFA) method.

The drawn line 'The frontier' indicates the efficient cost level (i.e. the lowest unit costs) of a given production.

In a DEA benchmarking model, the frontier is determined solely on the basis of information about the most efficient companies in the sector – the so-called frontier companies. The frontier in SFA has instead been statistically determined on the basis of a cost function based on information about all companies.

In the figure, it can be seen that company A produces 40 units of an output (for example drinking water) and has costs of DKK 30. The frontier shows that comparable companies can produce the same output for DKK 20. The model therefore regards company A as inefficient.



An efficiency score is calculated in the benchmarking. In this context, the efficiency score expresses how large a share of the companies' costs that is necessary to run an efficient company. The efficiency score will have a value of between 0-1. In the example in Boks 3.1, company A has costs of DKK 30, but should be able to operate with only DKK 20. The calculated efficiency score for the company is therefore $\frac{20}{30} = 0.67$. An efficiency score of 0.67 consequently indicates that company A should be able to operate at 67% of its current costs.[12]

Companies with an efficiency score below one are inefficient as they need to reduce their costs to achieve an efficient cost level. Conversely, companies with a score of one are efficient in the benchmarking relative to the other companies and are therefore not given an individual efficiency requirement. In DEA, companies with a score of one are therefore called “frontier companies”, as these companies make up the frontier with which the other companies are compared. In SFA, the frontier is calculated on the basis of all companies (both efficient and ineffective), and therefore there are no actual frontier companies in this model.

3.3.1 Information in the current benchmarking models

The benchmarking uses information from companies about their *production* and *costs* to calculate each company’s economic efficiency (efficiency score).

Regarding *costs,* both operating and construction costs are included in the benchmarking models. By using the companies’ total costs, operating and construction costs are assessed equally. Thus, it does not affect the companies’ assessment of when, for example, it will be most optimal to use operating solutions or invest in a new asset, as no distinction is made between operating costs and construction costs.

The companies’ *production* of drinking water and waste water (and climate adaptation), respectively, cannot be compared in a true and fair manner simply by, for example, comparing the number of cubic metres of supplied drinking water/treated waste water. The utility companies supply drinking water and waste water under different framework conditions that affect their costs. A company may be located in a geographical area which means that the company needs more pipelines, pressure booster, larger pumps or the like in order to supply consumers in their supply area. Such a company is not necessarily economically inefficient simply because it has more costs for these assets than a company with other and ‘cheaper’ framework conditions. Instead, the additional costs are linked to the assets and activities necessary for the company to supply consumers within the framework conditions under which the company operates.

Therefore, for the benchmarking models, a production volume measure has been constructed that is comparable across companies which basically supply the same service: drinking water or waste water. These measures are called “net volume measures”.[13]

Net volume measures are a weighted sum of a company’s assets and activities, such as the number of customers and the volume of water handled. In addition, the companies’ capacity is also included in the production volume, as the capacity is an expression of a necessary infrastructure that the companies make available in their supply area. The net volume measure therefore also includes, for example, the length of the company’s pipelines, the size of the pumping stations and the complexity of the water treatment. The weighting is based on the

[12] Depending on whether the benchmark is done using SFA or DEA, the efficiency score is calculated with or without noise being taken into consideration. In the method illustrated in Boks 1.1, it is assumed that the whole difference between company A’s actual costs and the efficient cost level is inefficiency. This corresponds to how the efficiency score is calculated using DEA. In SFA, part of this difference will be regarded as noise, which is why the efficiency score will not be calculated in exactly this way.

[13] Read more about the net volume measures for water and waste water companies in the annual methodology papers for the benchmarking here: https://www.kfst.dk/vandtilsyn/benchmarking/okonomiske-rammer-modelbeskrivelse-og-resultater/

standard costs that an average company will incur in acquiring the given asset or carrying on the given activity.

In the benchmarking, we use two net volume measures:

- *The OPEX net volume measure* – weighted sum of the company's production volume
- *The CAPEX net volume measure* – weighted sum of the company's fixed assets

When using the net volume measures, the assets and activities necessary for the individual water company are taken into account. It is therefore possible to take into account most of the main framework conditions under which the companies operate. For example, it is taken into account whether the company operates in a densely populated area, as assets and activities are weighted together with due consideration for the geographical area in which the company operates. In this way, it is taken into account that it is generally more expensive to repair, for example, pipelines, the more densely built up a supply area is.[14] The net volume measures can therefore be used to compare the companies across areas, as they take into account the company's activities and main framework conditions.

In this chapter, we only discuss the part of the different dimensions of security of supply that are not included in the net volume measures today, as this is where there may be challenges.[15]

However, all significant conditions do not necessarily need to be included directly in the models. The reason for this is that the companies in the benchmarking are measured against each other. If, for example, all companies implement a specific security of supply measure with the same effect and at the same costs, this will generally not affect the benchmarking. If a company spends more money than others on implementing the measure in question, the benchmarking will be affected. But it may also be expedient because the measure can then be implemented at a lower cost in the company in question. If, on the other hand, there is a situation in which a company chooses to invest in a higher standard than the other companies (in accordance with consumer preferences in the area), the benchmarking will generally overestimate the company's potential for efficiency improvement.[16]

3.3.2 What incentives do the current benchmarking models provide for security of supply?

As a starting point, it must be expected that a high level of security of supply costs more money to maintain than a low level. For example, higher security of supply may require better and more durable materials selection, better maintenance and monitoring and generally higher costs for other operational tasks.

[14] A further overall correction of the net volume measures is made based on the framework conditions: the age of the companies' assets and the density in the supply area. In this way, the calculation takes into special account the effect of these framework conditions that are not already directly included in the calculation of the net volume measures. For further information, see Appendix 3 to the methodology paper for the annual benchmarking here: https://www.kfst.dk/vandtilsyn/benchmarking/okonomiske-rammer-modelbeskrivelse-og-resultater/benchmarking-2021/.

[15] As a starting point, it is not a problem that some security of supply dimensions are included in the net volume measures, while others are specifically incorporated in the different models in Chapter 5. The reason for this is that the companies are measured relative to each other and that this difference in methodology is therefore the same for all companies. However, it may create model uncertainty if individual companies systematically choose different technological solutions for improvement of their security of supply than the rest of the sector.

[16] If there are few companies that deviate from the rest due to a framework condition, the measure may be included as a special condition for the individual companies which compensates them without it being incorporated directly in the model.

However, this will depend on a number of conditions. For example, there may be relatively high costs for remedying security of supply failures, which can make it costly to have a low security of supply level. Overall, however, we will assume that higher security of supply is connected with higher costs.

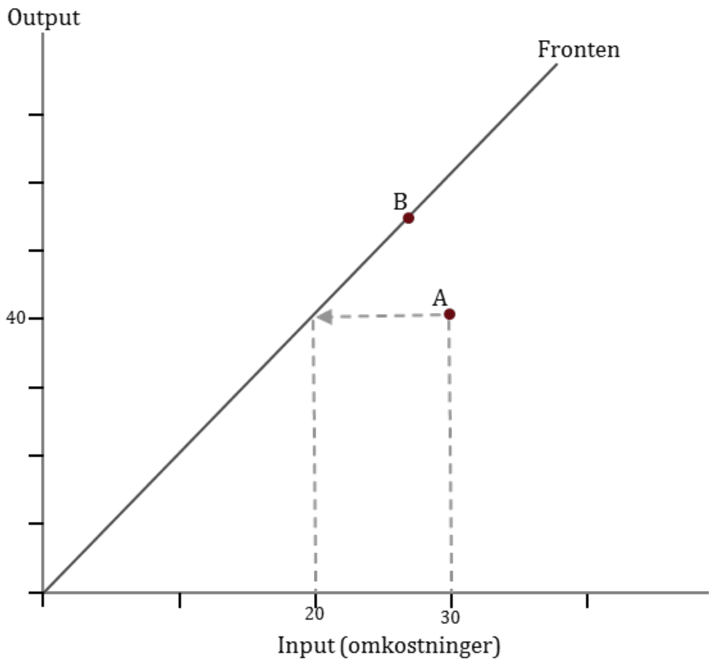
This means that the companies must increase their costs in order to provide a higher security of supply in response to an external wish for a higher level of security of supply. Correspondingly, the board of directors may, for example, decide to reduce the company's costs by lowering the security of supply level.

Companies may thus have an incentive to reduce their level of security of supply to meet higher efficiency requirements and to keep up with the economically best companies in the sector in question.

Figure 3.1 shows a simple example in which company A is inefficient in the benchmarking based on a DEA model. The company must reduce its costs from DKK 30 to DKK 20 in order to be as efficient as comparable companies. The company must continue to supply water to all its customers, which is illustrated by the company having to deliver a net volume measure of 40.

An assumption is then made that this company has chosen to invest in a new system to minimise water waste. This system is not included in the net volume measure, but the annual costs for the system are included in the company's total costs. The company can now choose to reduce its measured economic inefficiency by reducing or eliminating the costs for the system; if, for example, the system costs DKK 5 to run annually, company A can, other things being equal, halve its inefficiency by ceasing to use the system and thus lower its total costs from DKK 30 to DKK 25. In this way, the company will become more efficient in the benchmarking without having increased the efficiency of its day-to-day operations. In turn, the consumers will have a lower security of supply level.

Figure 3.1 **Benchmarking of security of supply**



Note: The figure shows a simple illustration of benchmarking with a DEA model, where company A is inefficient and must reduce its costs from DKK 30 to DKK 20 to become efficient. The costs comprise all costs, including costs for security of supply that are not part of the net volume measure.

Source: Own production

The companies therefore have financial incentives to reduce their security of supply in the current benchmarking models in those areas in which no additional contribution is allocated to the net volume measure for a high security of supply. For a mathematical review, see Heesche & Bogetoft (2021).[17]

3.3.3 Does a comparison of companies with different security of supply levels provide a true and fair view?

The current benchmarking models do not make any corrections for companies having different security of supply levels other than the corrections made in connection with the calculation of the net volume measure. Theoretically, we can therefore expect that companies with low security of supply are put in a relatively favourable position in the models and that companies with high security of supply are put in a poorer position because, other things being equal, they have higher costs.

Companies with high security of supply

Assume that company A in Figur 3.1 has a high security of supply level. The company's benchmark indicates that the company's costs should be DKK 20. The gap between the effective cost level and the company's actual cost level of DKK 30 is determined by the effective cost level of the sector. Company B is an efficient company. Now assume that company B has a low security of supply and thus also low costs for this. This means that part of company A's relative inefficiency is not necessarily economic inefficiency but an expression of additional costs for better security of supply relative to company B.

Company A therefore appears as economically inefficient due to its good security of supply. The company's executive board and board of directors may choose to reduce the security of supply level or become more efficient than company B on other items to meet the efficiency requirements in the long term.

Companies with low security of supply

Unlike companies with *high* security of supply, companies with *low* security of supply will, other things being equal, be faced with too low efficiency requirements today. This is due to two reasons:

1) If a company has lower security of supply than the other companies in the sector, its costs should be at a lower level than the other companies' costs. The company will therefore be faced with too low an efficiency requirement.

[17] The incentives work differently for efficient companies in the benchmarking. However, the conclusion is the same, i.e. that efficient companies today theoretically do not have an incentive for a high security of supply in the current economic benchmarking. For a review of incentives for efficient companies, see Appendix 1.

2) The number of companies in the benchmarking models is of importance to the efficiency measured for the companies. This is due to a statistical bias, described in, among others, Simar & Wilson (2000). We have outlined the problem as an example in Figure 3.2. In the figure, the broken line indicates the possible, but unknown, frontier. The full-drawn line indicates the estimated frontier, and the red dots show the individual companies.[18]

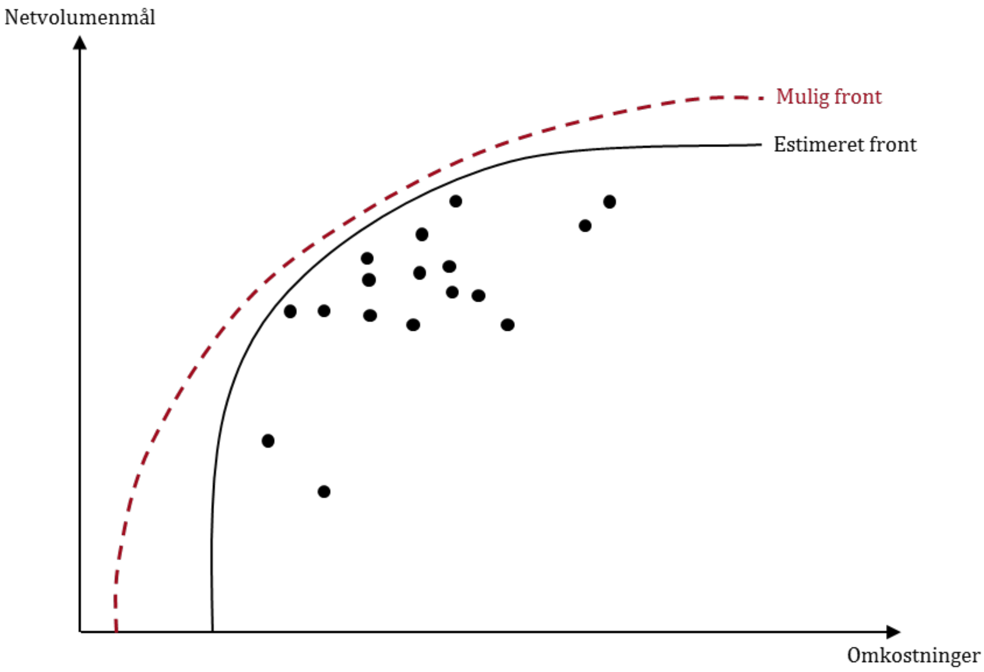
In a DEA benchmarking model, the frontier is formed based on observed data. In a DEA model, the frontier is therefore, by definition, inferior to the possible frontier – the reason being that even the best companies in the sector are not fully efficient. This is not as clear-cut for the frontier in an SFA model, but the same trend is seen.

When the observed frontier is always poorer than the possible front, the statistical bias is that the more companies we observe, the greater the likelihood will be that minimum one of them is close to being fully efficient. This can be seen in the figure by the two frontiers being close to each other at the point where there are many companies and far from each other at the point where there are few companies. This means that companies that are different and thus located on their own will statistically be compared with a frontier that is further from the true frontier than an ordinary company – they will thus be given too low an efficiency requirement.

This bias is amplified when the models do not take security of supply into account. In fact, this means that several companies with good security of supply do not actually have the opportunity to form the frontier, as they perform artificially poorly in the models as a result of increased costs for their security of supply. The number of companies that can make up the frontier will therefore be reduced, resulting in the frontier moving further away from the true frontier.

[18] The example is illustrated for a DEA model, but the same trends will also be applicable in SFA models.

Figure 3.2 **Difference between possible and estimated frontiers**



Note: The figure shows an example of how the true and estimated frontiers are statistically closer to each other in those areas in which there are many observations than where there are few observations. In the figure, the frontier has been shown for a model in which there is not assumed to be a linear correlation between costs and net volume measures.

Source: Own production

3.4 Security of supply and economic benchmarking in practice

In the previous section, we have shown that *theoretically* it does not give a true and fair view to compare companies with different security of supply levels (which are not captured by the net volume measure) and that the models currently do not provide a sufficient incentive for a high security of supply level. We would therefore expect to see this reflected in the results from the current benchmarking models. However, statistical analyses show that the problem has so far not played a significant role in the benchmarking of water companies in Denmark.

If the problem is of actual importance to the companies, companies with high security of supply should perform worse in the benchmarking models than companies with low security of supply. This is not the case, see the article “Er der en sammenhæng mellem høj forsyningssikkerhed og effektivitet?” (Is there a correlation between high security of supply and efficiency?) (Konkurrence- og Forbrugerstyrelsen, 2021 A).

In this article, we have used a regression analysis to examine whether an empirical correlation can be found between the companies’ efficiency scores and their security of supply level. We have specifically analysed the security of supply parameters presented in Chapter 4. We have looked at the results from the latest benchmarking models for both water companies and waste water companies. We find no evidence that companies with a high security of supply level have been given a lower efficiency score in the economic benchmarking so far.

We have also previously shown that, since the introduction of the regulation in 2009, overall, the regulation has not led to a reduced security of supply in the water sector regarding microbiological overruns for water companies (Bjørner, Hansen, & Jakobsen, 2021).[19]

Even though it can theoretically be argued that companies with higher security of supply should have higher costs and therefore appear as more inefficient in the benchmarking, this thus cannot be observed from the benchmarking models used today.[20]

There may be several reasons for this result. Firstly, as mentioned earlier, a large part of the costs for security of supply are already included in the net volume measure. Therefore, it is already today taken into some consideration that companies may have higher costs due to a higher security of supply level. Secondly, Danish water companies generally have a high security of supply level, and the difference in the level and the connected costs can therefore be expected to be relatively small and thus difficult to show statistically. In addition, there may also be an effect of companies with a high economic performance also having a high security of supply performance, which can be attributed to general good management efficiency in these companies.

Although we do not currently find that security of supply parameters have had an effect on the companies' benchmarking results in practice, we cannot rule out, however, that these or other parameters could have a significant effect in the future. We know that the challenge is theoretically present, and there is therefore a risk that we will also be able to observe the correlation in practice in the future.

[19] For the Danish version, see The Danish Competition and Consumer Authority (2020 B)

[20] We have also examined whether we can more directly find a correlation between the companies' security of supply level and their total costs. Here, too, we do not find any evidence that a high security of supply level is connected with correspondingly higher costs.

Chapter 4
International experience and other work with security of supply in economic regulation

Security of supply in the utilities sector is on the agenda in a number of countries and sectors. The approach to regulation of security of supply may differ, depending on the type of regulation used by the sector in general. In Denmark, the largest water companies are regulated by both revenue cap regulation and environmental regulation, which include minimum requirements and taxes connected with security of supply failures. Different security of supply parameters in the water sector are thus regulated in different ways today.

In this analysis, we are only dealing with economic incentives for security of supply through economic benchmarking. In this chapter, we describe international experiences with regulation of quality parameters in an economic benchmarking, and how other regulation of security of supply in the water sector in Denmark affects the economic benchmarking.

Other countries have also used benchmarking as a means of strengthening the economic incentive for high security of supply. The UK consultancy company Oxera has performed a review for us that describes how security of supply is included in economic regulation in a number of other countries and sectors today, and how it affects economic benchmarking (Oxera, 2019).

In addition, in 2020, we prepared an analysis of the possibilities of introducing sanctions and/or rewards for security of supply as part of the revenue cap regulation of water companies in Denmark, see (Konkurrence- og Forbrugerstyrelsen, 2021 D). Such sanctions and/or rewards will also be of significance to the handling of security of supply in economic benchmarking.

Here, we summarise the most important points from the two reports and their significance to any regulation of security of supply in economic benchmarking.

4.1 International experience with security of supply and benchmarking

There is generally increasing focus on the ability to handle the interaction between utility companies' economic performance and the quality they supply. Within the benchmarking literature, we therefore see a correspondingly increasing interest in benchmarking models that can take into account the weighing between economic and environmental performance. However, experience with actual implementation is relatively limited and reflects that although there is great interest in increasing use of quality parameters in economic benchmarking, the implementation thereof is a complex matter.

In a number of countries, benchmarking is used – as in Denmark – to regulate monopoly sectors, including, in particular, utilities sectors. The purpose is to contribute to creating an artificial competitive pressure for companies operating in monopoly markets. In particular, Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) benchmarking methods are relatively widespread regulatory methods. These methods are, for example, used for the economic regulation of the electricity sector in Norway and Austria and for regulation of the water sector in the UK and Denmark.

In 2020, we gave the UK consultancy company Oxera the assignment of mapping international regulators' experience with including quality parameters, such as security of supply, in their economic benchmarking.[21]

Two of the interviewed regulators have implemented security of supply parameters directly in their benchmarking model: the Norwegian and Finnish regulators of the electricity grid. Both regulators take security of supply failures into account in their economic benchmarking by calculating socio-economic costs of the companies' security of supply failures.

Both of these regulators measure security of supply failures as lack of supplied power (number of interruption minutes), where the socio-economic cost of the interruption minutes is calculated by estimating consumers' willingness to pay to avoid interruptions (in the electricity area typically called 'value of lost load' or VOLL).

The Norwegian regulator uses a DEA model. Value of lost load (VOLL) is incorporated as a cost on an equal footing with all other costs. This imposes a direct cost on the electricity grid companies in Norway for their failure to supply electricity corresponding to the estimated cost experienced by consumers from not having electricity at their disposal. The Norwegian regulator of the electricity grid has continuously developed the calculation of consumers' willingness to pay in order to avoid security of supply failures, and today calculates this on a differentiated basis, including based on type of consumer, time of interruption and duration.

The Finnish regulator of the electricity grid today uses a special benchmarking model[22]. However, it has previously used DEA and SFA models in which it has included the socio-economic costs of interruption minutes as part of the company's total costs – just as we see with the Norwegian regulator.

Today, however, Finland's benchmarking model does not include socio-economic costs on an equal footing with the companies' other costs. In 2010 and 2011, Finland experienced extreme weather conditions that caused unusually large interruptions in the electricity companies' supply (Oxera, 2019). This therefore led to very high socio-economic costs for interruption minutes for the electricity companies and thus misleading results in their benchmarking models (Oxera, 2019). Against this background, it was decided in Finland to change the way in which socio-economic costs are included in benchmarking. Today, the socio-economic costs connected with interruption minutes are instead modelled as an independent output rather than equating them directly with the companies' other costs.

Experience from both Norway and Finland indicates that it is complicated to implement security of supply in economic benchmarking. It requires continuous methodological considerations and development of data to maintain true and fair benchmarking of both economic performance and security of supply performance.

Apart from these two regulators, we do not have knowledge of other regulators that have integrated quality parameters (for example security of supply) directly in their economic benchmarking models.

[21] The report can be accessed on our website https://www.kfst.dk/vandtilsyn/analyser/forsyningssikkerhed-okonomisk-regulering-og-benchmarking/

[22] A so-called StoNED model developed by the Finnish regulator itself

4.2 Possible sanctions and rewards linked with security of supply

As a follow-up to the political agreement on adjusted regulation of the water sector from 2018, we published an analysis in 2021 on the possibilities of introducing economic sanctions and rewards based on the water companies' security of supply level (Konkurrence- og Forbrugerstyrelsen, 2021 D). The analysis presents proposals for maintaining and improving security of supply in the water companies. Sanctions and/or rewards are proposed for water companies depending on their security of supply level, including ensuring that green taxes in the waste water sector are incorporated in the benchmarking models.

The values of specific sanctions/rewards connected with security of supply failures are proposed to be based on consumers' willingness to pay in order to avoid failures in the security of supply parameters in question (Konkurrence- og Forbrugerstyrelsen, 2020 A).[23] This concerns, for example, consumers' willingness to pay in order to avoid a microbiological overrun.[24]

It is further proposed to introduce a number of precautionary considerations in the implementation of the sanctions/rewards for the companies.

In both the water and waste water sectors, there are already green taxes for environmental impact. However, green taxes are not included in the cost basis for the benchmarking models in the waste water sector. The same applies to the fees for water loss for the water companies. The reason for this is that, according to the legislation, these charges are to be treated as non-controllable costs (IPOs). This means that water companies are compensated 1:1 for costs associated with green taxes. In this way, there is no incentive to reduce the tax and thus to reduce the discharge of harmful substances by the waste water companies and to reduce water losses in the water companies.

It is therefore proposed in the analysis that the costs of the green taxes be 'activated' and made controllable by including them in the benchmarking and thus in the determination of the companies' individual efficiency requirements. In this way, the green taxes may have a real effect on the companies' behaviour.

By introducing sanctions/rewards and activating existing green taxes, these costs will also be included in the benchmarking.[25] This way of treating the companies' security of supply in the benchmarking is referred to as the "socio-economic model" in this report. Today, the companies are benchmarked solely based on business economic costs for production. By including taxes connected with the companies' security of supply level, the socio-economic costs associated with the companies' security of supply failure are instead taken into account – and not just production costs. In the socio-economic model, costs of security of supply failure are therefore equated with the company's actual production costs. In Chapter 5, we review the socio-economic model and its implications for the benchmarking models and their results, together with a number of other methods for handling security of supply in the benchmarking.

As mentioned earlier, the socio-economic model is used by the Norwegian electricity grid regulator today and has previously been used by the Finnish electricity grid regulator.

[23] The analysis has been performed using a so-called choice experiment.

[24] A microbiological overrun has been defined in Chapter 5.1,

[25] This consequently applies to both any sanctions and rewards. In this connection, any reward can be regarded as a negative cost in the benchmarking and therefore a deduction in the company's costs.

Chapter 5
Methods for implementing security of supply in economic benchmarking

There are several methods for including water companies' security of supply level in the benchmarking models used in economic regulation. Each method is based on different assumptions and they all have both advantages and disadvantages.[26]

We examine a number of these methods and, for each method, empirical results are presented for specific benchmarking models prepared for use in the analysis. We use data for the water companies to illustrate the effect of implementing security of supply in the benchmarking.

Table 5.1 is an overview of the methods examined theoretically and empirically.

Today, the water companies are benchmarked using both a Data Envelopment Analysis (DEA) model and a Stochastic Frontier Analysis (SFA) model. DEA and SFA are two different benchmarking methods, and not all methods we review in this chapter will be suitable for both models. We present all the methods as DEA models. For SFA, we only present the socio-economic method, as only this method has been found suitable for an SFA model in the water sector.

The model with independent parameters constitutes the simplest model, where security of supply parameters are simply added to the current models as separate parameters. However, this method does not produce accurate results as it does not ensure an expedient balance between economic performance and security of supply. With the model with independent parameters, the companies' efficiency score can be calculated by disregarding economic performance and focusing exclusively on the security of supply parameters. This leads to inexpediently high efficiency scores which are not necessarily an expression of the companies' economic performance. The remaining models presented in this chapter therefore seek to address this problem so that a true and fair measure of security of supply can be implemented in an economic benchmarking model.

The different methods are presented in separate empirical models. However, the methods are combinable so that, in practice, different security of supply parameters can be implemented in the same model with different methods.

[26] The Chapter is an overall review of the models published in "*Teknisk arbejdspapir: Forsyningssikkerhed i DEA-benchmarking* (Technical Working Paper: Security of supply in DEA benchmarking) (Konkurrence- og Forbrugerstyrelsen, 2021 B) and "*Teknisk arbejdspapir: Forsyningssikkerhed i SFA-benchmarking"* (Technical Working paper: Security of supply in SFA benchmarking) ((Konkurrence- og Forbrugerstyrelsen, 2022 B)). The technical working papers present more detailed descriptions of the theoretical considerations and empirical results of the methods.

Table 5.1 **Models for integration of security of supply**

Model	Description
D.0 and S.0 Current model	Current benchmarking models. D.0 indicates the current DEA benchmarking model and S.0 the current SFA benchmarking model. Security of supply is not included as a direct element in these models.
D.1 Independent parameters	*The model with independent parameters* is the simplest method of implementing security of supply in economic benchmarking, as the security of supply parameters are simply included as output without further conversions. In the model, security of supply is equated with everything else the company produces. This means that a company can appear as efficient by simply being the best performer on one single parameter, while being the worst performer on the remaining parameters. The results of the empirical model show that this will precisely become a major problem in the model with independent parameters. In principle, this method can be used for both the DEA and SFA models. However, for empirical reasons, this method is presented only for the DEA model. For a more detailed description of the application of this method in SFA benchmarking, see The Danish Competition and Consumer Authority (2022 B).
D.2 and S.1 Socio-economic costs	*Socio-economic costs* of security of supply failures are equated with the companies' operating costs. The socio-economic costs are calculated by, among other factors, consumers' willingness to pay in order to avoid security of supply failures. In principle, this method can be used for both the DEA model (D.2) and the SFA model (S.1).
D.3 Weight restrictions	In the benchmarking model, security of supply is handled by using so-called *weight restrictions*. Weight restrictions limit how great importance security of supply is allowed to have in the calculation of the efficiency scores that the model calculates for each individual company as an expression of their efficiency. Two models for setting the weight restrictions have been examined: relative and virtual restrictions. The first utilises degrees of willingness to pay to set a restriction. The second model weights security of supply relative to the other outputs in the model. This method can only be used for the DEA model.
D.4 Basis of comparison	The last model does not incorporate security of supply directly, but handles it by creating different *bases of comparison:* By ranking the companies based on their level of security of supply, a company's economic performance cannot be compared with companies with a poorer security of supply. Different methods for forming the basis of comparison are examined. This method is only used for the DEA model, as SFA requires more observations than those used in the regulation.

Note: The table shows the four models tested to integrate security of supply in a benchmarking model.

Source: Own production

One of the fundamental challenges of implementing security of supply in economic benchmarking is to ensure an expedient weighing between the importance of the companies' security of supply level and their economic performance. In the benchmarking models used in the current economic regulation, the companies' economic performance determines the result of the benchmarking (efficiency score). Adding the companies' security of supply level to the benchmarking provides quality parameters that will also be of importance to the companies' result. If many security of supply parameters are added to the economic benchmarking on an equal footing with economic parameters, we risk that security of supply will become of disproportionately large importance to the result of the benchmarking. The first model we present in this Chapter (the model with independent parameters, D.1) illustrates this very problem. The problem is a well-known challenge in the benchmarking literature and will be referred to in the following as the 'dimensionality problem', as it occurs when the number of dimensions (parameters) is increased (2001).

In addition, a number of theoretical challenges arise in the implementation of security of supply in the benchmarking. They concern, among other factors, how we define security of supply. The security of supply level is measured for the companies as security of supply failure. The parameters that characterise a company's security of supply level (such as the number of interruption minutes) will therefore be expressed so that a *higher* value of the parameter means a *lower* security of supply. The security of supply parameters are therefore what are known in the benchmarking literature as “undesirable outputs”. Undesirable outputs behave differently from normal production outputs. Normally, we will assume that *more* of an output is better, and we therefore want to *maximise* all outputs in an ordinary benchmarking model. However, the opposite is the case with undesirable outputs, as *more* of the undesirable output means *lower* security of supply. When we add the security of supply parameters as parameters in a benchmarking model, we therefore cannot model them as ordinary outputs. Instead, we need to take into separate account the security of supply parameters as *undesirable outputs* in the benchmarking model.

We address the challenge of undesirable outputs by treating the security of supply parameters as inputs rather than outputs.[27] The less input a company uses the better, which is consistent with the intuition behind the undesirable outputs, which represent security of supply failure. By treating undesirable outputs as inputs, we therefore assume that less is better for the security of supply parameters. As we do not want to require companies to minimise their security of supply level, we add the security of supply parameters to the model so that these are not minimised in the model, but are instead maintained.[28] In this way, the companies’ economic efficiency is assessed *given* their security of supply level.

There are many different ways to treat undesirable outputs in a DEA benchmarking model, and there are pros and cons to all of them. We have generally chosen to treat undesirable outputs as fixed inputs, as this is a relatively simple method. For a review of several ways of handling undesirable outputs, see Scheel (2001).

To illustrate the effect of the individual models, we compare their empirical results with the results from the current benchmarking models for water companies. In the following, these models are referred to as ‘the current model’ (and are designated as D.0 for the DEA model and S.0 for the SFA model). The current models are the ‘pure’ business economic benchmarking without the security of supply parameters that we know from the economic regulation today.

For the empirical results, we use data for the water companies for 2019[29], see Chapter 5.1. Table 5.2 shows the overall results for the different methods. The table shows that the model with independent parameters leads to high efficiency scores and a high number of frontier companies. It is to be expected that efficiency scores and the number of frontier companies will increase when we take security of supply into account. However, we will subsequently argue that the large increase in this model is not realistic and that it is due to theoretical problems with the model. The other models provide more consistent results and generally limit the increase in efficiency scores by moving from the current model without security of supply to a model with security of supply.

[27] The method is not relevant for the SFA model, as this Chapter does not only present an SFA model in which security of supply is added using socio-economic costs.

[28] We model the security of supply parameters as so-called ‘non-discretionary’ inputs.

[29] All models include the water companies that are benchmarked in connection with the economic regulation. Three of these companies (Kalundborg Overfaldevand, Vandfællesskabet Nordvestsjælland and Sjælsø Vand) have been excluded from the dataset, as these companies have a structure that can make a comparison with the remaining companies difficult. This means that 72 companies are included in the dataset. In addition, we assume constant returns to scale (CRS) in all empirical models in the same way as in the current benchmarking of the water companies.

The results in Tabel 5.2 are referred to on an ongoing basis in the following review of the individual models.

Table 5.2 **Results for the different methods for water companies – efficiency scores**

Model	Min.	1st quartile	Average	3rd quartile	Number of frontier companies
D.0 Current model	**0.49**	**0.67**	**0.76**	**0.83**	**6**
D.1 Independent parameters	0.49	0.71	0.83	1	19
D.2 Socio-economic costs	0.42	0.67	0.77	0.87	6
D.3 Weight restrictions	0.49	0.70	0.78	0.86	7
D.4.2 Basis of comparison	0.50	0.69	0.79	0.92	8

Note 1: The table shows an overview of benchmarking results, i.e. efficiency scores. It should be noted that the maximum is not stated, as it will always be 1 in a DEA model.

Note 2: The purpose of the empirical results is to compare the methods across each other. As we only have one empirical SFA model with security of supply, the results for this model are not shown.

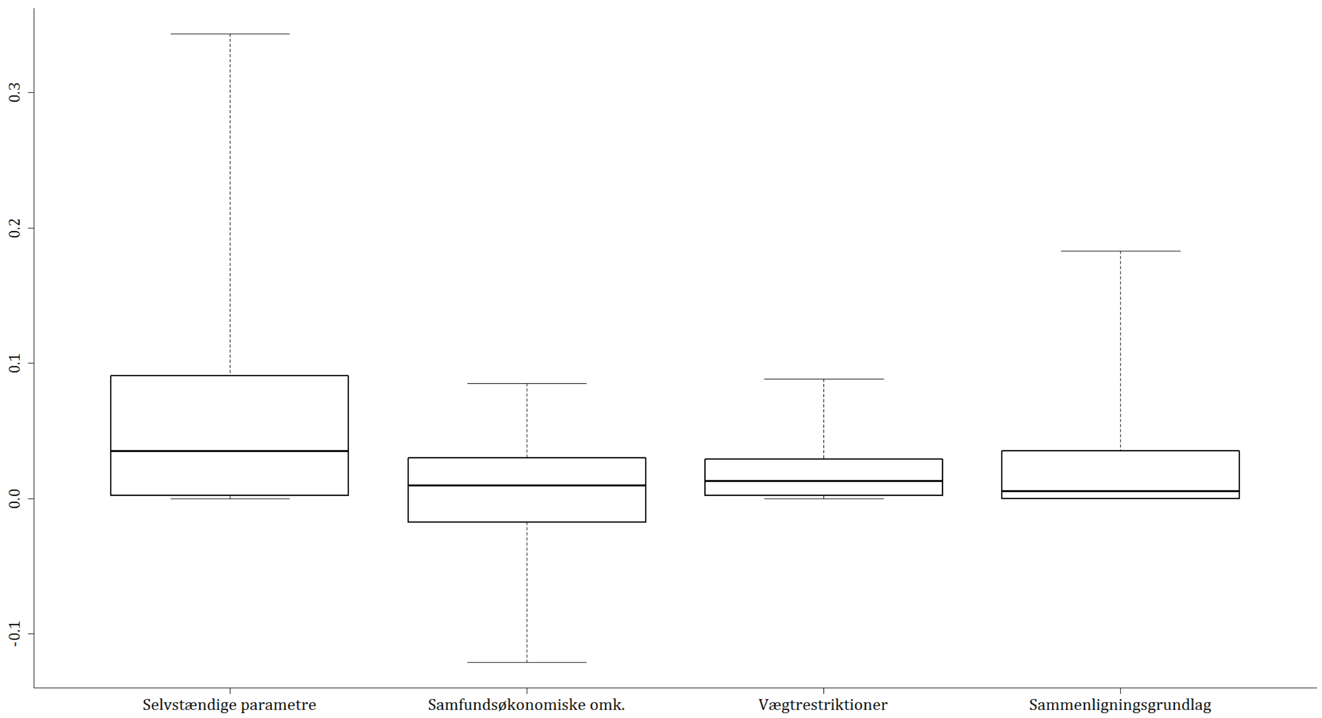
Source: Own production

Even though the results in Tabel 5.2 are relatively consistent, the results for the individual companies may vary greatly across the models. Figur 5.1 shows a *box plot* of the difference in efficiency scores by going from the current model to one of the possible models with security of supply. A value of, for example, 0.1 in the figure will indicate that a company achieves an efficiency score that is 0.1 higher in the given model with security of supply relative to the current model. It should be noted that the model with socio-economic costs is the only model in which it is possible to get a lower score than in the current benchmarking model.

In the figure, we see that many companies get a significantly higher efficiency score when we add security of supply relative to the current model. This is particularly evident for the model with independent parameters. The diversity of how much the efficiency scores change when implementing the other models is significantly smaller. Especially in the model with weight restrictions, we see relatively small diversity in the increase in efficiency scores at company level relative to the current model.

For a more detailed review of the results and further illustration of results at company level, see The Danish Competition and Consumer Authority (2021 B).

Figure 5.1 **Box plot of difference in efficiency scores between current benchmarking model and models with security of supply**



Note: The figure contains data on the difference between the efficiency score in the current model and the given possible model with security of supply. The box plot shows the median with the bold horizontal line, the box illustrates the upper and lower quartiles, and the outer points show the maximum and minimum differences in efficiency scores within each model.

Source: Own production

When making comparisons across the models, it is important to note that model D.2 with socio-economic costs does not take into account the parameter of microbiological overruns. There is thus a difference in the security of supply parameters which are included in this model and the remaining models. However, we can still compare the trends in the different empirical models overall to get an indication of the advantages and disadvantages of the different methods.

5.1 Security of supply data for empirical analyses

Security of supply for the water sector is defined by the Danish Ministry of Environment as:

- *Secure and stable handling of drinking water of good quality.*
    - *'Secure and stable' means that the drinking water supply is of satisfactory quality in relation to people and the environment, that the supply is efficient and stable from a consumer perspective, and that the catchment of groundwater takes place on an environmentally sustainable basis, i.e. without negatively impacting the water balance in the environment.* [30]

There may be many factors that can determine the extent to which a water company meets this definition. In the water and waste water sector, security of supply can therefore best be described using multiple indicators (typically more than in, for example, the electricity sector).

For the empirical analyses discussed in this Chapter, three security of supply parameters are used for the water companies. The three parameters are *examples* of possible parameters that could be integrated into the economic benchmarking. The three parameters therefore highlight the possibilities of integrating security of supply in the benchmarking models, i.e. both for these and for other similar parameters – current and future. The parameters have been selected based on a number of criteria, including a criterion that there must be sufficiently high data quality for benchmarking.

Tabel 5.3 summarises the three selected security of supply parameters. A more in-depth description of the data can be found in The Danish Competition and Consumer Authority (2021 C). Here, it is also described how data for the individual parameters have been collected and calculated for use in the analysis.

As Tabel 5.3 shows, the security of supply level has been described as observed security of supply failure. This means that the companies with the highest security of supply are those with the fewest incidents within the three parameters.

[30] The Danish Ministry of Environment is responsible for defining security of supply in the water and waste water sector, see, for example, (Konkurrence- og Forbrugerstyrelsen, 2021 C)

Table 5.3 **Security of supply parameters in the analysis**

Parameter	Description
Microbiological overruns	Number of microbiological 'contamination cases' seen in relation to the volume of water produced, where a correction has been made for the additional risk of overruns that occurs by the company having decided to expand its control programme. The overrun must be attributable to the utility company's responsibility.
Unplanned interruptions	Number of minutes of unplanned interruptions for all consumers throughout the supply area.
Water loss	Percentage of the volume of water pumped into the company's own distribution network that disappears as water loss.

Note: The table describes the three parameters used in the analysis work.

Source: Data memo on security of supply parameters

In this report, we only analyse empirical models for the water companies. As far as waste water companies are concerned, the Danish Environmental Protection Agency also identifies a number of relevant security of supply parameters that can be used in the future also to assess the waste water companies' security of supply level, see (Konkurrence- og Forbrugerstyrelsen, 2021 C). The benchmarking methods in this Chapter could thus also be used in the benchmarking of waste water companies.

Socio-economic costs of security of supply failures

For the models that use the socio-economic cost of security of supply failure, degrees of willingness to pay and payable taxes are applied to calculate the socio-economic cost connected with the various parameters.

Tabel 5.4 shows an overview of the socio-economic costs connected with security of supply failure associated with the three parameters we use in this analysis.

Table 5.4 **Willingness to pay[1] and security of supply taxes**

Parameter	Cost	Type
Microbiological overrunsr[2]	DKK 70.3 per overrun/1,000 water samples	Willingness to pay
Unplanned interruptions	DKK 4.3 per interruption minute	Willingness to pay
Water loss[3]	DKK 6.18 per m^3	Charge

Note 1: The willingness to pay has been adjusted for the net tax factor (NTF).

Note 2: The willingness to pay for microbiological overruns is to be understood as the willingness to pay to avoid one microbiological overrun per 1,000 water samples taken in the water company's pipeline network.

Note 3: For water loss, the tax for transported water is used. Today, water companies must pay a tax for water loss that exceeds 10 per cent of the pumped-out water volume.

Note: The table shows willingness to pay and taxes, which are used to value consumers' costs for security of supply failure.

Source: The willingness to pay has been stated in the analysis 'Consumer willingness to pay for improvements in the water sector' (Konkurrence- og Forbrugerstyrelsen, 2020 A). The rate of tax for transported water can be found on the Danish Ministry of Taxation's website https://www.skm.dk/skattetal/satser/satser-og-beloebsgraenser-i-lovgivningen/vandafgiftsloven/

Willingness to pay is to be understood as the annual additional payment that a consumer is willing to make on average in order to avoid a security of supply failure. The willingness to pay can thus be used as the cost of the failure for consumers. For every minute in which a water company *cannot* supply water to a consumer, it thus causes the consumers – and consequently also society – to incur a cost of DKK 4.3, which is today 'hidden' from the company. To find the total socio-economic cost of a company's number of interruption minutes, the willingness to pay is multiplied by all consumers' interruption minutes during a year. The same method is used for microbiological overruns, where the willingness to pay is DKK 70 per overrun per 1,000 samples.

An in-depth description of how willingness to pay has been arrived at can be found in *Consumer willingness to pay for improvements in the water sector* (Konkurrence- og Forbrugerstyrelsen, 2020 A).

The companies are already today liable to pay a tax of DKK 6.18 per m^3 for water loss that exceeds 10 per cent of the pumped-out water volume[31]. This tax is used as an estimate of socio-economic costs on an equal footing with the estimated willingness to pay. To find the total socio-economic cost of a company's water loss, the tax is multiplied by the *full* lost water volume, and not just the part of the water loss that exceeds 10 per cent. In this way, the companies have an incentive to reduce the water loss to the level at which the company's costs for a further reduction are higher than the tax.[32]

[31] The tax for transported water loss changed as at 1 February 2021. Link: https://www.skm.dk/skattetal/satser/satser-og-beloebsgraenser-i-lovgivningen/vandafgiftsloven/

[32] Tax on transported water is today handled as a so-called non-influenceable cost, which means that it is not included in the costs that form part of the current benchmarking. To give companies the right incentive for a low water loss, the cost should instead be influenceable and thus be included in the benchmarking.

5.2 The model with independent parameters (D.1)

The model with independent parameters (D.1) is the term we use for the simplest model for implementing security of supply in a DEA model. In the model with independent parameters, the security of supply parameters are directly included as separate parameters – i.e. three additional outputs (interruption minutes, water loss and microbiological overruns) are added to the current model for water companies. In this way, the security of supply parameters are included in the determination of the companies' efficiency score on an equal footing with the companies' other outputs (the net volume measures, see Chapter 3).

Box 5.1
Purpose of the model

The model with independent parameters must ensure that companies with high security of supply are compensated for the connected additional costs. The model does not provide an incentive for a specific security of supply level. This means that the companies are placed on an equal footing regardless of the security of supply level they choose. However, the connected cost of security of supply must be cost effective.

For empirical reasons, we only present this method as a possible DEA model and not as an SFA model. For a more detailed description of the application of the method in SFA benchmarking, see The Danish Competition and Consumer Authority (2022 B).

The model with independent parameters, where security of supply is implemented directly in the benchmarking model, has the advantage that it is simple. However, a challenge of the model with independent parameters is the dimensionality problem. When the number of parameters increases, the model allows companies to become fully efficient or experience a large increase in their efficiency score by simply focusing on security of supply (Heesche & Asmild, 2020, The Danish Competition and Consumer Authority, 2019). The reason for this is that the model makes it possible to calculate a company's efficiency without taking all parameters into account. This means that a company can theoretically become fully effective in the model by being the best performer on just one of the security of supply parameters even though the company's performance is poor on all other parameters, including the economic parameters.

The reason for the challenge is that security of supply is added as additional parameters without restrictions on their importance. This means that no upper (or lower) limit is set on the level of importance of security of supply in relation to the companies' finances (net volume measure, which constitutes the companies' production volume, and FATO, which constitutes the companies' cost base) in the calculation of the companies' efficiency. A company can thus become fully efficient despite poor economic efficiency, as long as the company has few security of supply failures.

Box 5.2
The model with independent parameters in brief

In the model with independent parameters, the security of supply parameters are added as separate parameters to the model. The security of supply parameters are therefore included in the benchmarking model on an equal footing with the OPEX and CAPEX net volume measure in the benchmarking volume.

What does the model look like?

Input	Output
FATO, Water loss, Interruption minutes and Microbiological overruns.	OPEX and CAPEX net volume measures.

The model with independent parameters will always result in the same or a higher efficiency score for all companies than the current model without security of supply. By introducing security of supply in the model through the model with independent parameters, parameters are added to the model, but the efficiency score can always be calculated by disregarding the added parameters. The model always uses the parameters that put the individual company in the best possible position, and the model can therefore never result in lower efficiency scores than in the current model without security of supply.

The challenge is not only theoretical, but also emerges from the empirical results for the model with independent parameters. If failures in security of supply are included with independent parameters, the efficiency scores increase significantly relative to the current model. The companies will always be able to achieve minimum the same score as in the model without the security of supply parameters. The average efficiency score is 0.76 in the current model, whereas it is significantly higher in the model with independent parameters with an average of 0.83, see Tabel 5.2.

Especially the companies that are most efficient with the current method experience the greatest increase in their efficiency score when the security of supply parameters are included in the model with independent parameters, and especially the frontier is significantly expanded in the model with independent parameters. In the specific case, the number of frontier companies increases from 6 to 19 companies when we add the security of supply parameters using the model with independent parameters. In this case, 13 companies will thus become fully efficient, solely by including the security of supply parameters in the model as separate parameters.

5.3 Socio-economic costs (D.2 and S.1)

In this model, we use the socio-economic costs of security of supply failures and add them to the companies' actual production costs in the benchmarking model. [33] This model has also been described in *Security of supply and regulation of the water sector* (The Danish Competition and Consumer Authority, 2021).[34] The model is similar to the current model, but the companies are no longer benchmarked solely on the basis of production costs, but also on the basis of the socio-economic costs of the companies' specific security of supply failures.

Box 5.3
Purpose of the model

The model with socio-economic costs model is to ensure that companies choose an optimal socio-economic security of supply level. The socio-economic optimal level depends on the cost to society of security of supply failures as well as the effective costs of ensuring security of supply. This means that, in addition to having a specific security of supply level, the companies must also provide this level in a cost-effective manner.

The socio-economic costs of security of supply failures are calculated on the basis of the willingness to pay and taxes described in Chapter 4. By multiplying these prices for security of supply failures by the companies' actual number of failures, a value for the socio-economic cost is calculated. This is the cost that is added to the companies' production costs (FATO) in the socio-economic model.

[33] The method is, for example, used in the regulation of the Norwegian electricity sector. Here, consumers' costs of unsupplied electricity are included as part of the company's costs in the economic benchmarking, see the Norwegian Water Resources and Energy Directorate (NVE) (2019)

[34] The analysis *Security of supply and regulation of the water sector* comprises a number of prudence considerations to reduce the effect on the revenue caps of integrating security of supply in the short term. In this analysis, we disregard such prudence considerations.

However, microbiological overruns are not included in this model. The estimate for the socio-economic costs connected with microbiological overruns is comparatively high relative to the costs for the other security of supply parameters. The high values can be reduced by including prudence considerations in the estimate, but this needs to be analysed further. The Danish Competition and Consumer Authority (2021 D) discusses various prudence considerations for the socio-economic cost of microbiological overruns.

By using the socio-economic model, we avoid that the number of dimensions increases when we add security of supply to the model, as was the case with the model with independent parameters. At the same time, this provides the companies with incentives for choosing an optimal security of supply level which is also cost effective.[35]

This is the only model of the presented models that gives the companies an incentive to act in a socio-economically optimal manner, thereby providing a socio-economically optimal security of supply level.[36] The challenge of the model is that it requires an estimate of the socio-economic costs for the relevant security of supply parameters. If a socio-economic cost cannot be linked to a given security of supply parameter, it is, however, possible to combine the socio-economic cost method with one of the other methods that is not conditional on a socio-economic cost having been calculated.

With a true and fair view of consumers' willingness to pay and thus estimates of the socio-economic costs, this method will therefore not only include the companies' costs for security of supply, but will also provide a further incentive for a socio-economically optimal security of supply level, which must be seen as an advantage relative to the other methods.

There is uncertainty connected with the calculation of the socio-economic costs of a lack of security of supply. Uncertainty in the estimate leads to similar uncertainty as to whether the model can provide the right incentives. If the uncertainty in the estimated willingness to pay is too high, the model may give the companies an incentive to focus on security of supply at a level that is not socio-economically optimal, and, in this case, it will not have an additional advantage relative to the other methods.

[35] To ensure that the companies have an incentive to commit themselves to the socio-economically optimal security of supply level in both the short term and the long term, this requires that the socio-economic costs are borne by the companies and are not simply included in the benchmarking. In the short term, the companies will not have an incentive to increase their security of supply level if the socio-economic costs are only included in the benchmarking and are not borne as actual costs. This problem arises because there is a recovery rate for the efficiency requirements currently made for the water companies and described in greater detail in *Security of supply and regulation of the water sector* (The Competition and Consumer Authority, 2021).

[36] Where the companies' marginal costs of security of supply for companies correspond to consumers' willingness to pay. [36] Read more about this in *Security of supply and regulation of the water sector* (The Danish Competition and Consumer Authority, 2021).

Box 5.4
Brief outline of model with socio-economic costs

In the model with socio-economic costs, the socio-economic costs connected with security of supply failures are added to the companies' production costs (FATO). Therefore, the model still has only one input, which now represents the total socio-economic costs of the companies' production.

With the right estimated socio-economic costs, the model gives the companies an incentive to achieve a socio-economically optimal security of supply level.

What does the model look like?

Input	Output
Sum total of FATO + socio-economic costs for water loss and interruption minutes.	OPEX and CAPEX net volume measures.

The socio-economic costs for the security of supply parameters are measured based on a number of factors, including by estimating consumers' willingness to pay to avoid security of supply failures.

The method can lead to both increases and decreases in efficiency scores relative to the current model without security of supply.

The empirical model with socio-economic costs generally produces results similar to those of the current model. This means that security of supply has an impact on the benchmarking, but not at a level at which it removes the incentive to streamline costs. Nor does it entail significant frontier changes when security of supply is included in the model with socio-economic costs for security of supply failures. Five out of six frontier companies are repeated in both models, see Tabel 5.2. We also see that the average score is very close to the average score from the current model. It should, however, be noted that the scores for the individual companies differ between the models, see Figur 5.1.

5.4 Weight restrictions (D.3)

In this model, we use weight restrictions to implement security of supply in the economic benchmarking. The method can only be used for DEA models, as the concept of 'weights' and thus also weight restrictions is not relevant for SFA models.

A weight restriction limits how much importance a single parameter may have in the calculation of the efficiency scores. Weight restrictions can be set for several parameters in the same benchmarking model. Weight restrictions can therefore limit the influence of the security of supply parameters on the companies' efficiency scores and can thus eliminate the dimensionality problem, which, with the model with independent parameters (D.1), resulted in an unrealistically large increase in the efficiency scores.

Box 5.5
Purpose of the model

The model with weight restrictions must ensure that companies with high security of supply are compensated for the connected additional costs. However, the model limits the compensation for the most extreme additional costs. The model does not provide an incentive for a specific security of supply level. This means that the companies are placed on an equal footing regardless of the security of supply level they choose. However, the connected cost of security of supply must be cost effective.

In the model with weight restrictions (D.3), we add all the security of supply parameters as separate parameters to the current DEA model in the same way as with the model with independent parameters. In addition, the security of supply parameters are subject to weight restrictions in the models to solve the problem that several parameters automatically increase the efficiency scores and the number of frontier companies (the dimensionality problem), which would otherwise lead to unrealistically high efficiency scores and an unrealistically high number of frontier companies.

In the model, we limit the ratio between the weighting of the security of supply parameters and the companies' costs (FATO). With this type of weight restrictions, we directly limit how much the companies' costs are allowed to increase when the security of supply parameters decrease (i.e. when the security of supply increases). The weight restriction is therefore relative and can be interpreted as limiting how much it may cost the companies to provide security of supply. It therefore also limits the increase in scores we see by moving from the current model to the model with independent parameters.

Just like in the model with independent parameters, the companies in the model with weight restrictions will always achieve the same or a higher score than in the current model.[37] However, it is possible to set the weight restrictions so that the efficiency score can both increase and decrease as a result thereof.

There is a flexibility in weight restrictions which makes it possible to define the overall framework for how large an effect security of supply is allowed to have, but which still gives a possibility for individual weighting of the parameters between the companies.[38] However, it is challenging to determine an expedient weight restriction if there is no knowledge of willingness to pay, production costs or the like, as, in such case, there will not be a basis for determining the weight restriction. In this analysis, we present a model that sets weight restrictions based on consumers' willingness to pay to avoid security of supply failures. The method is therefore similar to the model with socio-economic costs (D.2), but it allows the uncertainty about the estimate of the willingness to pay to benefit the companies that have poor security of supply. This method for setting weight restrictions is only one of many possible methods.[39]

Without estimates of the socio-economic costs, another option will be to define weight restrictions by using information about how important security of supply is to the companies' economic efficiency. In this way, an estimate of the business economic costs connected with security of supply is used instead. This can, for example, be achieved, through a so-called 'second-stage' analysis in which the correlation between the companies' level of security of supply and their economic efficiency is examined by means of regression analysis. If such an analysis produces significant results, we can estimate the importance of security of supply to economic efficiency. This can then be used to define the restriction – i.e. the weight restriction – for how important security of supply must be in the benchmarking model. Today, however, we cannot see any signs of a significant correlation between security of supply and the companies' economic efficiency (Konkurrence- og Forbrugerstyrelsen, 2021 A). We therefore do not present an empirical analysis of this type of weight restrictions.

[37] The reason for this is that the model weights the different outputs in such a way that the individual company is placed in the best possible position. The model can therefore weight one or more parameters with the value 0, which corresponds to the parameter not being included in the model for this company. The model will never weight the new parameters in a way that puts the company in a poorer position than if the parameter was not included.

[38] For a more detailed description of how weights occur in a DEA optimisation problem, see Appendix 2 The Danish Competition and Consumer Authority (2021 B).

[39] For empirical results for an alternative way of determining weight restrictions, see sub-analysis.

Box 5.6
Brief outline of model with weight restrictions

In the model with weight restrictions, the influence of the security of supply parameters on the efficiency score is limited by means of weight restrictions. In the specific model, we set an upper limit for how much the level of security of supply is allowed to 'weigh' in the model in relation to the companies' production costs. The specific weight restriction is based on the companies' willingness to pay. The weight restriction can be interpreted as a way of including security of supply in the benchmarking, but with the limitation that it must not cost the companies more to avoid security of supply failures than consumers are willing to pay.

What does the model look like?

Input	Output
FATO, Water loss, Interruption minutes and Microbiological overruns.	OPEX and CAPEX grid volume measures.

It should be noted that the model consists of the same parameters as the model with independent parameters (D.1). However, relative weight restrictions between the individual security of supply parameters and the companies' production costs (FATO) are added to the model.

Adding security of supply parameters to the model using weight restrictions can lead to both increases or decreases in the efficiency score, as the effect will depend on how the weight restrictions are set. With the specific method for setting weight restrictions that we use here, the model with weight restrictions for all companies will always result in the same or higher efficiency score than the current model without security of supply. This happens because, by introducing security of supply to the model with independent parameters, we only add parameters to the model with an upper limit on how important they are allowed to be. The efficiency score can therefore still be calculated by disregarding the added parameters.

In the model with the relative weight restrictions, the average efficiency score is 0.78, which is relatively close to the starting point in the current model, see Tabel 5.2. Especially companies that are already performing well in the current benchmarking experience an increase in their efficiency scores by including the security of supply parameters in the model with weight restrictions.

However, the increase is significantly below the average score of 0.83 from the model with independent parameters, where the security of supply parameters are added to the current model without weight restrictions. The model with weight restrictions precisely limits the unrealistically large increase in efficiency scores we see when using the model with independent parameters. This is particularly evident in the number of frontier companies, of which there are 19 in the model with independent parameters, but only seven in the model with weight restrictions.

5.5 Basis of comparison (D.4)

The basic principle of a model with a changed basis of comparison is that companies with *high* security of supply are not compared with companies with *low* security of supply. We assume that having a high security of supply level is costly, and that companies with high security of supply – and thus high costs – should generally not be compared with companies with low security of supply and correspondingly low costs.

This method has been developed for DEA models and will therefore not unambiguously provide the same incentives in the SFA model. In addition, it will require a large number of observations to change the basis of comparison in SFA, as the model requires a certain number of companies to provide a true and fair view. We therefore only present the method as a DEA model.

Box 5.7
Purpose of the model

The purpose of the model with a changed basis of comparison is to ensure that companies with high security of supply are not subject to an excessive efficiency requirement as a result of being compared with companies with low security of supply. The model does not provide an incentive for a specific security of supply level. This means that the companies are placed on an equal footing regardless of the security of supply level they choose. However, the connected cost of security of supply must be cost effective.

By using security of supply as a starting point for the companies' basis for comparison, we do not model security of supply directly in the benchmarking model. Instead, we use the companies' level of security of supply as a control variable for which companies are comparable with each other. This reduces the number of companies with which each company is compared in the benchmarking. We then apply the current economic benchmarking model to the reduced basis of comparison.

The basis of comparison is based on the companies' security of supply level. However, it is not unambiguous what security of supply covers, and, so far, we have primarily referred to security of supply as various security of supply parameters. By using several separate security of supply parameters to form the basis of comparison, the basis of comparison for the individual companies will, however, become very small, as a company will thus only be comparable with companies that have a higher security of supply level on all the individual parameters.[40]

We have therefore used a simplified approach, where we specifically use a weighted index of the separate security of supply parameters to describe the companies' overall security of supply level. We calculate the security of supply index using a simple average of the normalised parameters.[41] One of the challenges of this model is that we do not have enough information to weight the parameters. Therefore, we assume that the three security of supply parameters should be weighted equally. We thus assume that the costs connected with a normalised interruption minute are the same as the costs connected with, for example, a normalised microbiological overrun.

Box 5.8
Brief outline of model with basis of comparison

In the model with a changed basis of comparison, the security of supply parameters are used to determine which companies should, as a minimum, be comparable. Assuming that a higher security of supply level is costly, a company can only be compared with companies with a higher security of supply level than their own. Companies with a lower security of supply level will not have spent the same costs on security of supply. It is therefore not reasonable to compare a company with companies that have a lower security of supply level, as they will generally appear more economically efficient due to their lower security of supply costs.

What does the model look like?

Input	Output
FATO.	OPEX and CAPEX net volume measures.

[40] See The Danish Competition and Consumer Authority (2021 B) for a review of other ways of defining the basis of comparison based on the security of supply parameters.
[41] See The Danish Competition and Consumer Authority (2021 B) for a detailed review of the method.

It should be noted that the same parameters are included in this model as in the current model. However, in this model, not all companies are included in an overall model, as the companies' security of supply level, determined using a security of supply index, decides the basis of comparison individually for each individual company.

The method will always result in companies achieving at least the same score as in the current model, as the method can only *reduce* the number of companies with which each company is compared, which will always lead to the same score or an improved score.

Results from the empirical model show that the results from the model with a changed basis of comparison are generally close to those from the current model. The average efficiency score increases from 0.76 in the current model to 0.79 in the model with a changed basis of comparison, and the number of frontier companies increases from six to eight. With this method, however, there will still be some companies that experience relatively large increases in their efficiency score if the company has a low economic performance, but a high security of supply level, which means that they can only be compared with a few other companies.

Chapter 6
Discussion and recommendation

Based on the analysed methods, we discuss the possibilities of integrating security of supply in the economic benchmarking of water companies in Denmark. On the basis of these discussions, we recommend which methods are best suited for such integration.

Table 6.1 shows the five overall issues that a benchmarking model with security of supply must be able to address. The issue of *accurate requirements* describes how good the various benchmarking methods are at finding the company's true efficiency score. *Desired incentives* describe whether the methods provide an incentive to streamline costs. *Handling of multiple and special parameters* describes whether the methods are suitable for handling security of supply parameters that may be special. *Data quality* describes the extent to which the model can handle any data uncertainty. *Model complexity* describes how complicated the theory used in the methods is.

The table shows how each model addresses each of these issues. The table shows that none of the models scores highest on all issues, but that they have different strengths and weaknesses.

However, the socio-economic model scores high on both accurate requirements, desired incentives and the possibility of handling multiple parameters in the model. With a fairly accurate estimate of the socio-economic cost associated with security of supply failure, the socio-economic model is therefore also the preferred model.

However, both the model with weight restrictions model and with other basis of comparison are useable if there are significant security of supply parameters that need to be taken into account in the economic benchmarking, but where there is no accurate estimate of the socio-economic costs connected with the parameter.

The individual issues are discussed in the remaining part of this Chapter. The methods can be combined in one benchmarking model. This means that if multiple security of supply parameters are to be included in the benchmarking, it is possible to incorporate one parameter by using one method, while another security of supply parameter in the same benchmarking model is used by incorporating another method.

Table 6.1 **Model overview**

	Independent parameters	Socio-economic model	Model with weight restrictions	Model with other basis of comparison
Accurate requirements	Red	Green	Green	Yellow
Desired incentives	Yellow	Green	Yellow	Yellow
Handling of multiple and special parameters	Red	Green	Yellow	Yellow
Data quality	Yellow	Yellow	Yellow	Yellow
Complexity of the model	Green	Yellow	Red	Yellow

Note: The table shows how well the model handles significant problems. Green indicates that the model is good, yellow that there is uncertainty, but that the model can handle it, and red indicates that there is a significant drawback.

Source: Own production

6.1 Accurate requirements

All the presented models have been developed to lay down accurate requirements. It can nevertheless be argued that some models are *more* accurate than others when it comes to incorporating security of supply.

The model with independent parameters (D.1) and the model with another basis of comparison (D.4) are models that take security of supply into account in such a way that no company risks having too low efficiency scores in relation to the economic benchmarking model used today. The reason for this is that the companies that are efficient today will remain efficient in these models. Conversely, this also means that there is a significant risk that efficiency scores will become artificially high for the companies that have very high security of supply and concurrently poor economic efficiency. The reason for this is that the companies in the models can be assessed as fully efficient solely because of their high security of supply. This may ultimately result in excessively high water prices for undertakings and consumers.

With the socio-economic model (D.2) and the model with weight restrictions (D.3), we will, in theory, be able to set more accurate requirements than today without consumers risking unnecessarily high prices, for which there is a risk in the models with independent parameters (D.1) and other basis of comparison (D.4). However, this means that the companies will have a greater risk of having too stringent efficiency requirements if the model does not provide accurate estimates. This risk can be handled if the models include prudence considerations for the companies. Such prudence considerations are already today used in the benchmarking which address the main uncertainties in the models.

The socio-economic model (D.2 and S.1) is theoretically the most accurate of the four models and also has the fewest empirical challenges. To the same extent as the current model, the socio-economic model lays down accurate requirements for the companies' production costs while taking security of supply more into account.

Empirical results show that the model with weight restrictions (D.3) on average estimates efficiency scores that are slightly higher than in the socio-economic model (D.2 and S.1). This may be an advantage *if* there is great uncertainty in the estimates of the socio-economic costs, because the companies are thus not subject to too high model-related risk, which may result in too high requirements[42]. In other words, the model with weight restrictions may constitute a form of prudence consideration towards the companies, for example if there is significant uncertainty about the socio-economic costs of a security of supply parameter.

Our overall assessment is that both the socio-economic model and the model with weight restrictions (D.2, S.1 and D.3) lay down accurate requirements for the companies based on their security of supply. In both models, it is possible to achieve a sufficient weighing between the consideration for economic efficiency and high security of supply without this entailing a risk of unnecessarily high prices for consumers. For the model with independent parameters (D.1), there is a significant risk that the company's efficiency score will be too high, to the detriment of consumers. We therefore find that it does not lay down accurate requirements. Likewise, there is a risk that the model that uses a different basis of comparison (D.4) calculates too high efficiency scores. However, it is possible to reduce that risk by using a normalised index of the security of supply parameters, see Chapter 5.5.

6.2 Desired incentives

Whether it is an advantage to integrate security of supply in the economic benchmarking model depends, in particular, on whether the chosen model provides the companies with a well-founded and true and fair economic incentive for a high security of supply level, and whether the companies are concurrently faced with accurate requirements for their economic efficiency based on their security of supply level[43].

Overall, the socio-economic model (D.2 and S.1) provides the most true and fair incentives to improve security of supply, as they take into account the cost to society of security of supply failures. The remaining models (D.1, D.3 and D.4) do not provide incentives for a socio-economically optimal security of supply level, but for improving the existing incentive to have a high security of supply level.

Incentives in models that do *not* use socio-economic costs

The three models which do *not* use socio-economic costs (D.1, D.3 and D.4), challenge the incentive structure for improving security of supply. This means that the companies have a low incentive to improve their security of supply. In some cases, the models may even provide an incentive to reduce security of supply. Which incentive the company has depends in particular on how expensive it is for the company to improve its security of supply.

We assume that it costs money to increase security of supply. Therefore, the companies' incentives depend on how much it will cost them to increase their security of supply relative to the companies with which they are compared.

A company has an incentive to increase its security of supply if it can do so at a lower cost than the companies that make up the frontier. The reason for this is that, by improving its security of supply, the company thus improves its efficiency by moving closer to the frontier. If, conversely, it is more expensive for the company to increase its security of supply than it is for the frontier companies, increasing the security of supply will put the company in a poorer position in the benchmarking because higher costs for security of supply will move them further away from the frontier – other things being equal. In other words, this means that the company can technically improve its efficiency score by reducing its security of supply. The methods can

[42] Model-related risk can also result in too low requirements. The model with weight restrictions does not solve this challenge.
[43] This is further described in Chapter 3.

thus mean that companies that have high security of supply costs may have an incentive to reduce their security of supply.

Our assessment is that the three models that do not use socio-economic costs (D.1, D.3 and D.4) do not fully provide the desired incentives for a high security of supply level. However, they provide better incentives than the current benchmarking model, and it may therefore still be an advantage to use these models.

Incentives in models *with* socio-economic costs

The incentives in the socio-economic model (D.2 and S.1) differ from those used in the remaining models. Here, security of supply is included as a socio-economic cost that is added to the companies' costs. This means that the companies have an incentive for a high security of supply level.

Under this model, the companies will have to pay the actual socio-economic costs if there is to be the right economic incentive. This means that if the company's security of supply level has a cost for the consumers (a socio-economic cost), the company must repay that cost (an economic sanction) to the consumers. When this sanction is included in the company's total costs, which form part of the benchmarking, companies with low security of supply will have a relatively poorer efficiency score than those with high security of supply.

A benchmarking model with socio-economic costs will thus provide the companies with an incentive to have a socio-economically optimal security of supply level. To avoid paying a sanction for poor security of supply, the company has an incentive to improve its security of supply. The security of supply will be increased to a level at which further improvement is more expensive than the sanction that will be imposed on the companies. This is the socio-economically optimal level. Proposed models for setting such a sanction are described in the analysis *Security of supply and regulation of the water sector* (The Danish Competition and Consumer Authority, 2021).

The socio-economic model (D.2 and S.1) thus provides the companies with good incentives for improving their security of supply[44].

6.3 Can the model handle multiple and special parameters?

The benchmarking methods used must be able to handle multiple and special parameters. Our analyses show that these are challenges that mean that some of the analysed benchmarking methods are not directly applicable, while other methods can handle the parameters to a sufficient extent.

If security of supply is to be integrated in an economic benchmarking model, it must be expected that the number of parameters in the model will increase, other things being equal. At the same time, the security of supply parameters will be special parameters due to how they are measured and the fact that many companies' consumers will not experience a security of supply failure (called 0 parameters). This may present challenges in a benchmarking model.

[44] It is a prerequisite that there is knowledge of the values of the socio-economic costs. The challenges that may exist in finding these values are described in section 1.4.

Overall, these challenges do not arise in the socio-economic model (models D.2 and S.1). In the remaining models (D.1, D.3 and D.4), where security of supply is incorporated as new parameters, the challenge occurs to varying degrees. Especially in the model with independent parameters (D.1), where security of supply is included as additional parameters without conversion, the challenges mean that the model is not usable.

Multiple parameters (dimensionality problem)
In a benchmarking model, the number of parameters and the number of companies included in the database have a major impact on how good a method is; few companies combined with many parameters may challenge the precision of the model. This is referred to as the dimensionality problem[45]. In the Danish water sector, approximately 75 companies are included in the benchmarking model for water companies and 105 for waste water companies. The relatively low number of companies means that it is important to pay attention to the dimensionality problem when adding more parameters.

The dimensionality problem is of central importance because it can make the efficiency scores so uncertain that they do not provide a true and fair view. In most cases, this will mean that the companies' efficiency scores are overestimated, to the detriment of consumers, see above regarding true and fair requirements[46]. The dimensionality problem is further described in Chapter 5.

The dimensionality problem is a challenge in the model with independent parameters (D.1) as well as the models with weight restrictions and other basis of comparison (D.3 and D.4), while the problem does not arise in the socio-economic model (D.2 and S.1). In the model of independent parameters (D.1), the problem is particularly great because the security of supply parameters are included without any conversion. In the model with weight restrictions (D.3), the weight restrictions precisely reduce the problem, while, in the model with other basis of comparison (D.4), we merge the security of supply parameters, which reduces the problem, though without eliminating it entirely. In the model with socio-economic costs (D.2 and S.1), the dimensionality problem does not arise because no new parameters are added. This is a significant advantage of this model.

The challenges regarding the dimensionality problem are of central importance to whether a method can be applied. Considering this, we judge that the model with independent parameters (D.1) is not suitable for integrating security of supply, whereas the models with weight restrictions and other basis of comparison (D.3 and D.4) sufficiently handle the problem for the models to be usable. However, the models with socio-economic costs (D.2 and S.1) are the most useful because the problem does not arise.

Special parameters may be a problem in model with independent parameters and model with weight restrictions
As previously described, the security of supply parameters are events that consumers want to avoid, such as supply interruptions. This type of parameter, which describes something undesirable, can be difficult to incorporate in a benchmarking model.

[45] The term 'dimensionality problem' is primarily used about Data Envelopment Analysis (DEA) in the literature. In Stochastic Frontier Analysis (SFA), it is referred to as challenges with the number of degrees of freedom. But as the challenges in DEA and SFA are the same, we have chosen to refer to it as the dimensionality problem for both methods.

[46] Especially for DEA methods, efficiency scores are estimated too highly. For SFA, the dimensionality problem means that the efficiency scores generally become more imprecise, both upwards and downwards.

In the models in which the parameters are incorporated directly (the model with independent parameters as well as the model with weight restrictions (D.1 and D.3)), such negative 'supplies' are handled as *undesirable outputs*, which can be a challenge. The socio-economic model (D.2 and S.1) and the model with limited basis of comparison (D.4) do not entail the same challenge.

In the model with independent parameters (D.1) and the model with weight restrictions (D.3), we have chosen to handle the undesirable outputs by including them as inputs. Inputs are characterised by companies and consumers wanting a low value, which is also the case for the security of supply parameters.[47]

When we use security of supply as inputs in the model, this means that the underlying assumptions about security of supply change characteristics. Normally, we would assume that the companies use costs to produce an output together with a certain security of supply level. Now, we implicitly assume that the companies produce an output by applying a volume of costs as well as a security of supply level. This leads to three new assumptions about the models:

1) When the security of supply parameters increase, the company's output must also increase. If this is not the case, the company will appear as inefficient. We find this assumption to be realistic, as companies with a high output have several stretches and areas in which security of supply failures may arise.

2) The companies must have a trade-off between their costs and security of supply. We thus assume that it is costly to increase the security of supply – for example reducing the number of interruption minutes. This means that companies can, for example, choose to lower their costs at the expense of poorer security of supply, but still produce the same output. Conversely, companies can achieve better security of supply against increasing their costs and thus continuing to produce the same output. In our opinion, this assumption is also realistic.

3) Finally, we assume that the companies can always reduce their security of supply without changing either costs or output.[48] Although the companies obviously have no interest in doing this, it is an important underlying assumption when estimating the model.

   We assess that the assumption is met for the parameters interruption minutes and microbiological overruns, but not necessarily for water loss. If the companies increase their water loss, they will, in fact, need to pump more water into the system to continue supplying the demanded volume of water. This will increase both their costs and their output.

   We cannot measure how crucial a breach of this assumption is in practice, but we do not expect it to be of decisive importance to the final results. The reason for this is that the costs for the extra pumped water volume only represent a small part of the companies' total costs. This means that the assumption holds true for the majority of the costs.

[47] The so-called undesirable outputs are a recognised problem in the scientific literature for benchmarking studies. There are several views on how they can be included in a model, but there is not yet a consensus on one single correct way of handling them.
[48] The assumption is only relevant in DEA.

Alternative models for handling undesirable outputs also face a number of challenges. We therefore assess that this method for handling the undesirable outputs as inputs is best suited for use in the economic benchmarking model for the Danish water sector.[49]

All models thus handle the specific security of supply parameters adequately.

'0 parameters' may be a problem in model with independent parameters and model with weight restrictions

A number of companies have not experienced a failure in their security of supply and therefore do not have any interruption minutes and/or microbiological overruns. In those cases, the parameter will have a value of 0.

Parameters with a value of 0 constitute a challenge in the models in which security of supply is included as independent parameters. Security of supply is included as an independent parameter in the model with independent parameters (D.1) and the model with weight restrictions (D.3).

For mathematical reasons, companies with a so-called 0 parameter can only be compared with other companies that also have a value of 0 on the same parameter[50]. This will mean that the model places these companies in an artificially favourable position because they are only comparable with a few other companies. In the extreme case in which only a single company has one parameter with a value of 0, this company will always be regarded as fully efficient.

In the model with independent parameters (D.1), this is a challenge that we cannot solve. For the companies which have a value of 0 for one of the security of supply parameters, there is a significant risk that these companies will be placed in an artificially favourable position in the model as a result thereof.[51]

In the model with weight restrictions (D.3), the problem is reduced by our introduction of weight restrictions. Depending on how these weight restrictions are determined, companies that have a value of 0 for a parameter may well be compared with other companies that do not have a value of 0 for the parameter. However, this will not always be the case, and we therefore risk continuing to calculate artificially high efficiency scores for some of these companies.

The challenge of 0 parameters will always mean that the companies are placed in a more favourable position, i.e. that the efficiency score is overestimated. This is to the benefit of the companies, but is potentially to the detriment of consumers. Nevertheless, our assessment is that this issue is not of decisive importance to the choice of models, although 0 parameters represent a challenge in the model with independent parameters (D.1) and in the model with weight restrictions (D.3). However, it is important to be aware of the problem and continuously analyse the impact thereof on the companies that are affected by it. This is to ensure that consumers do not pay unnecessarily high prices.

[49] For a general discussion of the handling of undesirable outputs, see Dakpo, Jeanneaux, & Latruffe (2016) or Scheel (2001).

[50] This applies to DEA models and only to parameters that are included as inputs (or, in our case, undesirable outputs) in the model.

[51] The empirical analyses show that there are relatively many companies with a value of 0 for microbiological overruns. For all these companies, there will be a possibility of comparison with others. This will reduce the risk of the score being overestimated. However, for interruption minutes, there are only a few companies with a value of 0, which increases the risk of overestimation.

However, the challenge means that models that are not affected (the socio-economic model and the model with other basis of comparison (D.2, S.1 and D.4)) are better alternatives regarding this problem.

6.4 Importance of data quality

Regardless of the benchmarking methods used to implement security of supply, data and data quality are essential. The better the data quality, the more valid the benchmarking results. Furthermore, the models that use socio-economic costs are sensitive to the socio-economic costs having been correctly estimated.

Quality of security of supply data
The companies have reported financial data to the regulator since the economic regulation was introduced in 2009. Since then, the quality of economic data has continuously improved. The data quality for security of supply has not previously been used for regulatory purposes, but only for a dialogue between water companies and their owners. Therefore, the quality of these data is not equally high.

Therefore, we expect that the data quality for security of supply must be improved on an ongoing basis if security of supply is to be integrated in the benchmarking in the future, see Chapter 4.

Therefore, both the sector and the regulator must use more resources to collect and quality check data.

External impact on security of supply
Security of supply failures may occur for a number of reasons. In this analysis, we assume that all security of supply failures can be attributed to the companies' own responsibility. This may, for example, be poorly maintained pipelines, weak asset management or general human errors.

However, security of supply failures may also have external causes, for example if a contractor hits a water pipe or because of extreme weather conditions. This means that, in certain cases, companies may experience poor security of supply, even though they focus strongly on having a high level. If it is possible to determine who is responsible for a security of supply failure, we can use this information to include only those failures for which the companies can be regarded as responsible. However, we do not yet have enough data to incorporate this.[52]

Estimation of socio-economic costs
Socio-economic costs are directly included in the socio-economic model (D.2 and S.1). Socio-economic costs can also be used to set weight restrictions (D.3). The estimation of socio-economic costs affects the results of the models and the associated incentives. It is therefore important that the socio-economic costs are accurately estimated.

In our analysis, we use willingness to pay, which is estimated in 'Consumer willingness to pay for improvements in the water sector' (Konkurrence- og Forbrugerstyrelsen, 2020 A), as well as the tax for water waste from the environmental regulation (Miljøstyrelsen, u.d.) to describe

[52] It is often not possible to establish the responsibility, as there may be several concurrent causes of a failure. For example, poor mapping of pipelines may be the reason why a contractor hits them.

the socio-economic costs. The estimated willingness to pay is positive and significant, but still contains some uncertainty.[53]

If there is uncertainty about the estimates of willingness to pay, this will have a direct impact on the validity of the benchmarking model. The willingness to pay is estimated on the basis of hypothetical choices by consumers. There will always be some uncertainty about willingness to pay when this concerns services not sold in a well-functioning market.

A sustained focus on updating the estimates for willingness to pay is therefore necessary. The updates must ensure that the willingness to pay reflects, to the greatest possible extent, the actual willingness to pay that underlies the security of supply parameters and their development. At the same time, a continuous update can be combined with a continuous development of the estimates, so that, over time, they can contain multiple factors such as consumer type, demographics, time of day, etc.

6.5 Complexity of the model

When security of supply is integrated in our benchmarking models, they become more complex, as we use more technical benchmarking tools than in a model without security of supply. More advanced models may present challenges for several reasons:

Firstly, it is more time-consuming for the regulator to develop, maintain, implement and explain models and their incentives, the more advanced they become. This requires the use of more resources by the regulator.

Secondly, the companies must likewise use more resources to understand the model. If the companies do not understand the model *overall*, it is difficult for them to grasp its incentives and arrange their decision-making behaviour accordingly. It is not the objective and it is not necessary that all companies understand all technical aspects of the models; nor is this the case today. But a more advanced model requires even greater confidence among the companies that the regulator applies the most expedient model and shows the necessary considerations.

We find that both the regulator and the sector can generally handle models that are more advanced.

In the model with independent parameters (D.1) and the socio-economic model (D.2 and S.1), we do not use any other benchmarking tools than those used in the current benchmarking model, as the security of supply parameters are simply added. The models are therefore not regarded as being much more complicated than the current model. In the models with weight restrictions (D.3) and other basis of comparison (D.4), the parameters are also added without conversion. However, because new benchmarking tools are used to reduce the challenges this presents (the dimensionality problem), the complexity increases significantly. Especially the model with weight restrictions (D.3) will make great demands on the regulator and the sector.

[53] In our current benchmarking model, we do not include security of supply. This can be interpreted to mean that we implicitly assume that the willingness to pay is DKK 0. We assess that the estimated, positive and significant willingness to pay gives a more true and fair view than using a willingness to pay of DKK 0.

In the socio-economic model (D.2 and S.1), the challenge lies mainly in how the socio-economic costs are estimated. This places requirements on the regulator to make the method transparent.

6.6 Recommendations

It is possible to integrate security of supply in the current benchmarking models in a way that provides an incentive for socio-economically optimal security of supply levels.

The analysis results show that the integration will result in more accurate efficiency requirements than today, while also encouraging continued high security of supply in the water sector, as it gives the companies an increased economic incentive for security of supply.

If specific security of supply parameters are incorporated in the economic benchmarking model, it is of central importance that the choice of method is based on a specific assessment of which method is best suited for the specific parameter. This will include an assessment of the data quality for the parameter, the extent to which there is an accurate estimate of the socio-economic costs, and how important the individual security of supply parameter is for both the company and society.

The benchmarking model uses two overall benchmarking methods; DEA and SFA. The results of the analysis show that there are differences in how security of supply parameters are best incorporated.

In the same benchmarking model, it is possible to use different benchmarking methods for different parameters concurrently. This means that parameters with an estimated socio-economic cost can be incorporated with the socio-economic method, while parameters without an estimated socio-economic cost can be incorporated with other methods.

Overall recommendations
Recommendations based on the results of the analysis are listed in Box 6.1.

Box 6.1
Recommendations

Recommendations

» For security of supply parameters where sufficiently accurate socio-economic costs have been estimated, the socio-economic model (D.2 and S.1) is used.

» For other significant security of supply parameters that prove necessary to take into account in economic benchmarking and where socio-economic costs have not (yet) been estimated, the models with weight restrictions or changed basis of comparison (D.3 or D.4) are used.

» A benchmarking model in which security of supply is integrated as independent parameters (D.1) is not expedient, as it does not concurrently set accurate efficiency requirements.

» Further work is being done to improve the data quality and calculate socio-economic costs for security of supply parameters of importance to consumers, undertakings and the water companies' finances.

Appendix A
Incentives for efficient companies in the current regulation

If companies are fully efficient, i.e. they are at the frontier of the sector in question, illustrated by company A in Figur 3.1, they do not have the same incentive to reduce their security of supply in order to reduce their costs as company A. The reason for this is that company A does not have an efficiency requirement that needs to be recovered. If they nevertheless reduce their costs, the frontier will simply move so that the effective cost level in the sector becomes correspondingly lower.

However, there is another factor that means that efficient companies may also have an incentive to reduce their costs by reducing their security of supply. The reason for this is that a recovery rate of eight years is used – i.e. it is assumed in the setting of the benchmarking-based individual requirements that companies with a potential for efficiency improvement can become fully efficient in eight years. In other words, they must streamline $\frac{1}{8}$ of their inefficiency per year (Konkurrence- og Forbrugerstyrelsen, u.d.).

This means that the efficient companies, just like the inefficient companies, may have an incentive to reduce their security of supply. We show this with a simple example in Figur 7.1.

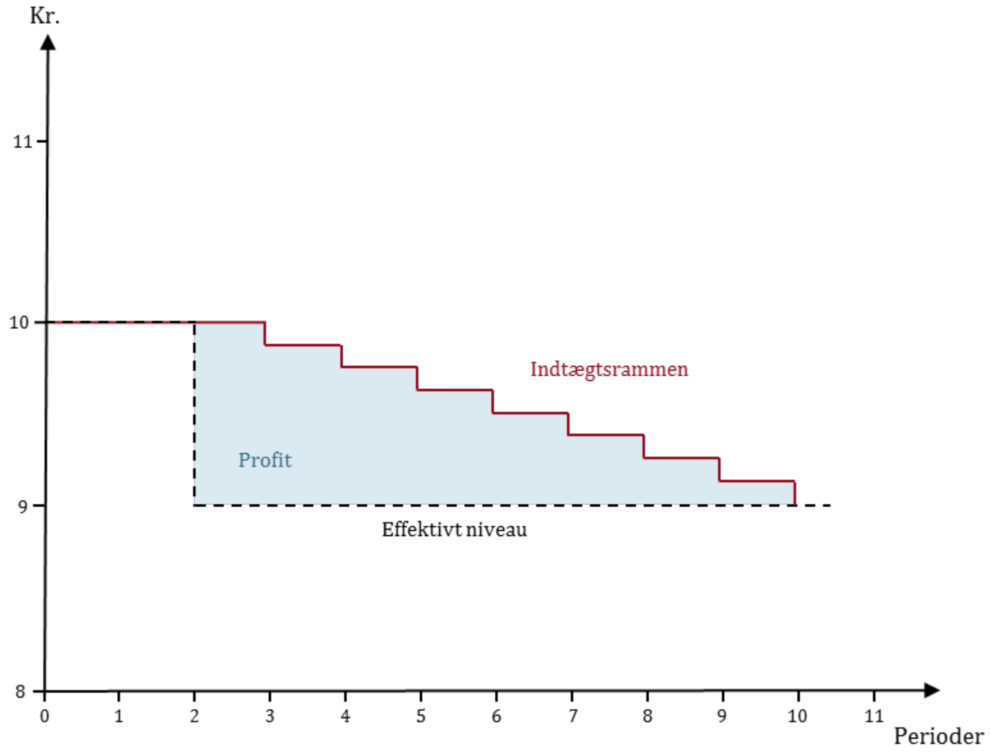
Example: Assume that the efficient company A has a revenue cap of DKK 10 from period 0 to 2 indicated by the red line in Figure 7.1. Further, assume that the company also has actual costs of DKK 10. As the company is efficient, the frontier and the effective level are calculated on the basis of the company's own costs. This means that the company's effective level is also DKK 10 in periods 1 and 2 indicated by the black broken line and the red line following each other during this period.

In period 2, company A chooses to reduce its security of supply by a value corresponding to its costs falling by DKK 1 in all future periods. This means that the effective level decreases correspondingly by DKK 1 as shown in the figure.

However, the company's revenue cap does not follow the cost reduction. Ideally, the revenue cap must be equal to the company's effective level. In fact, this means that the company will not be permitted to charge more than necessary from consumers. However, due to the eight-year recovery rate, the revenue cap will not be set equal to the effective level. In turn, the revenue cap will only decrease by 1/8 of the reduction for the effective level. The following year, the revenue cap will decrease by another 1/8, and only after eight years will the revenue cap again be equal to the effective level. This can be seen in the figure by the red line and the broken line only meeting each other in period 10.

Based on the above, there is a mismatch between a reduction in the company's costs and the accompanying reduction in the revenue cap. This gives the company a profit equal to the area marked in the figure. The area covers a profit for the company of 8/8 of the decrease in the effective level in the first year, 7/8 in the second year, 6/8 in the third year, etc. Over eight years, this gives an overall profit of DKK 4.5.

Figure 7.1 **Correlation between effective level and revenue cap for an efficient company**



Note: The figure shows how reducing the effective level of an efficient company gives the company a profit. The figure is simplified so that some details that are not relevant to the discussed issue have been omitted.

Source: Own production

Efficient companies are therefore allowed to overcharge as a result of a reduction in security of supply, which gives them an incentive precisely to make this reduction[54].

[54] It should be noted that we do not know the companies' actual security of supply costs. It is therefore not possible to correct the recovery rate or the model for this.

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