STENA2012 – Benchmarking TenneT TSO 2007-2011

A REPORT PREPARED FOR ACM

July 2013

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Contents

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1 Introduction

1.1 Background

Regulatory benchmarking has been informing the tariff regulation for TenneT TSO ("TenneT") since 2005. In the absence of national comparators, the international regulatory benchmarking ECOM+ and e3grid in 2003, 2005, 2008 and 2012 with extensions in 2006 and 2010, were used as basis for the determination of the individual X-factor during the second, third, fourth and fifth regulatory periods.

Frontier/Sumicsid/Consentec are currently undertaking a European electricity transmission system operator benchmarking study on behalf of Bundesnetzagentur and other European regulators (including ACM). That study, e3grid2012, consists of two phases:

- *Generic benchmarking analysis* – in this phase the benchmarking study is based on generic assumptions, which may deviate from the national regulatory settings.
- *Country specific analysis* – in this phase the benchmarking study takes into account country specific factors based on national regulatory settings.

Phase two (*country specific analysis*) is to be initiated on request from national regulators and this study is in response to ACM's request to country-specific analysis for the Netherlands.

1.2 Our tasks

The Dutch regulator, ACM, has commissioned Frontier/Sumicsid/Consentec to undertake phase 2, the country specific analysis, for the Netherlands: the STENA2012 project. This includes *inter alia* the robust calculations of static incumbent cost efficiency.

The analysis is to use parameters (interest rate, life time, asset groups) set by ACM, where these parameters may differ from those used in the e3grid2012 study.

1.3 Milestones STENA2012

In the following we list the main milestones for the STENA2012 project.

Table 1. Milestones STENA2012

Milestone	Date
White Paper	21 May 2013
1.STENA2012 Workshop	24 May 2013
2.STENA2012 Workshop	24 June 2013
STENA2012 draft report	17 July 2013
STENA2012 draft report (update)	24 July 2013
STENA2012 final report	25 July 2013

Source: Frontier/Sumicsid/Consentec

1.4 Organisation of report

The report is organised as follows:

- **Section 2** discusses TenneT specific challenges which are addressed in the STENA2012 project.
- **Section 3** discusses the e3grid2012 model specification and the adjustments for STENA2012.
- **Section 4** discusses the specific Runs in STENA2012 and the results.
- **Section 5** summarizes the analysis.

2 TenneT – Specific challenges

In terms of responsibilities and organization, TenneT does not differ fundamentally from the average European TSO. The main differences are in terms of:

- **Asset base** – TenneT is responsible not only for the EHV grid. It also has a HV network operating at the 110kV-150kV level.
- **Operating area** – TenneT has the second smallest service area in the international sample while it serves an area with a large population which may result in population density driven costs.

In addition, TenneT has raised several other potential operator-specific conditions through the e3grid Call Z process with regard to incremental costs due to soil type and coastal area. These claims were partly accepted in the e3grid2012 project and respective incremental costs were deducted from TenneT's cost base (thus allowing TenneT to enter the benchmark with a lower cost base).

2.1 Asset base – EHV and HV grid

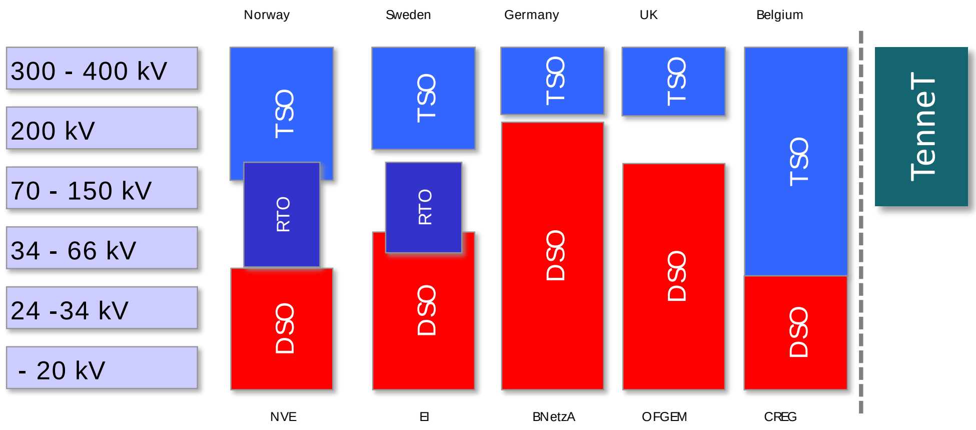
In this section we discuss the challenges to TenneT as they relate to its asset base.

2.1.1 TSO operating HV grids

The inclusion of HV activities (110kV-150kV) in a TSO is not unique to TenneT (**Figure 1**):

- HV activities within a TSO – For example, the French TSO RTE has a variety of EHV and HV even MV activities in its networks.
- Separate HV activities within a regional transmission operator (RTO) – In Norway and Sweden, intermediate HV voltage levels are operated by regional transmission operators (RTOs).

Figure 1. International outlook of electricity network vertical separation



Source: Frontier/Sumicsid/Consentec

The combined asset database of the e3grid2012 study includes data of several thousand km of cable and lines at or below 70 kV for other TSOs apart from TenneT.

The e3grid2012 sample reveals (**Figure 2**, TenneT is represented by the red point):

- The majority of TSOs have at least a small positive share of HV assets.
- 10 out of 22 TSOs have HV assets[1] in excess of 10% of its total assets/cost.
- 4 TSOs have a higher share of HV assets than TenneT.
- There is a subset of five operators with a significantly higher share of HV assets compared to the total European average[2] (17.4%) as well as the average per operator (19.8%)[3]. There is another subset of five operators with a slightly higher share of HV assets above the average. However, we also note that not all TSOs in the subset have delivered data in sufficient detail to allow detailed analysis of costs at the HV level.

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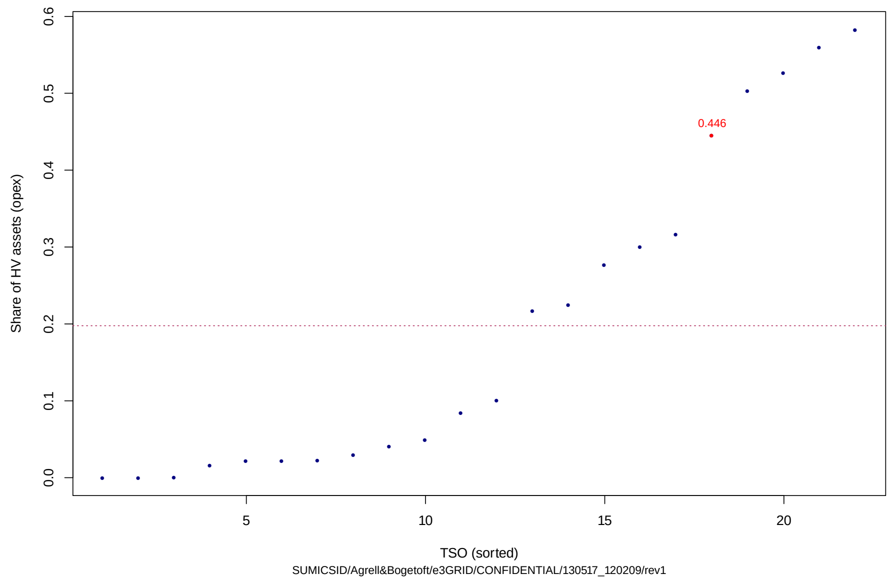
1 Defined as assets with voltage level below and equal 150 kV.

2 Defined as: European average = HV assets for all TSOs / total assets for all TSOs. The assets are weighted by the opex weights.

3 Defined as: operator average = (SUM over TSO's {HV assets per TSOs / total assets per TSOs}) / number of TSOs. The assets are weighted by the opex weights.

Figure 2. Shares (normalised opex) of HV assets (R1/2011) for e3grid 2012



Source: Frontier/Sumicsid/Consentec

It is therefore also important to ensure that the (relative) costs for HV and EHV are correctly estimated.

2.1.2 Scope of network functions

From an economic perspective, not only the voltage level of the TSO matters for the benchmarking analysis, but also the scope of the operation and the related design of the network. In terms of network layout we distinguish between:

- DSO networks that are radial;
- passive grids serving transportation purposes only; and
- TSO networks that are meshed network subject to active control and serving also supply security tasks.

Thus, the definition of the scope of the efficiency analysis (i.e. distinguishing between TSOs and DSO) may be more important than just a distinction between *asset specificity* (i.e. the voltage level at which lines are operated).

This distinction has indirectly also already been discussed as part of the e3grid2012 study (**Figure 3**). In the e3grid2012 assessment, the total expenditure for the transmission system operators is analysed for a subset of TSO activities including only:

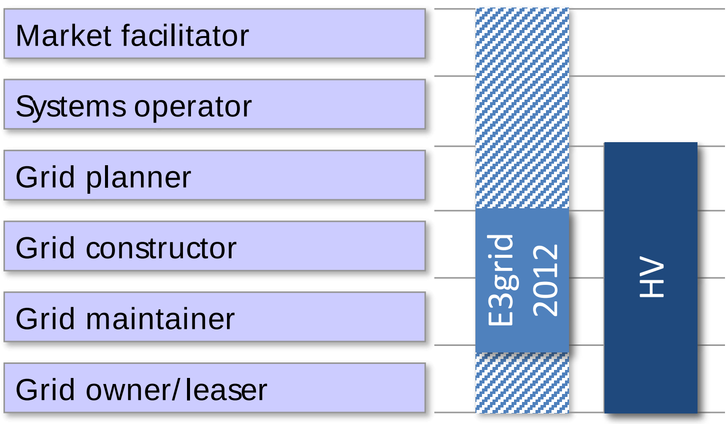
- Grid constructor; and

- Grid maintainer.

The other three TSO activities – Market facilitator, System operator, Grid planner, Grid owner/leaser – were deliberately excluded from the e3grid2012 benchmarking analysis.

By contrast, for a cost benchmark of distribution system assets at the HV level, the scope is limited *a priori*, as the Market facilitator, System operator activities are typically not performed at the HV level. The benchmarking analysis will likely focus on the activities Grid planner, constructor, maintainer and owner from **Figure 3**.

Figure 3. Evaluation scope for e3grid2012 and HV operations



Source: Frontier/Sumicsid/Consentec

2.1.3 Services of Regional Transmission

The design of the transport service is based on principal power system economics: The transportation of electricity generates losses that are inversely proportional to the voltage level. Thus, for a specific range of transportation distances and energy volumes, it is optimal to transport energy at medium (MV) or high (HV) voltage rather than low (LV) or extra-high (EHV).

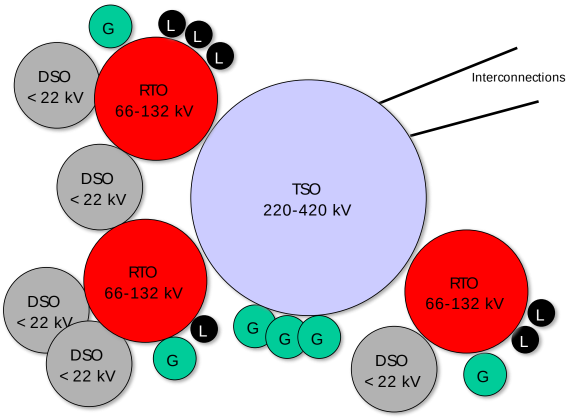
This explains why there are sub-transmission networks in all modern power systems, usually in the range 60-130 kV. However, HV networks may differ substantially from each other, for a number of reasons:

- Function and structure – Some HV networks operate mainly unidirectional flows from the transmission to the MV distribution networks. Others serve to connect medium scale power stations as well as distribution networks and thus are more similar to transmission networks;

- Cable vs. overhead line – Cables are rare assets in today's EHV networks. Due to a more favourable cost ratio, the share of cables is much higher in HV networks. From one HV network to another the cable share may differ significantly. For instance, cables are often used in urban/metropolitan areas. Other SOs have opted for cables with the aim of improving quality of supply or to shorten authorisation procedures.

The relatively wide spectrum of types and functions of HV networks makes it more challenging to measure the efficiency of HV networks in an isolated way (i.e. as separate activities). In fact, networks usually have been (and are still being) planned in an integrated process across voltage levels. As EHV and HV networks can mutually substitute for their respective functions to some extent, there is a risk that by separately assessing the HV network such synergies are overlooked. This can result in potential distortions of the efficiency measurement, because from one country to another the degree of integration of EHV and HV planning and operation may differ notably, and specific planning decisions may have led to different function sharing between the tower network layers.

Figure 4. Schematic example of organization of DSO, RTO and TSO grid integration



Source: Frontier/Sumicsid/Consentec

Hence, when comparing TSOs some of which operate both EHV and HV networks – such as the sample available for this study –, this therefore speaks in favour of an integrated model where the HV activities are evaluated jointly with EHV activities.

2.1.4 International practice

Furthermore, it is also useful to consider, how HV systems or sub-systems are treated from a legal and regulatory perspective:

- Vertically integrated TSO – With the notable exception of Belgium and to a certain extent France, where the TSO covers MV and HV down to 34 kV, most other European countries have assigned 132 kV and below to the DSOs.
- HV activities as part of the DSO – DSO regulations apply to HV grids in most EU countries (e.g. Germany), except where installations are owned and operated by a TSO.
- RTO model in Norway and Sweden – only Norway and Sweden recognise RTOs as entities that are subjected to distinct regulatory rules.

Belgium

The Belgian TSO, Elia, operates a national grid with about 5,700 km overhead lines and 2,600 km cables, of which 2,500 km are overhead lines and 2,100 km are cables at 30-70 kV and the rest 150-380 kV. The revenue cap for Elia is calculated for the vertically integrated unit. The TSO here operates with both the system responsibility and the asset ownership for all high voltage transmission in the country, a result of a vertical integration prior to the deregulation and unbundling.

Germany

The German DSOs report outputs and costs per voltage level. However the revenue is set for the integrated DSO and not distinguished by HV, MV or LV voltage levels. The use of potentially large ranges of voltage levels in the benchmarking analysis is not problematic in the German setting as there are at least some 180 DSOs included in the comparison.

TSOs in Germany are subject to a separate international benchmarking, most recently e3grid2012. The TSO benchmark is limited to assets at EHV and TSO operations.

Sweden and Norway

The network regulation in Sweden maintains the distinction between DSO and RTO, where the RTO are subject to a price regulation framework, whereas the DSOs are regulated with a revenue-cape regulation. The regulation differs between area concessions (for low and medium voltage installations) and concessions for lines (for medium and high voltage up to 220 kV). Technically, the RTO in Sweden differ from Norway in terms of asset types, about 30,600 km overhead lines and only 600 km land cables (2%) compared to 18,000 km overhead lines and 1,350 land and sea cables (9%). The situation in Sweden compared to Norway is different also in terms of concentration: in Sweden the 9 RTOs are in the hands of only four groups: Vattenfall, Fortum, Skelleftea Kraft and E.ON.

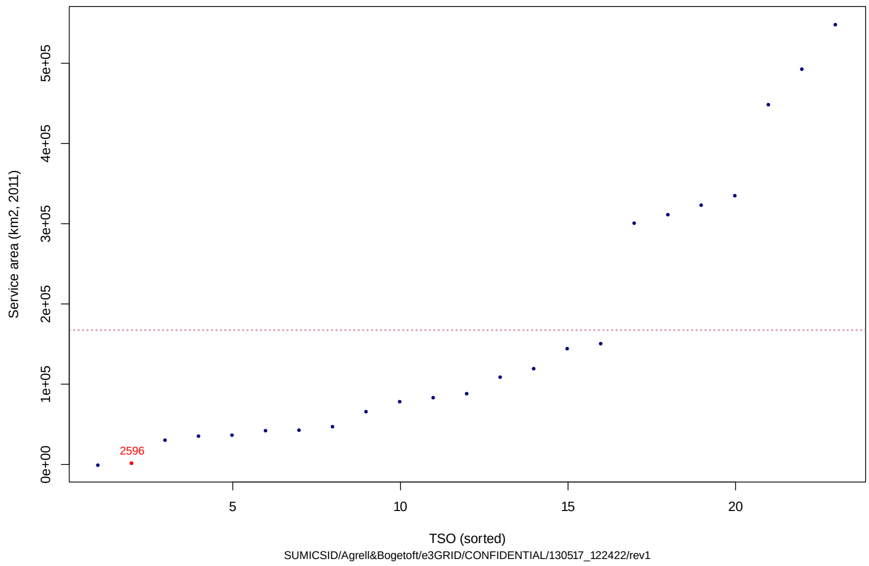
TenneT – Specific challenges

2.2 Operating area

We next discuss the implication of the density of the service area for the benchmarking analysis.

TenneT has the second smallest service area in the sample (**Figure 5**; TenneT is represented by the red point). As seen in the previous STENA study (Agrell and Bogetoft, 2010), the inclusion of a direct density measure – as a potential environmental cost driver – leads to disproportionate marginal cost predictions for TenneT in a DEA context with endogenous dual prices, which motivated the use of alternative methods.

Figure 5. Delivery area (km2 yEnv.total.land.use, 2011) for e3grid operators



Source: Frontier/Sumicsid/Consentec

In the e3grid2012 study the network complexity in relation to settlement structures is reflected through two parameters:

- The size of densely populated areas in the service area;
- The share of angular towers in all towers – For the purpose of the analysis this parameter is defined as the weighted line length multiplied by the share of angular towers of the total number of towers.

The economic intuition behind the first parameter is that density may lead to higher specific cost per asset due to

- more cost-intensive infrastructure crossings;
- complicated topology; and

- access-protected assets.

TenneT – Specific challenges

3 E3grid2012 and STENA2012 – Model specification and parameters

We understand that ACM wishes there to be a close alignment between the e3grid2012 and STENA2012 project, which run in parallel. This means that the principle model specification used in e3grid2012 is also used in STENA2012. However, some specific Dutch parameters in line with national regulation decisions for 2007-2011 shall be used in STENA2012, in particular respective values for WACC, depreciation periods, CPI.

Hence, in the following we discuss:

- the generic model specification for e3grid2012; and
- national parameters used in STENA2012.

3.1 E3grid2012 – model specification

3.1.1 E3grid2012 – Structure of model specification and efficiency calculation

In principle any efficiency analysis can be described as a sequence of the following steps:

- **Scope of benchmarking** – The e3grid2012 project relates to Grid construction, Grid maintenance and Administrative support. By contrast excluded from the benchmark are potential TSO functions of Market facilitation, System operations and Grid planning. Offshore activities have also been excluded from the analysis.

- **Benchmarking methodology** – Data Envelopment Analysis (DEA) is used as benchmarking technique. This choice is motivated by the (limited) size of the sample of 21 TSOs. It is also the technique used in previous similar studies. A concern has been raised that a sample of 21 companies may be small for a respective benchmark. However, we point out that a small sample in DEA tends to lead to higher efficiency scores than the same analysis in a larger sample. Therefore, the small size tends to be to the benefit of the efficiency scores of the firms (and is not in itself a detriment).

- **Definition of benchmarked costs** – The benchmarking is based on total expenditures (Totex), which is the sum of operating expenditures (Opex) and capital expenditures (Capex). The benchmarking only relates to costs associated with the scope of activities listed before. The benchmarked costs are adjusted to make them internationally comparable, e.g. salary adjustment.

- **Cost driver analysis and model specification** – Engineering logic and statistical analysis is employed in e3grid2012 to identify the parameters, which reflect the
  - supply task of the transmission system operator; and
  - other structural and environmental parameter that have an impact on the TSOs' costs.
- **Calculation of efficiency scores and sensitivity analysis** – In the final step in e3grid2012 the efficiency scores of the TSOs were calculated using the benchmarking methodology, benchmarked costs and identified costs drivers. Sensitivity analysis has been used to explore the robustness of the results, e.g. by identifying and eliminating outliers. Second stage regression analysis has been used whether there would have been other parameters that could have helped explained identified inefficiencies.

3.1.2 E3grid2012 – Results from cost-driver analysis

The cost-driver analysis in e3grid2012 resulted in a model specification including three outputs:

- **NormalisedGrid** – This is a cost-weighted measure of the assets in use. The technical asset base serves as a proxy for the complexity of the operating environment of the firm. The efficiency analysis then no longer questions whether the assets are needed, but questions whether the assets have been procured prudently (at low prices) and whether the company and the assets are operated efficiently.
- **Densely populated area** – The size of the area with a population density more or equal 500 inhabitants/sqkm may require more complex routing of transmission lines (e.g. more corners to pass houses or to cross traffic routes, higher towers to fulfil minimum distance requirements), combining of multiple circuits on one tower in order to save land.
- **Value of weighted angular towers** – This is a weighted measure of the angular towers in use, where the weight is based on the normalised grid for overhead lines per voltage level. This parameter constitutes a correction factor for a "special condition" class of lines. The parameter is technically well motivated and exhibits the expected sign in the regression model in the log-linear form.

All parameters are statistically significant and have the expected signs in the relevant model specification runs.

Hence, in the following we define the model with the respective outputs:

E3grid2012 and STENA2012 – Model specification and parameters

Table 2. e3grid2012 Model parameters

	Model e3grid2012
Input parameter	Totex (after Call Z adjustments)
Output parameters	NormalisedGrid
	Densely populated area
	Value of weighted angular towers

Source: Frontier/Consentec/Sumicsid

The benchmarking analysis not only considers the above mentioned cost drivers. Companies have also been invited to claim any company specific cost differences, which are not reflected by other included (or tested and rejected variables). The claims were reflected as an adjustment to the cost base (i.e. such cost were excluded from the benchmark), if they were properly motivated and also quantified by the TSO. In total we received 66 such claims of which 35 were reflected by adjusting the cost base of companies. These reflected claims related to:

- **Structural claims** – These claims allowed the TSOs to specify "special conditions" of power lines and cables. The structural claims comprised three aspects:
  - Higher costs due to lines in mountainous regions;
  - higher costs due to lines in coastal areas; and
  - higher costs for cables in cable tunnels.
- **Individual claims –** These claims were unique for TSOs.

3.1.3 E3grid2012 – DEA specification

The outputs from the cost-driver analysis are used when calculating the DEA efficiency scores. In addition we make the following specification for DEA for our base model:

- **Non-decreasing-returns to scale** – The cost-driver analysis in e3grid2012 allows the assessment of returns-to-scale in cost functions and gives an indication for returns-to-scale specification for DEA. Our statistical model indicates increasing returns to scale in the cost function, which we have reflected by a non-decreasing-returns-to-scale (NDRS) specification in DEA. NDRS makes an allowance for smaller companies potentially finding it harder to achieve the same average cost efficiency as larger firms, while not giving large firms an allowance for potentially being too large.

- **DEA outlier analysis using dominance and super efficiency test** – DEA efficiency scores may be dependent on single observations of peer companies with low cost. In order to increase the robustness of the analysis it is important to assess, if the results are driven by companies with exceptional characteristics ("outliers"). This is done by outlier analysis in DEA, which consists of screening extreme observations in the model against average performance using two tests: dominance test and super efficiency test. We follow the tests as prescribed in the German ordinance on incentive regulation (ARegV).

- **DEA outlier analysis using selected Capex break methodology** – In e3grid2012 we introduce an additional outlier analysis in DEA to assess the feasibility of the efficiency frontier by analysing the investment stream of peer companies to ensure that the investment stream is not understated. For peer companies without full history of its investment stream from 1965-2011 we apply an adjustment calculation ("Capex break methodology") to adjust their Capex and then recalculate the DEA efficiency scores for the sample and adjusted costs due to Capex break for selected peer companies. The application of Capex break for each run is indicated specifically in e3grid2012, it was applied to two operators. We should stress that this adjustment has been applied to "soften" the efficiency benchmark for the other firms, i.e. to ensure structural comparability.

- **DEA weight restrictions** – Moving to a DEA based best practice evaluation (without weight restrictions), the relative importance of the different cost drivers will be endogenously determined and different for every TSO so as to put each TSO in its best possible light. For such reasons DEA should also be referred to as a "benefit-of-the-doubt approach". In a small data set – with potentially few peer companies - it makes the analysis extremely cautious. Our first analysis has shown that for some companies DEA would assign strong weights to the cost drivers of value of weighted angular towers and densely populated area, while no weight is attached to the NormalisedGrid. This however stands in contradiction to engineering knowledge and our statistical analysis, which indicates that the NormalisedGrid is the main cost driver. In our base model we therefore use weight-restrictions in DEA to limit the relative importance we allow to be given to the different cost drivers. We inform this analysis by the coefficients (cost elasticities) estimated in the statistical analysis. In fact we have explored the confidence interval for each of the variable and use upper and lower value restrictions on the weights which lie even outside the 99% confidence intervals (this implies that they weights we use include the true values with a probability in excess of 99%). We specify the constraints as a variation in the allowed weights within -50% and +50% of the statistical estimates for the respective coefficient (cost driver).[4]

E3Grid2012 base model is defined as:

Table 3. Model parameters for e3grid2012 base model

	DEA model
Sample	21 TSOs
Input	Totex (after Call Z adjustments)
Outputs	NormalisedGrid
	Densely populated area
	Value of weighted angular towers
Returns to scale	Non-decreasing-returns to scale
Weight restriction	+/-50% of the cost elasticities estimated in a regression model with the above variables
Selected Capex break	Applied to 2 TSOs

Source: Frontier/Sumicsid/Consentec

We conclude that the e3grid2012 base model will also be used as the base model for STENA2012.

3.2 STENA2012 – model parameters

ACM provided us with data on:

- consumer price index;
- depreciation periods; and
- WACC (real).

These values were used instead of the respective parameters in e3grid2012.

4 For technical details about the imposition of weight restriction in the linear programming problems, see Bogetoft/Otto (2011, Ch 5), Bogetoft (2012, Ch.4), Thanassoulis/Portela/Allen R (2004, Ch 4), Charnes/Cooper/Wei/Huang (1989), Olesen/Petersen (2002), Podinovski (2004), Wong and J. E. Beasley (1990).

3.2.1 Consumer price index

ACM provided us with the series of consumer price index from CBS which are used in the national regulation. In national regulation August-August CPI values are used and a one year time-lag for CPI data is applied.[5]

For STENA2012 we adjusted the CPI used for TenneT accordingly.

3.2.2 Depreciation periods and WACC

ACM provided us with depreciation periods for network assets and the WACC used for the regulatory period 2007-2011. Based on this information we adjusted the annuity factors used to calculate the Capex for all TSOs in STENA2012. The differences compared to the e3grid2012 values are illustrated in **Table 4**.

5 For the Dutch CPI figures see: **Annexe 3: Consumer Price Index (Netherlands)**

Table 4. Annuities used in e3grid2012 and STENA2012

WACC (real, pre tax)	E3grid2012	4.36%	STENA2012	6.00%
Asset class	**Life time**	**Annuity E3GRID**	**Life time STENA**	**Annuity STENA**
Lines	60	4.72%	55	6.25%
Cables	50	4.94%	50	6.34%
Circuit	45	5.11%	42	6.57%
Transformers	40	5.32%	35	6.90%
Compensating	40	5.32%	42	6.57%
Series	40	5.32%	42	6.57%
Dispatching	30	6.04%	30	7.26%
Towers	30	6.04%	30	7.26%
Other	30	6.04%	30	7.26%
Offshore	30	6.04%	30	7.26%
Lines	60	4.72%	55	6.25%

Source: Frontier/Sumicsid/Consentec, ACM

3.2.3 National parameters and affected e3grid2012 parameters

The national parameters influence the calculation and level of various input and output data from e3grid2012:

- **Opex** – the indexation of Opex is based on the national CPI (August-August). This has no impact on the Opex 2011 as all costs are reported as 2011 values.

- **Capex** – the indexation of the investment stream is based on the national CPI (August-August). In STENA2012 the annuities for all TSOs are calculated on a (pre-tax) real interest rate of 6.00%. This will tend to increase the share of Capex on total costs and increase the importance from the Capex efficiencies on the overall efficiency score.

- **NormalisedGrid** – For consistency, the cost weights for the Capex part of the NormalisedGrid in STENA2012 are calculated using annuities with a (pre-tax) real interest rate of 6.00%. This will increase the Capex part of the NormalisedGrid for all TSOs.

- **Value of weighted angular towers** – For consistency, the cost weights for the Capex part of the NormalisedGrid in STENA2012 are calculated using annuities with a (pre-tax) real interest rate of 6.00%. This will increase the Capex part of the NormalisedGrid for overhead lines used as the weight for the angular towers and as a result the value of weighted angular towers for all TSOs.

4 STENA2012 – Results

The STENA 2012 project intends to perform a reliable and robust performance assessment of the TenneT cost efficiency. In order to allow a comprehensive assessment ACM defined specific runs for this study. The runs are all based on the e3grid2012 model specification. The runs differ from each other by using variants of the cost base of TenneT and a variant for the reference group.

We note that in the following runs the input and output data from the other TSOs are only adjusted based on the STENA2012 annuities outlined in **Section 3.2.2** compared to the data used in e3grid2012.

For each of these runs we have estimated separate coefficient values using regression analysis for

- NormalisedGrid;
- Densely-populated area; and
- Value of the weighted angular towers

and used these to set the weight restrictions in DEA in a range of +/-50% around the coefficients.[6]

In the following we present results for the STENA2012 – Primary models. For additional model variants we refer to **Annexe 2: STENA2012 variants.**

4.1 STENA2012 – Primary models

In the following we discuss the STENA2012 primary models corresponding to the e3grid2012 base model described in **Table 3**. The three variants are illustrated in **Table 5**.

6 For details of the results we refer to: **Annexe 1: Regression results for STENA2012 runs**

Table 5. STENA2012 – primary models

	Costs after adjustment with national parameters	NorNed (cost and assets included)	Capex break applied for TenneT (year)	Costs and assets included	Sample size
STENA2012 base case	x	x		EHV + HV	21
STENA2012 excluding NorNed	x			EHV + HV	21
STENA2012 WEU	x	x		EHV + HV	13

Source: Frontier/Sumicsid/Consentec

- **STENA2012 base case** – including all costs from TenneT;
- **STENA2012 excluding NorNed** – excluding NorNed from the costs and the outputs;
- **STENA2012 WEU** – including a reduced reference set of only 13 TSOs.

4.2 STENA2012 Primary model – base case

The STENA2012 base case corresponds to the base case from e3grid2012 and is described in **Table 6**.

Table 6. STENA2012 Base case

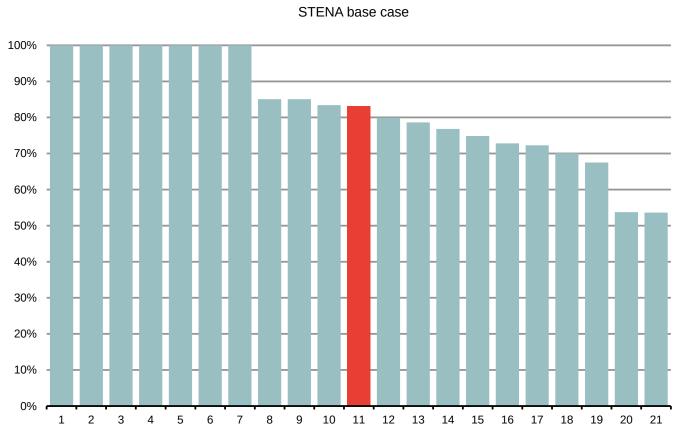
	DEA model
Sample	21 TSOs
Input	Totex (after Call Z adjustments)
Outputs	NormalisedGrid
	Densely populated area
	Value of weighted angular towers
Returns to scale	Non-decreasing-returns to scale
Weight restriction	+/-50% of the cost elasticities estimated in a regression model with the above variables
Selected Capex break	2 TSOs

Note: STENA2012 annuities are used for all TSOs to calculate the Capex

Source: Frontier/Sumicsid/Consentec

Figure 6 illustrates the distribution of efficiency scores for the e3grid2012 base model. The results are after DEA outlier analysis using dominance and superefficiency test. In addition selected Capex break is applied to 2 TSOs.

Figure 6. STENA2012 Base case



Note: TenneT is red bar

Source: Frontier/Sumicsid/Consentec

The average efficiency is 83% and the minimum efficiency is 54%. 7 TSOs obtain a score of 100% (including 4 outliers based on dominance and superefficiency test). The efficiency score for TenneT is 83%.

Table 7. STENA2012 Base case

	STENA2012 Base case
TenneT	**83%**
Mean Efficiency (including outliers)	83%
Min Efficiency (including outliers)	54%
Outliers	4
100% companies (including outliers)	7

Source: Frontier/Sumicsid/Consentec

4.3 STENA2012 Primary models – excluding NorNed

In this variant we assess the impact from NorNed on the efficiency score of TenneT by excluding NorNed from

- **Costs** – We have excluded:

- 324.3 Mio.€ in the year 2008 from the investment stream corresponding to the declared investment costs from TenneT for NorNed; and
- 12.5 Mio.€ for the years 2008-2011 from the Opex for the function maintenance.

- **NormalisedGrid** – We have excluded from the calculation of the NormalisedGrid from Call X:
  - DC cable; and
  - HVDC Conversion station.

The STENA2012 excluding NorNed run is described in **Table 8**.

Table 8. STENA2012 excluding NorNed

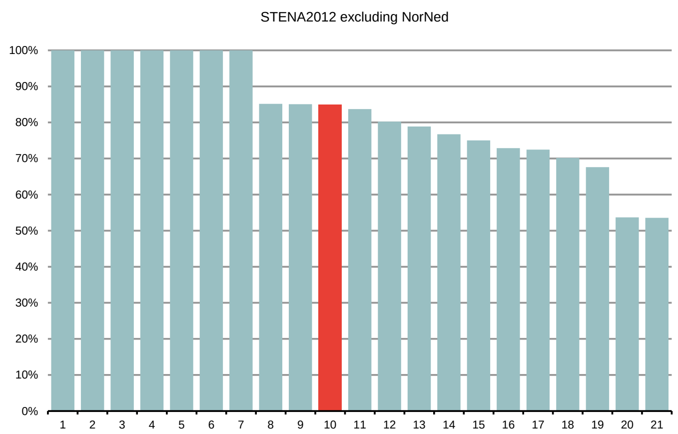
	STENA2012 excluding NorNed
Sample	21 TSOs
Input	Totex (after Call Z adjustments) – **adjustment of Opex and Capex for NorNed costs**
Outputs	NormalisedGrid – **adjustment for NorNed assets**
	Densely populated area
	Value of weighted angular towers
Returns to scale	Non-decreasing-returns to scale
Weight restriction	+/-50% of the cost elasticities estimated in a regression model with the above variables
Selected Capex break	2 TSOs

Note: STENA2012 annuities are used for all TSOs to calculate the Capex

Source: Frontier/Sumicsid/Consentec

Figure 7 illustrates the distribution of efficiency scores for the STENA2012 excluding NorNed base model. The results are after DEA outlier analysis using dominance and superefficiency test. In addition selected Capex break is applied to 2 TSOs.

Figure 7. STENA2012 excluding NorNed



Note: TenneT is red bar

Source: Frontier/Sumicsid/Consentec

The average efficiency is 83% and the minimum efficiency is 54%. 7 TSOs obtain a score of 100% (including 4 outliers based on dominance and superefficiency test). The efficiency score for TenneT is 85%.

Table 9. STENA2012 excluding NorNed

	STENA2012 excluding NorNed
TenneT	**85%**
Mean Efficiency (including outliers)	83%
Min Efficiency (including outliers)	54%
Outliers	4
100% companies (including outliers)	7

Source: Frontier/Sumicsid/Consentec

4.4 STENA2012 Primary models – WEU

In a judicial recourse following the study in 2009, ACM heard arguments from TenneT concerning the origin and operational differences between the countries in the general e^3GRID study, in particular countries operating networks with predominately wooden towers and countries from Eastern Europe.

Table 10. STENA2012 WEU

	STENA2012 WEU
Sample	**13 TSOs**
Input	Totex (after Call Z adjustments)
Outputs	NormalisedGrid
	Densely populated area
	Value of weighted angular towers
Returns to scale	Non-decreasing-returns to scale
Weight restriction	+/-50% of the cost elasticities estimated in a regression model with the above variables
Selected Capex break	2 TSOs

Note: STENA2012 annuities are used for all TSOs to calculate the Capex

Source: Frontier/Sumicsid/Consentec

In this variant we reduce the reference set for the benchmarking to only 13 TSOs (**Table 11**) from Western Europe, excluding the "low-cost" technologies. The other specification of costs and outputs corresponds to the STENA2012 base case model (see **Table 10**).

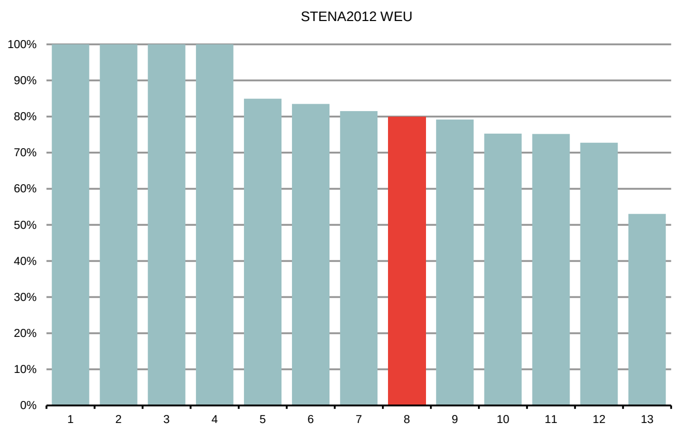
Table 11. STENA2012 WEU – Reference set of 13 TSOs

TSO reference set – STENA2012-WEU	
APG	TenneT
Energinet.dk	REN
TransnetBW	REE
TenneT Germany	NGET
Amprion	SPTL
50Hertz	RTE
Creos	

Source: Frontier/Sumicsid/Consentec

Figure 8 illustrates the distribution of efficiency scores for the STENA2012 WEU model. The results are after DEA outlier analysis using dominance and superefficiency test. No selected Capex break is applied.

Figure 8. STENA2012 WEU



Note: TenneT is red bar

Source: Frontier/Sumicsid/Consentec

The average efficiency is 83% and the minimum efficiency is 53%. 4 TSOs obtain a score of 100% (including 2 outliers based on dominance and superefficiency test). The efficiency score for TenneT is 80%.

Table 12. STENA2012 WEU

	STENA2012 WEU
TenneT	**80%**
Mean Efficiency (including outliers)	83%
Min Efficiency (including outliers)	53%
Outliers	2
100% companies (including outliers)	4

Source: Frontier/Sumicsid/Consentec

We note that this result is affected by a change in the estimated cost relationship in the sample of 13 TSOs. This also implies a change in the weight restrictions applied in DEA.

5 STENA2012 – Summary

The Dutch regulator, ACM, has commissioned Frontier/Sumicsid/Consentec to undertake a country specific analysis for TenneT. This analysis should inform ACM on the static incumbent cost efficiency.

ACM wishes there to be a close alignment between the e3grid2012 and STENA2012 project, which run in parallel. This means that the principle model specification used in e3grid2012 is also used in STENA2012, while some specific Dutch parameters in line with national regulation decisions for 2007-2011 are used in STENA2012, in particular respective values for WACC, depreciation periods, and CPI. We use Data Envelopment analysis (DEA) to derive efficiency scores. We apply weight restrictions in DEA that vary by +/-50% around the coefficient value estimated through regression analysis for the respective model specification.

We have grouped the STENA2012 runs into the following categories:

STENA2012 – Primary models

The efficiency scores as described in the main text are summarised below.

Table 13. STENA2012 Primary models – summary

	TenneT efficiency score
STENA2012 Base case	83%
STENA2012 excluding NorNed	85%
STENA2012 WEU	80%

Source: Frontier/Sumicsid/Consentec

STENA2012 – Variants

In addition to the base model runs we have undertaken sensitivity analysis. This is summarised in an annex. The efficiency scores for the sensitivities are summarised below.

Table 14. STENA2012 Variants – summary

	TenneT efficiency score
STENA2012 Composite variable (strict weight restriction) (weight restrictions based on +/-0% range of the cost elasticities estimated in regression model)	75%
STENA2012 unrestricted (no weight restrictions)	100%
STENA2012 Opex efficiency	86%
STENA2012 Constant-returns to scale	83%
STENA2012 Capex break - 2000	91%
STENA2012 Capex break - 2008	100% TenneT is outlier

Source: Frontier/Sumicsid/Consentec

STENA2012 – Summary

6 Literature

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Annexe 1: Regression results for STENA2012 runs

In the following we show the regression results for the STENA2012 runs which were used to set the weight restrictions in a range of +/-50% around the coefficients. In addition, the results show that in all STENA2012 variants the outputs

- NormalisedGrid;
- Densely-populate area; and
- Value of the weighted angular towers

are significant and have the expected signs.

STENA2012 – Base case

Table 15. Regression results

OLS log-linear (robust)	Coefficient
Intercept	9.634***
NormalisedGrid	0.471***
Densely populated area	0.138***
Value of weighted angular towers	0.277***
Observations (#)	102
adjR2 (%)	91,2%

Note: *** 99%; panel of 102 observations for the years 2007-2011; adjR2 from OLS estimation

Source: Frontier/Sumicsid/Consentec

STENA2012 – excluding NorNed

Table 16. Regression results

OLS log-linear (robust)	Coefficient
Intercept	9.656***
NormalisedGrid	0.462***
Densely populated area	0.137***
Value of weighted angular towers	0.285***
Observations (#)	102
adjR2 (%)	91,2%

Note: *** 99%; panel of 102 observations for the years 2007-2011; adjR2 from OLS estimation

Source: Frontier/Sumicsid/Consentec

STENA2012 – WEU

Table 17. Regression results

OLS log-linear (robust)	Coefficient
Intercept	8.064***
NormalisedGrid	0.664***
Densely populated area	0.070***
Value of weighted angular towers	0.248***
Observations (#)	62
adjR2 (%)	92,9%

Note: *** 99%; panel of 102 observations for the years 2007-2011; adjR2 from OLS estimation

Source: Frontier/Sumicsid/Consentec

STENA2012 – Opex efficiency

Table 18. Regression results

OLS log-linear (robust)	Coefficient
Intercept	6.937***
NormalisedGrid	0.959***
Densely populated area	0.018***
Value of weighted angular towers	0.031**
Observations (#)	102
adjR2 (%)	98.5%

Note: *** 99%; **95%; panel of 102 observations for the years 2007-2011; adjR2 from OLS estimation

Source: Frontier/Sumicsid/Consentec

STENA2012 – Capex break 2000

Table 19. Regression results

OLS log-linear (robust)	Coefficient
Intercept	9.529***
NormalisedGrid	0.516***
Densely populated area	0.143***
Value of weighted angular towers	0.230***
Observations (#)	102
adjR2 (%)	90.2%

Note: *** 99%; panel of 102 observations for the years 2007-2011; adjR2 from OLS estimation

Source: Frontier/Sumicsid/Consentec

STENA2012 – Capex break 2008

Table 20. Regression results

OLS log-linear (robust)	Coefficient
Intercept	9.679***
NormalisedGrid	0.452***
Densely populated area	0.136***
Value of weighted angular towers	0.296***
Observations (#)	102
adjR2 (%)	87.5%

Note: *** 99%; panel of 102 observations for the years 2007-2011; adjR2 from OLS estimation

Source: Frontier/Sumicsid/Consentec

Annexe 2: STENA2012 variants

In this Annex we discuss sensitivity analysis, STENA2012 variants.

Table 21. STENA2012 - variants

	Costs after adjustment with national parameters	NorNed (cost and assets included)	Capex break applied for TenneT (year)	Costs and assets included	Variant	Sample size
STENA2012 Composite variable (strict weight restriction)	x	x		EHV + HV	Weight restrictions based on +/-0% range of the cost elasticities estimated in regression model	21
STENA2012 unrestricted	x	x		EHV + HV	No weight restrictions in DEA	21
STENA2012 Opex efficiency	x	x		EHV + HV	Focus only on Opex efficiency	21
STENA2012 Constant-returns to scale	x	x		EHV + HV	Constant returns to scale in DEA	21
STENA2012 Capex break 2000	x	x	2000	EHV + HV		21
STENA2012 Capex break 2008	x	x	2008	EHV + HV		21

Source: Frontier/Sumicsid/Consentec

STENA2012 Composite variable (strict weight restriction)

In the current STENA2012 runs we defined weight restrictions for DEA in a range of +/-50% around the cost elasticities from the respective regression model. In this variant we set a strict weight restriction based on a +/-0% range around the cost elasticities. This means that we define a composite variable defined as the weighted sum of

- NormalisedGrid;
- Densely-populated area; and
- Value of weighted angular towers

where the weights are derived from the regression coefficients.

The STENA2012 Composite variable run is described in **Table 22**.

Table 22. STENA2012 Composite parameter (strict weight restriction)

	STENA2012 Composite variable
Sample	21 TSOs
Input	Totex (after Call Z adjustments)
Outputs	NormalisedGrid
	Densely populated area
	Value of weighted angular towers
Returns to scale	Non-decreasing-returns to scale
Weight restriction	**+/-0% of the cost elasticities estimated in a regression model with the above variables**
Selected Capex break	2 TSOs

Note: STENA2012 annuities are used for all TSOs to calculate the Capex

Source: Frontier/Sumicsid/Consentec

Figure 9 illustrates the distribution of efficiency scores for the STENA2012 Composite variable (strict weight restriction) model. The results are after DEA outlier analysis using dominance and superefficiency test. In addition selected Capex break is applied to 2 TSOs.

Figure 9. STENA2012 – Composite variable (strict weight restriction)

Note: TenneT is red bar

Source: Frontier/Sumicsid/Consentec

The average efficiency is 80% and the minimum efficiency is 52%. 7 TSOs obtain a score of 100% (including 4 outliers based on dominance and superefficiency test). The efficiency score for TenneT is 75%.

Table 23. STENA2012 – Composite variable (strict weight restriction)

	STENA2012 Composite variable
TenneT	**75%**
Mean Efficiency (including outliers)	80%
Min Efficiency (including outliers)	52%
Outliers	4
100% companies (including outliers)	7

Source: Frontier/Sumicsid/Consentec

STENA2012 Unrestricted

In this variant we relax the weight restriction and calculate a model without weight restrictions.

The STENA2012 unrestricted run is described in **Table 24**.

Table 24. STENA2012 Unrestricted (no weight restriction)

	STENA2012 unrestricted
Sample	21 TSOs
Input	Totex (after Call Z adjustments)
Outputs	NormalisedGrid
	Densely populated area
	Value of weighted angular towers
Returns to scale	Non-decreasing-returns to scale
Weight restriction	**non**
Selected Capex break	2 TSOs

Note: STENA2012 annuities are used for all TSOs to calculate the Capex

Source: Frontier/Sumicsid/Consentec

Figure 10 illustrates the distribution of efficiency scores for the STENA2012 unrestricted model. The results are after DEA outlier analysis using dominance and superefficiency test. In addition selected Capex break is applied to 2 TSOs.

Figure 10. STENA2012 – unrestricted (no weight restriction)

Note: TenneT is red bar

Source: Frontier/Sumicsid/Consentec

The average efficiency is 91% and the minimum efficiency is 59%. 11 TSOs obtain a score of 100% (including 4 outliers based on dominance and superefficiency test). The efficiency score for TenneT is 100%.

Table 25. STENA2012 – Unrestricted (no weight restriction)

	STENA2012 unrestricted
TenneT	**100%**
Mean Efficiency (including outliers)	91%
Min Efficiency (including outliers)	59%
Outliers	4
100% companies (including outliers)	11

Source: Frontier/Sumicsid/Consentec

STENA2012 – Opex efficiency

In this variant we modified the cost data in order to calculate efficiency scores only for Opex. We adjusted the Totex by replacing the companies' Capex by the NormalisedGrid Capex. This allows focussing on the efficiency of the Opex by using the same output parameters in the DEA model.

Table 26. STENA2012 Opex efficiency

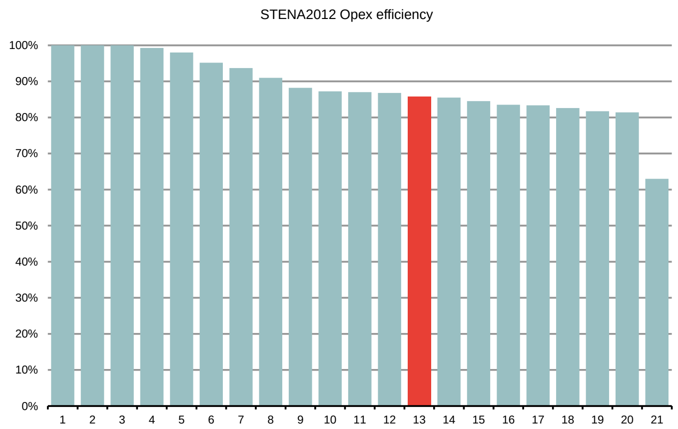
	STENA2012 Opex efficiency
Sample	21 TSOs
Input	Totex (after Call Z adjustments) – **replacement of Capex by NormalisedGrid Capex**
Outputs	NormalisedGrid
	Densely populated area
	Value of weighted angular towers
Returns to scale	Non-decreasing-returns to scale
Weight restriction	+/-50% of the cost elasticities estimated in a regression model with the above variables
Selected Capex break	not necessary as NormalisedGrid Capex is used instead of Capex

Note: STENA2012 annuities are used for all TSOs to calculate the Capex

Source: Frontier/Sumicsid/Consentec

Figure 11 illustrates the distribution of efficiency scores for the STENA2012 Opex efficiency model. The results are after DEA outlier analysis using dominance and superefficiency test.

Figure 11. STENA2012 – Opex efficiency



Note: TenneT is red bar

Source: Frontier/Sumicsid/Consentec

The average efficiency is 88% and the minimum efficiency is 63%. 3 TSOs obtain a score of 100% (including 2 outliers based on dominance and superefficiency test). The efficiency score for TenneT is 86%.

Table 27. STENA2012 – Opex efficiency

	STENA2012 Opex efficiency
TenneT	**86%**
Mean Efficiency (including outliers)	88%
Min Efficiency (including outliers)	63%
Outliers	2
100% companies (including outliers)	3

Source: Frontier/Sumicsid/Consentec

STENA2012 – constant returns to scale

The STENA2012 primary models have a non-decreasing-returns to scale specification. In the following we show the results for the constant-returns to scale specification.

Table 28. STENA2012 constant returns to scale

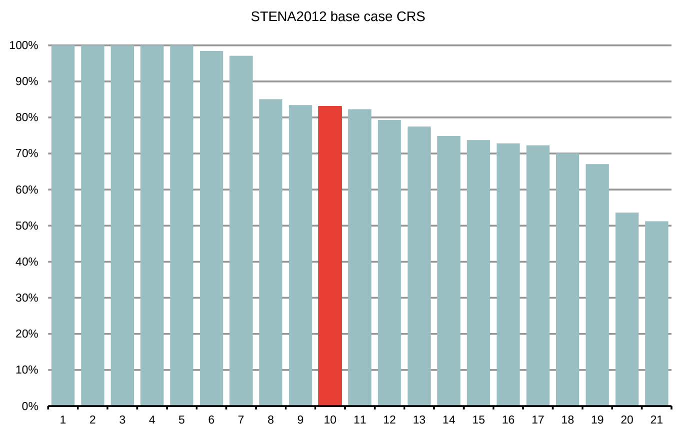
	STENA2012 CRS
Sample	21 TSOs
Input	Totex (after Call Z adjustments)
Outputs	NormalisedGrid
	Densely populated area
	Value of weighted angular towers
Returns to scale	**constant-returns to scale**
Weight restriction	+/-50% of the cost elasticities estimated in a regression model with the above variables
Selected Capex break	2 TSOs

Note: STENA2012 annuities are used for all TSOs to calculate the Capex

Source: Frontier/Sumicsid/Consentec

Figure 12 illustrates the distribution of efficiency scores for the STENA2012 constant-returns to scale model. The results are after DEA outlier analysis using dominance and superefficiency test. In addition selected Capex break is applied to 2 TSOs.

Figure 12. STENA2012 - constant returns to scale



Note: TenneT is red bar

Source: Frontier/Sumicsid/Consentec

The average efficiency is 82% and the minimum efficiency is 51%. 5 TSOs obtain a score of 100% (including 3 outliers based on dominance and superefficiency test). The efficiency score for TenneT is 83%.

Table 29. STENA2012 – constant returns to scale

	STENA2012 CRS
TenneT	**83%**
Mean Efficiency (including outliers)	82%
Min Efficiency (including outliers)	51%
Outliers	3
100% companies (including outliers)	5

Source: Frontier/Sumicsid/Consentec

STENA2012 Capex break

In this variant we assess the impact from two variants of the Capex break methodology[7]. In the previous ACM study from 2009[8], TenneT benefitted from

[7] For details on the capex break methodology see: e3grid2012, *Method Note 1: Capital break methodology – Opening balance adjustment*, Version 1.6, March 2013.

a specific evaluation of their incumbent Capex efficiency in 2000. Using a restricted dataset of 13 continental operators from e^3GRID 2008, it was concluded that the Capex of TenneT for 2000 contained at least 21.8% inefficiency. Further, the sheer magnitude of the HV investment has a substantial impact on the regulatory asset base of TenneT. In order to assess the sensitivity of the Totex results to these specific Capex influences, we apply the Capex break methodology to the investment stream from TenneT and use two cut-off years:

- 2000; and
- 2008 – when TenneT was appointed as the Grid Operator of all 110/150 kV networks as a consequence of the WON (Wet Onafhankelijk Netbeheer).

We note that we do not apply the Capex break methodology to the other TSOs in the sample (except for the selective peers where selected Capex break applies).

The STENA2012 Capex break run is described in **Table 30**

Table 30. STENA2012 Capex break

	STENA2012 capex break
Sample	21 TSOs
Input	Totex (after Call Z adjustments) – **Capex break for 2000 (2008)**
Outputs	NormalisedGrid
	Densely populated area
	Value of weighted angular towers
Returns to scale	Non-decreasing-returns to scale
Weight restriction	+/-50% of the cost elasticities estimated in a regression model with the above variables
Selected Capex break	2 TSOs

Note: STENA2012 annuities are used for all TSOs to calculate the Capex

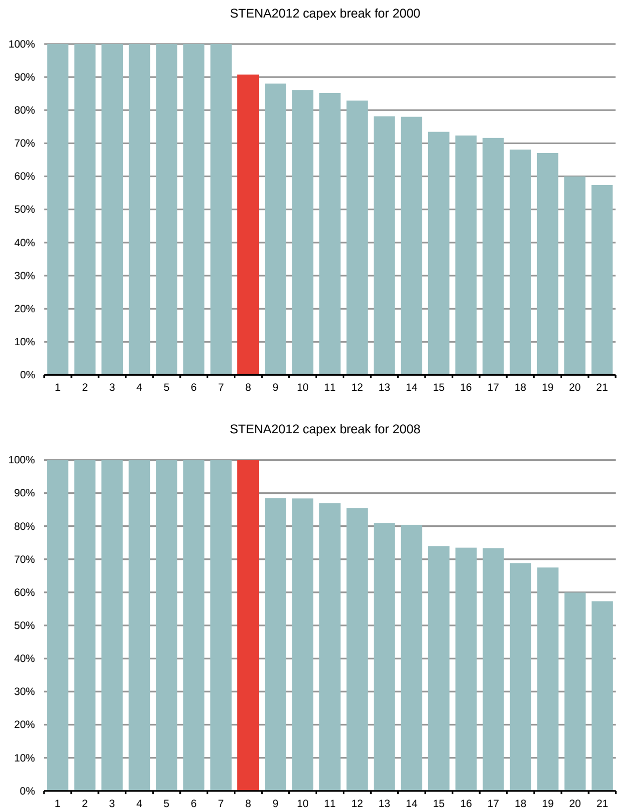
Source: Frontier/Sumicsid/Consentec

Figure 13 illustrates the distribution of efficiency scores for the STENA2012 Capex break 2000 and 2008 models. The results are after DEA outlier analysis

8 Sumicsid, *Benchmarking TenneT EHV/HV (Project STENA)*, Final Report, 2010.

using dominance and superefficiency test. In addition selected Capex break is applied to 2 TSOs.

Figure 13. STENA2012 Capex break for 2000 and 2008



Note: TenneT is red bar

Source: Frontier/Sumicsid/Consentec

The average efficiency is 84% (85%) and the minimum efficiency is 57% (57%). 7 TSOs obtain a score of 100% for the Capex break 2000 case (including 4 outliers based on dominance and superefficiency test). The efficiency score for TenneT in the Capex break 2000 case is 91%. 8 TSOs obtain a score of 100% for the Capex break 2008 case (including 5 outliers based on dominance and superefficiency test), where TenneT is identified as outlier. The efficiency score for TenneT in the Capex break 2008 case is 100%.

Table 31. STENA2012 Capex break for 2000 and 2008

STENA2012 Capex break	2000	2008
TenneT	**91%**	**100%** (TenneT is outlier)
Mean Efficiency (including outliers)	84%	85%
Min Efficiency (including outliers)	57%	57%
Outliers	4	5
100% companies (including outliers)	7	8

Source: Frontier/Sumicsid/Consentec

Annexe 2: STENA2012 variants

Annexe 3: Consumer Price Index (Netherlands)

Table 32. Consumer Price Index (%)

Year	%	Year	%
1963 August	1.9	1988 August	0.9
1964 August	8.4	1989 August	1.1
1965 August	4.3	1990 August	2.4
1966 August	5.8	1991 August	4.6
1967 August	3.9	1992 August	3.5
1968 August	3.3	1993 August	2
1969 August	6.9	1994 August	2.6
1970 August	5.4	1995 August	1.5
1971 August	7.6	1996 August	1.9
1972 August	7.4	1997 August	2.6
1973 August	8.1	1998 August	1.7
1974 August	9.8	1999 August	2.6
1975 August	10.7	2000 August	2.5
1976 August	8.3	2001 August	4.7
1977 August	6.8	2002 August	3.3
1978 August	4.2	2003 August	2.1
1979 August	3.8	2004 August	1.1
1980 August	7.1	2005 August	1.8
1981 August	6.4	2006 August	1.4
1982 August	5.9	2007 August	1.1
1983 August	2.6	2008 August	3.2
1984 August	2.8	2009 August	0.3

1985 August	2.3	2010 August	1.5
1986 August	-0.5	2011 August	2.6
1987 August	0.2	2012 August	2.3

Source: ACM

Annexe 3: Consumer Price Index (Netherlands)

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