ECOM+ Results 2005

FINAL REPORT

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OPEN

2006-06-01

Disclaimer

This is the final anonymized report of the second round of the ECOM+ project on benchmarking of transmission system operators, delivered 2005-10-30 by the authors, professors Per AGRELL and Peter BOGETOFT for SUMICSID AB. The report is for public release in this version, there exists also an confidential version with sensitive data and results.

The project has been commissioned by the regulators of Austria, Denmark, the Netherlands, Norway and Portugal. The contents has not been subject to review by the Commissionees and does not represent a regulatory ruling in itself, but is intended to inform such proceedings subject to applicable legal frameworks.

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ECOM+ Results 2005
Final report, open. Project no: 321
Release date: June 01, 2006

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Version history

Ver	Date	Status	Concerns	Auth
1.00	16.10.05	Release	Partial results	PA
2.00	30.10.05	Final	Closed version, complete	PA
3.00	01.05.06	Final	Open version, abridged	ML
3.10	01.06.06	Final	Open version, revised after review	PA

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Summary

Transmission system operators (TSOs) are key actors in the integrated electricity market. Charged with the responsibility of planning, installing, operating, maintaining and expanding the national grids, their importance for the social welfare effects cannot be understated. Any default in their real time assurance of supply reliability and safety may cause economic, technical and environmental disruptions everywhere in the underlying networks. Synergies between interrelated tasks and economies of scale have lead the European countries to adopt the organization of integrated transmission system operators, even in the liberalized and unbundled market structure. This also implies a difficulty to assess the operating efficiency of the operators, being national legal monopolies. Nevertheless, due to their size and unique importance, there is a need to inform the regulatory proceedings on their provision of value to the chain.

This is the anonymized and abridged version of the second report on the ECOM+ (Efficiency of Construction, Operations and Maintenance, improved) model in regulatory use. The mathematical structure is simple in its derivation of a standardized unit cost measure and a relative efficiency measure. However, the report also provides details on econometric approaches to elicit more information from submitted data and to enrich the performance assessment. The model takes into account inflation, exchange rates, investment horizons, assets lives, asset groupings and country specific factors for each asset group. In this run, the method has been enhanced with methodologically sound partial measures that control for investment profile and scale, based on linear programming, as well as dynamic measures to study the changes over time of both the efficiency frontier and the individual TSOs.

The in-depth benchmarking process in ECOM+ contains a techno-economic screening of the TSO operations as to assure data quality for full comparability and to allow useful interpretations, both for the operational development and regulation. The interactive process, consisting of four workshops where TSOs, regulators and consultants discuss and review topics such as asset definitions, cost decomposition and benchmarking methods, intends to create an open and transparent environment for information exchange. The data validation process consists of multiple elements related to the reporting tools (feasibility), the cost decomposition guide (information) and the initialization from the annual report (validation) using a double additive and subtractive scheme to arrive at the benchmarked cost. A technical team was in charge of the definition and review of the asset types, categories and their relative weights. The expert weights, parameters and preliminary results have been disseminated prior to and discussed during and after workshops to ensure full understanding of the results.

A particular difficulty in international benchmarking of transmission operations is how to handle operator-specific conditions. To comply with the high requirements on transparency and neutrality in the expert assessment, a new process was implemented to systematically investigate any operator-specific factors evoked by the TSOs as potentially creating significant, durable and exogenously determined cost increases. The motivated expert assessments were regularly distributed to all participants to ensure an equitable reporting process, in particular when introducing new asset categories. E.g., several changes were made to the capital and operating cost estimation for mountainous and alpine lines following the assessment.

Quality provision is a credo for the transmission system operators and the IEM Directive highlights the importance of implementing regulatory measures as to safeguard the reliability and resilience of the grid. Contrary to output-based metrics previously used, ECOM+ is strictly based on the real deployed grid assets, which means that quality resulting from reinforcements, new investments and meshed structures are promoted, not penalized, in the benchmarking. This property makes the ECOM+ a safe and sound instrument for the partial performance assessment that could be applied without jeopardizing the investments related to quality and capacity provision.

The ECOM+ model was in 2004/2005 applied to six transmission system operators, denoted in this version with the identifiers E, F, G, H, I, and J. The study comprises operating expenditure from 2000 to 2003 in addition to the investment and assets since 1965.

Besides the static results of unit cost and efficiency score for the years 2000 to 2003, the study also documented a range of dynamic efficiency scores for the period, such as the frontier shift and the individual efficiency catch-up. In addition to extensive sensitivity analyses for all relevant parameters for each operator, the study also applied advanced methods to determine cautious bounds for the efficiency assessments, taking into account issues such as scale and capital base.

Altogether, the ECOM+ model provides a reliable set of benchmarking information for a very important and complex regulated operation, using a transparent, systematic and scientifically sound method to standardize asset portfolios and cost reports as to determine reliable and well supported and documented efficiency estimates.

1. Organization

1.01 This report is the final report of the second round of the ECOM+ project on international benchmarking of transmission system operators in 2004/2005.

Project team

1.02 Project leader from SUMICSID is Senior Associate Per Agrell, prof.dr. The project team consisted also of senior associate Peter Bogetoft, prof.dr., consultants Daniele Benintendi and Mathias Lorenz, from SUMICSID and chief engineer Jacques Deuse, ph.d., Tractebel Engineering.

1.03 The project group consists of the transmission operators and regulators that decide to join the project, thereby agreeing to provide data for analysis and to share results within the project. The term *member* denotes below a participating TSO, irrespective of which organization that actually will contract and/or finance the study.

1.04 The regulatory authorities in Austria (E-Control GmbH), Denmark (Danish Energy Regulatory Authority), the Netherlands (Dte, Dutch Energy Regulator), Norway (NVE, Norwegian Energy Directorate) and Portugal (ERSE) have jointly conducted a project on international benchmarking of central grids in 2004/2005.

1.05 removed

Background

1.06 The ECOM+ project of 2003 between the regulators of Austria (E-Control GmbH), Denmark (KS), the Netherlands (Dte), and Norway (NVE) continued the previous TSO benchmarking project of 2001/2002 in order to establish a firm methodological and empirical base for robust estimates of TSO efficiency in construction, operations and maintenance (ECOM). The results of the 2003 round were promising and a general interest was expressed to make the exercise a repeated activity in the interest of regulators as well as the regulated TSOs.

Objectives

1.07 The ECOM+ 2004 project aimed at

1) *Methodological developments on efficiency decomposition and dynamics*
The method has been enhanced with an explicit portfolio of static and dynamic efficiency measures to monitor, decompose and interpret efficiency and cost changes over time.
2) *Data definition work*
Both asset data base and the operating cost reporting definitions have been revised, clarified and codified in two separate reports presented at workshops in an interactive format.
3) *Data extension by new members*
New members have been invited to join the project and hereby increase the data material.
4) *Data validation*
Extensive data validation, using new control routines, has been made of all data to increase the validity of the sample. Technical and economic audits will be conducted on selected subsamples of the data. Advanced statistical analysis will be made on aggregated to compare with other public economic and technical information.
5) *Weight validation*
Selective in-depth weight validation has been carried out using the previous three-stage process. This stage may also involve a directed effort towards specific asset groups (e.g. converter stations and HVDC cables) to improve the quality of these assessments.

New elements

1.08 The new ECOM+ round has used the experience from the earlier studies to improve the data and weight validation procedure and outcome, to extend the methodology for dynamic assessments, and to enhance the project management, e.g. by simplified and clearer confidentiality structures as explained below, and by extended use of site visits to get a better appreciation of the local conditions and the local difficulties delineating the individual asset and costs elements.

1.09 The revisions of the ECOM+ method implements all changes proposed as further work in the 2003 report, i.e. the specifics related to landowner compensation, specific assets and the process changes proposed for weight validation, country specifics and cost reporting. In more detail, the ECOM+ 2004 project includes the following enhancements compared to the 2003 exercise:

1) *Methodological enhancements*
As outline above and in a separate chapter below, dynamics, interpretation and learning effects will be extended in the new model.

2) *Data validation enhancements*
More time and resources allocated to data validation and definitions from economic and technical expertise, and to weight cross validation by SUMICSID staff and technical experts. Site visits by the staff to each participant will ensure full comprehension of the reporting requirements and constitute an element of control. In addition, one economic and one technical unannounced audit will be undertaken on selected assets and TSOs.

3) *Process quality enhancements*
Project members now have a contractual right to undertake an independent audit of all data and calculations to increase its regulatory and procedural quality. Analogously, possible detected misreporting by members will be managed according to predefined principles by SUMICSID.

4) *Common confidentiality agreement*
All participants agree on the same confidentiality agreement, warranting strict confidentiality to all data and two classes of confidentiality of results, open and restricted disclosure.

5) *Two report versions*
The restricted version contains all results, but no data, and is circulated as a member-only report. The open version contains results for members that have not requested closed circulation of results and is distributed to members that have not acknowledged the restricted release rules.

6) *Comprehensive package*
Compared to 2003, the current project includes a flat fee for all activities related to project kick-off, initiation, site visit, pre-result discussion and final debriefing.

7) *Sensitivity analyses*
Each participant can design supplementary sensitivity analyses at a nominal fee.

Deliverables

1.10 The project contained following deliverables:

1) Workshop 1: Project kickoff
Brussels, 26.11.2004. (Appendix A1)

2) Workshop 2: ECOM+ model, weights and intervals. 25.02.2005. (Appendix A2)

3) Preliminary runs: ECOM+results under opex definition 1.0 06.05.2005

4) Workshop 3: ECOM+ new member integration. Brussels, 06.05.2005. (Appendix A3)

5) Workshop 4: ECOM+ operating cost workshop. Copenhagen, 23.06.2005. (Appendix A4)

6) Preliminary runs: ECOM+results under opex definition 2.0 02.10.2005

7) Final report: ECOM+results, 11.10.2005

1.11 The fourth workshop (Brussels, 23.06.2005) was arranged pro bono by SUMICSID at the request of the project members to reach a consensus on the operating cost reporting standard. The workshop was preceded by documentation and included prepared statements by several members on the topic.

1.12 Project start 01/10/2004.

1.13 Project termination 01/05/2005.

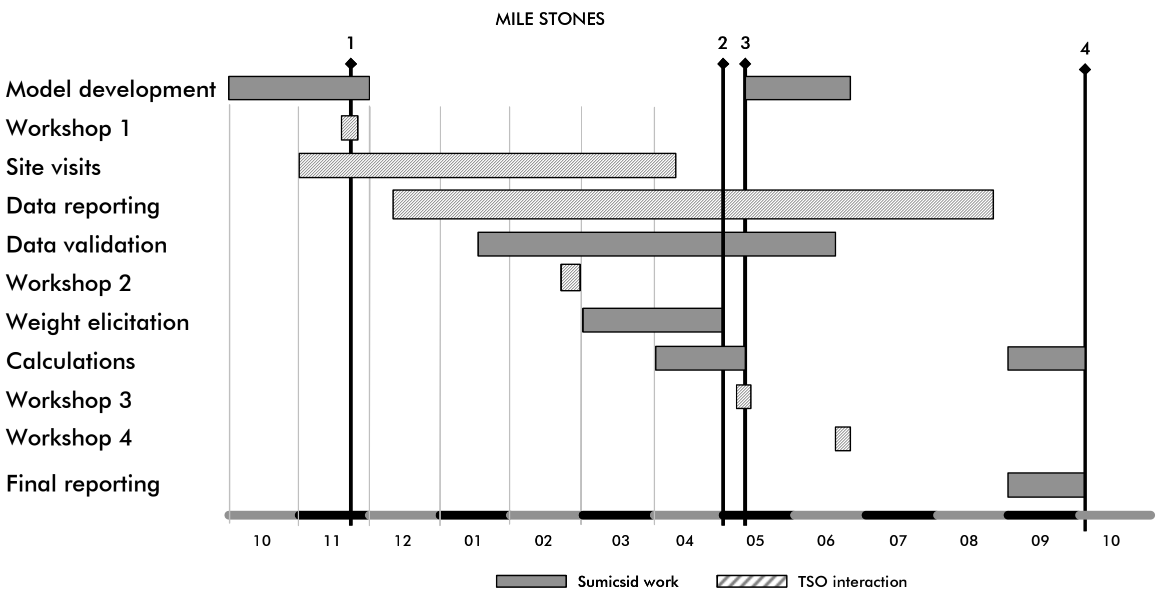

Figure 1-1 Project plan ECOM+ 2004.

Milestones TSO

1.14 Workshop 1 (A+B) 26/11/2004 **Milestone 1**

1.15 TSO data coordinator appointed 01/12/2004

1.16	TSO final asset data delivery:	15/03/2005	
1.17	TSO description delivery	15/04/2005	
1.18	TSO final data verification:	**29/04/2005**	**Milestone 2**
1.19	TSO final cost data delivery:	09/09/2005	
1.20	TSO statement of final results:	21/10/2005	

Activities SUMICSID

1.21	Workshop 1	26/11/2004	**Milestone 1**
1.22	Site visits to TSO E - J	11/2004 – 01/2005	
1.23	Methodology (c) finished	31/12/2004	
1.24	Workshop 2	02/2005 – 03/2005	
1.25	Internal validation (d) finished	01/09/2005	
1.26	Workshop 3 (weights)	06/05/2005	**Milestone 3**
1.27	Workshop 4 (OPEX)	23/06/2005	
1.28	Preliminary results	02/10/2005	
1.29	Final reporting (internal)	**14/10/2005**	
1.30	Final reporting (external)	**30/10/2005**	**Milestone 4**

Document status

1.31 This report and its appendixes are together with the Data Definition Guide issued 17/11/2004 (revised 31/05/2005, version 1.6, Appendix A14) and the Operating Cost Reporting Guide issued 13/05/2005 (revised 06/07/2005, version 2.1, Appendix A15) the deliverables of the project.

1.32 This report is OPEN, meaning that it is considered non-confidential information according to the confidentiality agreement of the project.

Outline

1.33 This report is opened with an introduction to TSO assessments in Chapter 2. The ECOM+ model is defined in Chapter 3; the implementation and the numerical estimations are discussed in Chapter 4, followed by a discussion on country specifics in Chapter 5. The participating grids of TSO J to G are presented in Chapter 6 through 11. Service quality and maintenance expenditure are discussed in Chapter 12. The main results of the study are presented in Chapter 13. Sensitivity analyses are presented in Chapter 14. Finally, the reported is concluded with some suggestions for further work in Chapter 15.

Other publications in the project

1.34 Several guides and notes have been produced during the project and made public through the dedicated webpage ecom.sumicsid.com

1)	Project Plan	17/12/2004		
2)	Note on Methodology	01/10/2004		
3)	Model Confidentiality Agreement	07/10/2004		
4)	Data definition guide	31/05/2005	version 1.6	A14
5)	Cost reporting guide	06/07/2005	version 2.1	A15

2. System and model description

2.01 The fundamental objective of a transmission system operator is to ensure the electrical stability of the interconnected system so that electrical energy can be transported from generators to distribution networks. The operator provides open access to the transmission system, monitors and controls system operations to ensure a moment-to-moment energy balance, manages congestion, schedules generation (or reviews the technical feasibility of schedules submitted by others), acquires ancillary services such as disturbance reserves and voltage support, and plans or approves requests for maintenance of transmission and generation facilities. Many system operators also administer spot and real-time balancing energy markets. These operators generally perform metering, accounting, settlement, and billing for the markets, but may also initiate, enforce or administer market instruments related to congestion, supply safety and load control.

2.02 By distinguishing six important functions or roles, the autonomy and independency of an operator may be put in a correct context to enable, among other things, performance assessments (cf. Figure 2-1). The functions are:

X Market facilitation

S System operations

P Grid planning

C Grid construction

M Grid maintenance

F Grid owner/financing

2.03 The first three functions are *strategic functions* with long-term impact on system performance. The functions C and M are *operational functions* with comparatively fewer long-term system-wide impacts. The ownership is normally tightly connected to regulatory and institutional practices.

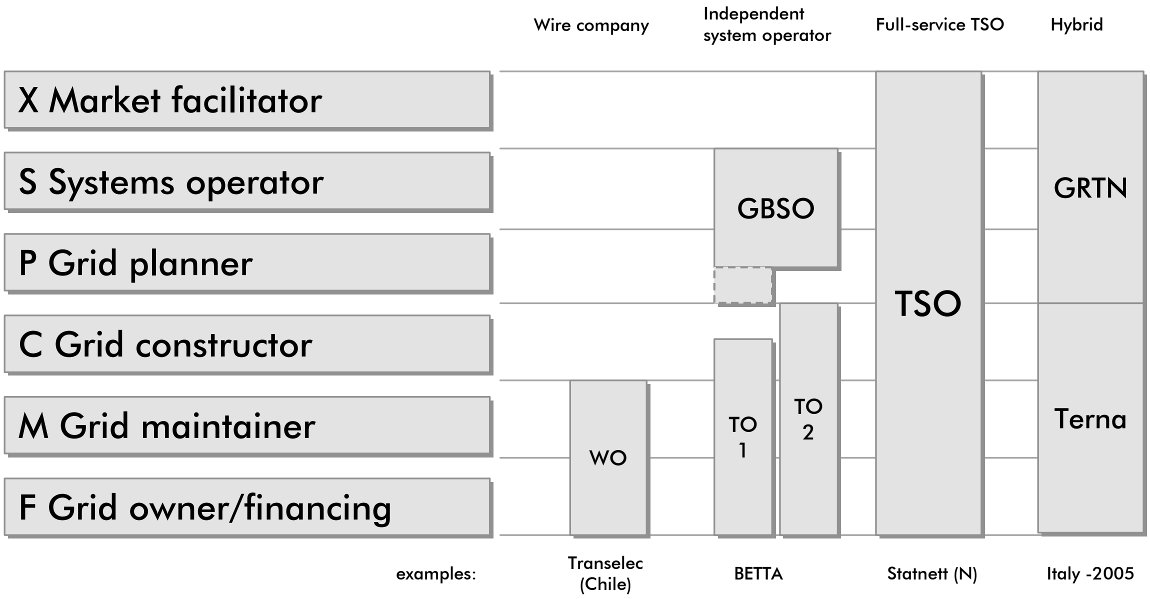

Figure 2-1 TSO Functions and Organizational Type.

X Market Facilitation

2.04 The establishment, monitoring and enforcement of an advanced electricity exchange require to some extent the informational support of the transmission system operator. The TSO will necessarily be involved in the final settlement of the delivery of the good and may also pose additional fees for its transmission. Independent market operators normally handle the clearing, trading and management of financial instruments for the electricity market. The activities for this function involve all information costs and direct resources related to the management, facilitation or administration of market places, including measurement, calculation and dissemination of price signals (node prices, price zones), preparing annual surveys and forecasts for use by the market's current and potential players and to illustrate compliance with public service obligations, information for settlement of claims and contract flows from exchanges, backup agreements and research and development into market functioning, mechanisms and contracts. If applicable, responsibilities related to the information flows to related markets (green certificates, renewable fuels, DSM, DER, preferential feed-in tariffs) are also considered market facilitation.

2.05 Costs and revenues related to transitional or permanent retail engagements, such as procurement, billing, losses and resale of energy to captive or non-captive clients are considered specific cases of market facilitation.

S System Operations

2.06 The purpose of system operations is to ensure the real-time energy balance, to manage congestion, to schedule and dispatch generation (or to review the technical feasibility of schedules submitted by others) to perform failure analysis and detection, to manage the availability and coordination for preventive and reactive reparations, and to acquire ancillary services such as disturbance reserves and voltage support, maintaining technical quality and balance within the coherent electricity supply system, also ensuring that the necessary supply capacity for physical regulation of the system is available. System operations are subject to the limitations of the existing grid, but information arrangements and tariff structure may either aggravate or alleviate congestion management problems. It also deals with the day-to-day management of the network functionality, including personnel safety (instructions, training), equipment security including relay protection, operation security, coordination with operations management of the neighbouring grids, coupling and decoupling in the network and allowances to contractors acting on the live grid. Given its central position in terms of market and technical information, the competence and independence of the system operator will have short- as well as long-term effects on social welfare. System operations may entail delegating operational balance services to subordinate (regional) transmission coordinators with limited decision rights.

2.07 In particular, we refer all costs and revenues from national and international congestion management to system operations, as well as all direct and indirect costs related to balance markets.

2.08 Costs, imposed or not, for spinning reserves, capacity provision or out-of-market guarantees or caps in case of power shortage are for the purposes of this presentation referred system operations.

P Grid Planning

2.09 The analysis, planning and drafting of grid expansion and network installations involve the internal and /or external human and technical resources, including access to technical consultants, legal advice, communication advisors and possible interaction with governmental agencies for preapproval granting.

C Grid Construction

2.10 The grid constructor implements the plans from the grid planning once all necessary authorizations have been granted. Construction involves tendering for construction and procurement of material, interactions, monitoring and coordination of contractors or own staff performing ground preparation, disassembly of potential incumbent installations, temporary site constructions and installations, installation of equipment and infrastructure, recovery of land and material, test, certification and closure of the construction site.

2.11 In particular, all expenses related to site selection and environmental impact analyses are classified as grid construction since this cost normally is activated with the investment.

M Grid Maintaining

2.12 The maintenance of a given grid involves the preventive and reactive service of assets, the staffing of facilities and the incremental replacement of degraded or faulty equipment. Both planned and prompted maintenance are included, as well as the direct costs of time, material and other resources to maintain the grid installations. It includes routine planned and scheduled work to maintain the equipment's operating qualities to avoid failures, field assessment and reporting of actual condition of equipment, planning and reporting of work and eventual observations, supervision on equipment condition, planning of operations and data-collection/evaluation, lawn moving, tree cutting and emergency action.

F Grid Owner

2.13 The grid owner is the function that ensures the long-term minimal cost financing of the network assets and its cash flows, including debt financing, floating bonds, equity management, general and centralized procurement policies, leasing arrangements for grid and non-grid assets, management of receivables and adequate provision for liabilities (suppliers, pensions, etc). Note that it does not include all potential tasks of a financial department for a transmission operator that is involved in the downstream market, i.e. procurement and resale of energy on competitive or captive markets. In this function, we also include the central managerial functions (board and director) that are unavoidable and intrinsically linked to the legal existence of the firm.

Summary

2.14 Consider the organizational chart for a full service transmission system operator in Figure 2-2 below. The activities are divided into functions under the joint management of a CEO, answering to a Board of Directors or corresponding. The central management is supported by some off-line support unit that performs joint activities, monitors and reports implementation of central policies, typically strategic planning, communication, human resources, and legal services. Each function performs the activities previously discussed using staff, fixed and variable resources. The importance weights of the functions may be deducted from letters of instruction, electricity acts, internal mission statements, annual reports and accounting statements. Note that the ECOM+ study only concerns the functions related to C and M in example of how to recreate this basis of comparison from an arbitrary organizational model under separated accounts as in Figure 2-1 the IEM Directive 2003/54, marked in red in Figure 2-2.

Multifaceted evaluation

2.15 Recognizing the multiple functions of the TSO, their importance and interdependence, on the one hand and the institutional design interests that lie behind a certain organizational structure, on the other hand, it is important that the benchmarking reflects the societal interests. To be effective in our quest to coordinate the transmission industry and to motivate optimal efforts, we must find benchmarks that do not only measure the measurable today, but that also warrant for continued and reliable performance in the future. A comprehensive framework for such evaluation has been presented in the Charter of Accountability (Agrell, Bogetoft, 2002).

The basic ECOM+ measures

2.16 The ECOM model is a spotlight on the absolute and relative efficiency of the 'wire company', i.e., the grid builder and maintainer roles of the TSO.

2.17 First we compare the realized actual OPEX and CAPEX (measured in a standardized way) to measures of the size of grid from the point of operations and maintenance, SizeOfGridOPEX, and construction, SizeOfGridCAPEX. The latter provides measures of expected equipment costs and is constructed using medium to medium-high international maintenance and building norms, and can be seen as cost drivers. The result of comparing the realized costs to our constructed measures of SizeOfGrid is called the unit costs UC.

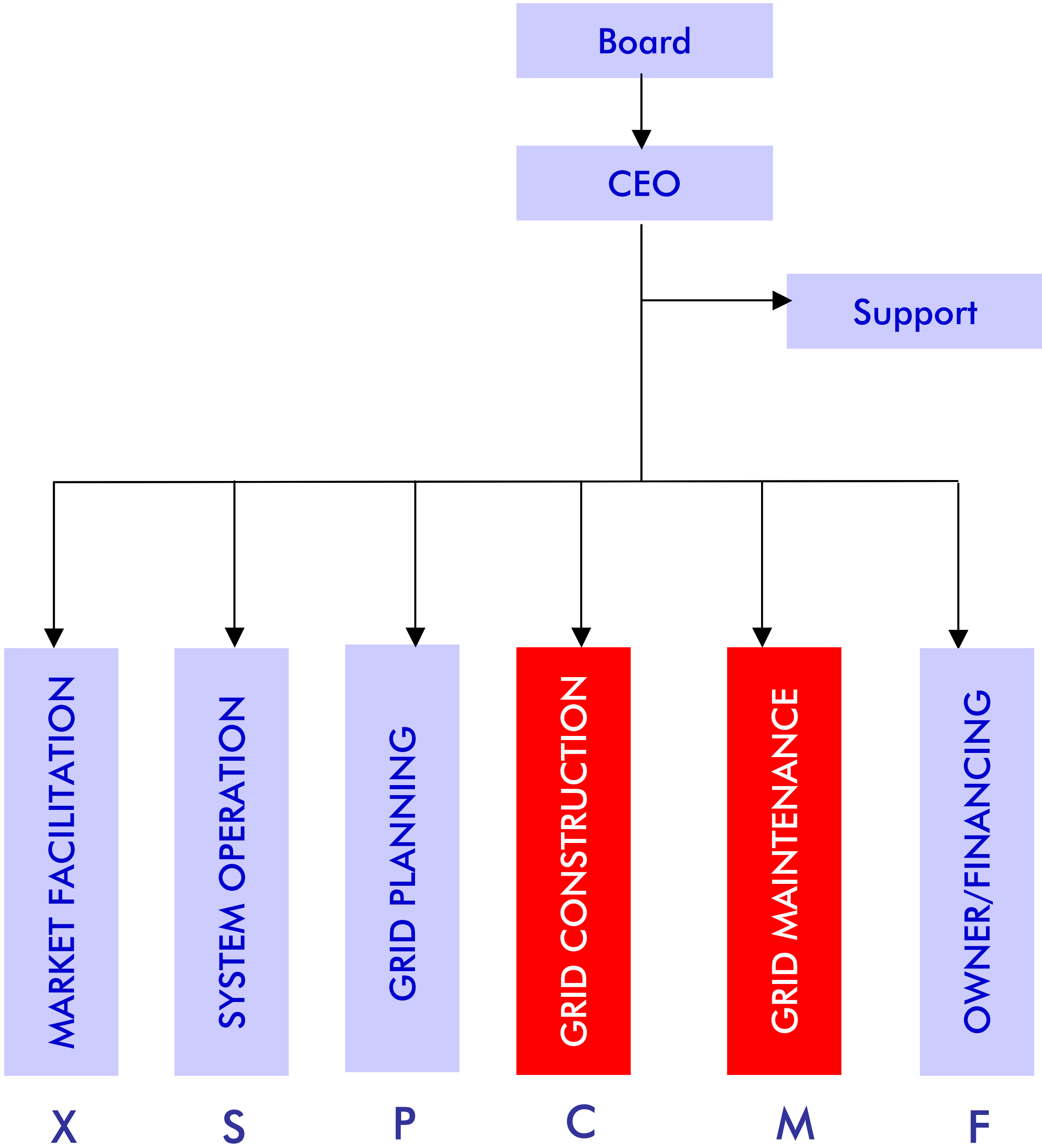

Figure 2-2 Organizational chart of transmission system operator.

2.18

$$UC = \frac{ActualCosts}{SizeOfGrid} = \frac{OPEX + CAPEX}{SizeOfGridOPEX + SizeOfGridCAPEX}$$

2.19 The UCs give absolute evaluations and can be used in budgeting.

2.20 Second, by comparing the unit costs across the sample of participating TSOs, a *relative measure* of efficiency, E, is obtained

$$E = \frac{\text{Min UC}}{\text{UC}}$$

2.21 It measures how large a percentage of the realized unit costs is needed if best practice in the sample were implemented. It hereby provides a relative performance evaluation that will depend on the TSOs in the sample.

Presumptions

2.22 The unit cost UC and the efficiency E provide *cautious estimates* in the sense that they do not evaluate whether the existing components are the relevant ones. In particular, the TSOs are provided full "reimbursement" for quality upgrades that are reflected in the amount of equipment installed. Likewise, the use of more expensive equipment is "compensated" at least to the extent that it is reflected in the list of asset items that we use.

2.23 On the other hand, the basic ECOM+ measures, UC and E are challenging by presuming *constant return to scale*, i.e. by presuming that no diseconomies exist from being neither small nor large. This constant return to scale (crs) presumption is contrasted with the less demanding varying return to scale (vrs) assumption in Figure 2-3 below. The idea of the latter is that there may be diseconomies from being too small, e.g. because of high fixed costs, as well as possible from being too large, e.g. coordination and incentive problems in huge hierarchies or possible lack of competition on the supply market.

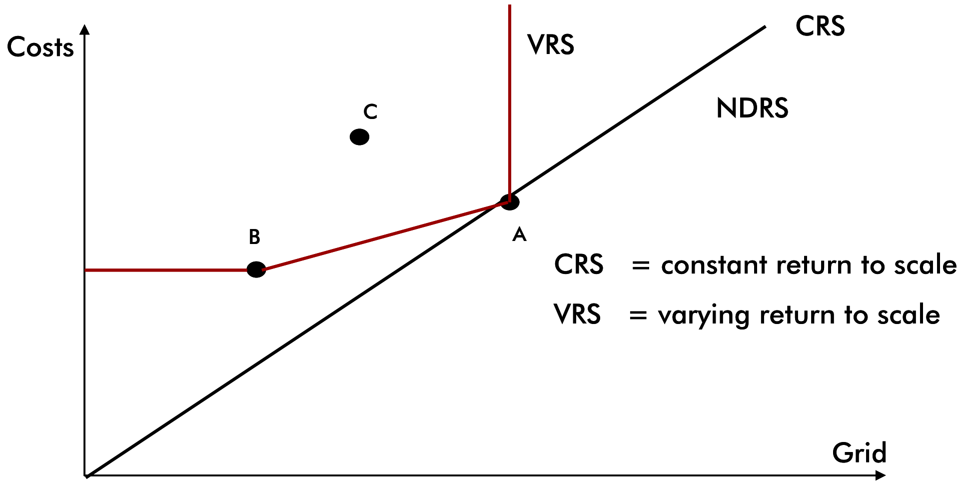

Figure 2-3 Return to scale

2.24 The basic measures are also challenging by requiring an optimal *trade-off* between construction and maintenance. This is reflected in the addition of these costs (after making them comparable by using annuity evaluations of the investment streams)

OPEX + CAPEX

In the terminology of productivity analysis, the measure presumes perfect cost substitution or allocative efficiency in the sense that the TSO should allocate optimally between investment and maintenance. This may not be the most useful nor relevant presumption taking into account controllability, likely regulatory uses nor the need to distinguish between past and present merits.

2.25 Moreover, and in part as a consequence of the last observation, the basic measures tend to be *dominated by historical investments*. This is not surprising given that the TSO business is basically a very capital intensive infra-structure activity. For these reasons, one can argue that TSOs should have a primary focus on its construction activities. On the other hand, the sunk costs nature of the investments and the need to discuss also what can be changed in the short run suggest that some alternative or supplementary measures may be useful.

Partial and refined ECOM+ measures

2.26 The above presumptions and possible drawbacks of the basic measures suggest that some decompositions may be relevant. In this round of the ECOM+ benchmarking, we have therefore set out to refine and improve the performance measures. First of all, we have developed partial measures of OPEX and CAPEX unit costs and efficiency. Secondly we have developed measures to capture changes over time.

2.27 To distinguish between performance in the construction and the maintenance operations, a first *naive* approach is use partial unit costs

$$UC^{N}_{OPEX} = \frac{OPEX}{SizeOfGridOPEX}$$
$$UC^{N}_{CAPEX} = \frac{CAPEX}{SizeOfGridCAPEX}$$

2.28 Using these we can then also derive *naïve partial efficiencies* by comparing the unit costs to the best practice in the sample

$$E^{N}_{OPEX} = \frac{\text{Min } UC^{N}_{OPEX}}{UC^{N}_{OPEX}}$$
$$E^{N}_{CAPEX} = \frac{\text{Min } UC^{N}_{CAPEX}}{UC^{N}_{CAPEX}}$$

2.29 Measures like these are commonly used, but they are naive and suffers from possible paradoxes.

2.30 Firstly, and most importantly, the comparison basis may end up being ideal and non-realizable. We might end up comparing with ideal but unrealistic partial standards. If no existing TSO has been able to minimize both OPEX and CAPEX unit costs simultaneously, it may not be relevant to compare to the ideal unit constructed by taking best OPEX practice from one TSO and best CAPEX practice from another. It is like being compared to person with a brain like the brightest, the speed of the fastest, and the look of Miss Universe. This obvious fallacy of partial evaluations is illustrated in Figure 2-4 below.

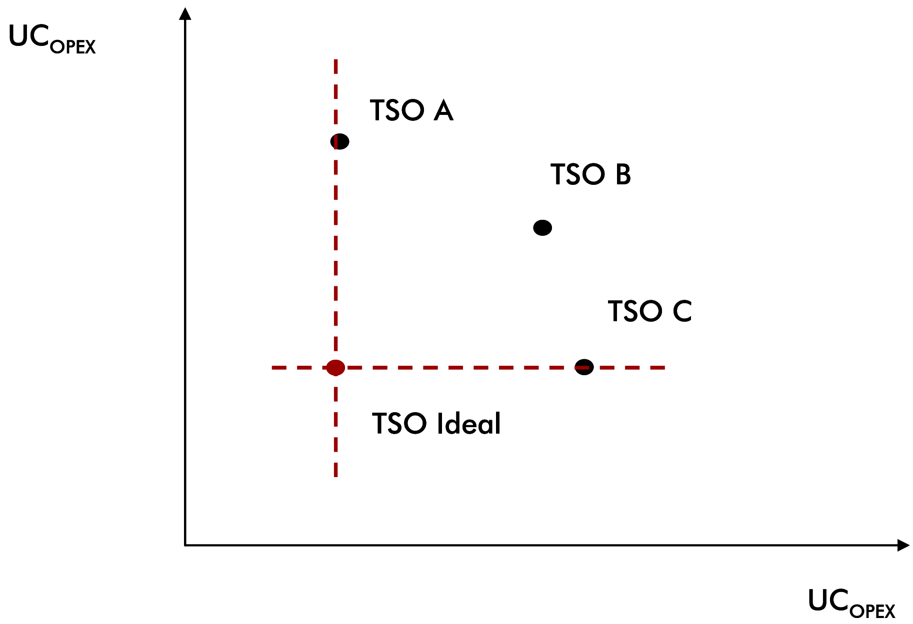

Figure 2-4 Infeasible ideal

2.31 Secondly, it is theoretically possible for one unit, say TSO A, to have better OPEX and CAPEX efficiency than another unit, TSO B, and to have the total efficiency ranking reversed. This phenomena is known as the Fox Paradox and was first discussed in the literature by Fox(2003). The reason for this paradox is the relative importance of the two tasks. To determine the overall performance, it is not enough to do relatively better in both dimensions. The relative size of the most efficient sector matters also. Thus, if TSO A has a relatively large part of it activities allocated to the least productive activity, TSO B may outperform it by having more emphasize on the most productive dimension. The small example in Table 2-1 below illustrates this

Table 2-1 Fox paradox

TSO	UC_{OPEX}	UC_{CAPEX}	UC
A	1/2	1/4	2/6=0.33
B	0.15/0.2	2.1/8	2.25/8.2= 0.27

2.32 To avoid these possible fallacies of the commonly used but naive partial measures, we have used an integrated approach, where the OPEX performance of one unit can only be judged against units (or combinations of units) that are doing better on the other input CAPEX (as well as on the outputs) and vise versa. This is illustrated in Figure 2-5 below where we have – for the purpose of illustration, presumed that all TSO produce the same output, e.g. the same constructed and maintained grid.

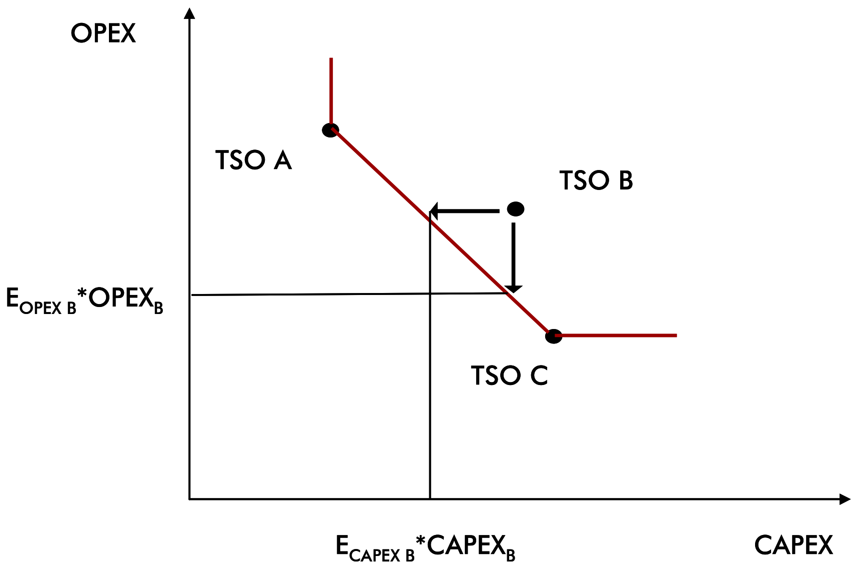

Figure 2-5 Partial measures

2.33 Specifically, we use the same aggregations and standardizations of the costs and grid size measures as in the total measure, but we look at them in a two inputs – OPEX and CAPEX - two outputs – SizeOfGridOPEX and SizeOfGridCAPEX technology model.

2.34 Assuming that the technology is free disposable (since spending extra costs is not a problem) and convex (since local substitution between the costs is possible) we use simple Linear Programs to evaluate the partial OPEX efficiency of a given unit i, $E_{OPEX\ i}$ as

$$\begin{aligned}
\min\ & E_{OPEX\ i} \\
\text{s.t.}\ & E_{OPEX\ i} \cdot OPEX_i \geq \sum_k z_k OPEX_k \\
& CAPEX_i \geq \sum_k z_k CAPEX_k \\
& SizeOfGridOPEX_i \leq \sum_k z_k SizeofGridOPEX_k \\
& SizeOfGridCAPEX_i \leq \sum_k z_k SizeofGridCAPEX_k \\
& \sum_k z_k = 1
\end{aligned}$$

2.35 Likewise we can evaluate the partial CAPEX efficiency of a given unit i, $E_{CAPEX\ i}$ as

$$
\begin{aligned}
\min \quad & E_{CAPEX\,i} \\
\text{s.t.} \quad & OPEX_i \geq \sum_k z_k OPEX_k \\
& E_{CAPEX\,i} \cdot CAPEX_i \geq \sum_k z_k CAPEX_k \\
& SizeOfGridOPEX_i \leq \sum_k z_k SizeofGridOPEX_k \\
& SizeOfGridCAPEX_i \leq \sum_k z_k SizeofGridCAPEX_k \\
& \sum_k z_k = 1
\end{aligned}
$$

2.36 Technically, this is similar to do DEA analyses with only OPEX as discretionary variable in the OPEX efficiency evaluation, and only CAPEX as discretionary in the CAPEX efficiency case.

2.37 Observe also that this approach (by restricting the weights to sum to 1) impose varying return to scale. The latter allows for possible diseconomies of running comparatively small or large networks.

2.38 We note also that this approach leads directly to the partial efficiencies. No partial unit costs are calculated since they would ideally presume independence between the OPEX and CAPEX which is precisely what may lead to flawed partial measures.

Dynamic ECOM+ measures

2.39 It is also important for regulatory uses, for internal learning etc to evaluate the changes over time, i.e. to distinguish progress and regress in the performance of the TSO. Over time, both the behavior of an individual TSO and the nature of the technology changes. This is illustrated in Figure 2-6 below.

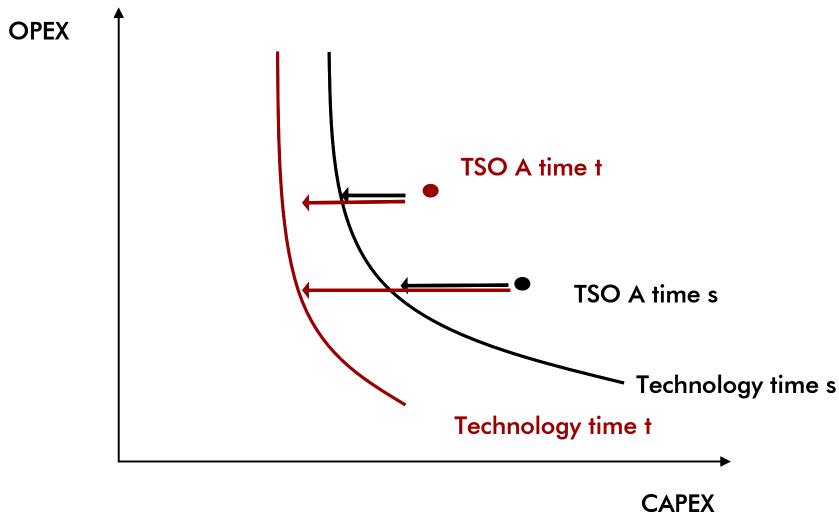

Figure 2-6 Dynamics

2.40 The standard approach to dynamic evaluations is to use so-called Malmquist indices. They measures the change from one period to the next by the geometric mean of the performance change relative to the past and present technology.

2.41 Specifically, let $E_i(s,t)$ be a measure of the performance of TSO_i in period s against the technology in period t. The performance measure may be any of the ones we have looked at above, i.e. the total efficiency, the naïve OPEX and CAPEX efficiencies and the partial OPEX and CAPEX efficiencies. (Note than in the case of the non-naïve partial measures, we would use data from the TSO in period s and data from the other TSOs from period t. More precisely, on the right hand sides of the inequalities in the LP programs, the data would be from period t while they would be from period s on the left hand side). We could even use inverse unit costs as the performance measure.

2.42 Now, TSO_i 's improvement from period s to period t can be evaluated by the Malmquist index $M_i(s,t)$ given by

$$M_i(s,t) = \sqrt{\frac{E_i(t,s)}{E_i(s,s)}\frac{E_i(t,t)}{E_i(s,t)}}$$

2.43 The intuition of this index runs as follows. We seek to compare the performance in period s to period t. The base technology can be either s or t technology, so we take geometric mean. Improvements make nominator larger than denominator. Hence, M > 1 corresponds to progress and for example M=1.2 would suggest a 20% improvement from period s to t, i.e. a fall in the resource usage of 20%.

2.44 The change in performance captured by the Malmquist index may be due to two, possibly enforcing and possibly counteracting factors. One is the technical change, TC, that measures the shift in the production frontiers corresponding to a technological progress or regress. The other is the efficiency change EC which measures the catch-up relative to a fixed frontier. This decomposition is developed by a simple rewrite of the Malmquist formula above given by

$$M_i(s,t) = \sqrt{\frac{E_i(t,s)}{E_i(s,s)} \frac{E_i(t,t)}{E_i(s,t)}}$$

$$= \sqrt{\frac{E_i(t,s)}{E_i(t,t)} \frac{E_i(s,s)}{E_i(s,t)}} \cdot \frac{E_i(t,t)}{E_i(s,s)}$$

$$= TC_i(s,t) \cdot EC_i(s,t)$$

2.45 Again the interpretation is that values of TC above 1 represent technological progress – more can be produces using less resources – while values of EC above 1 represents catching-up, i.e. less waste compared to the best practice of the year.

2.46 The Malmquist measure and its decomposition is useful to capture the dynamic developments from one period to the next. Over several periods, one should be careful in the interpretation. One cannot simply accumulate the changes since the index does not satisfy the so-called circular test, i.e. we may not have M(1,2) x M(2,3) = M(1,3) unless the technical change is so-called Hicks-neutral. This drawback is shared by may other indices and can be remedies by for example using a fixed base technology. This however, is beyond the scope of this report.

More caveats

2.47 As discussed above, the synergies involved in the organization of a TSO combined with the horizon of investment render a point estimate difficult. The ECOM model gives an estimate of the absolute and relative efficiency of the selected activities only and this input-oriented estimate is valid only under an effective output-oriented control, such as an imposed and uniform quality standard. When these assumptions are valid and the data provided to form the comparison is flawless, the ECOM score can be employed in addressing the *costs of the benchmarked activities*.

3. Formal model description

3.01 In this chapter, we give a detailed and somewhat more mathematical description of the basic building blocks of the ECOM+ model, viz. the standardized OPEX, CAPEX, SizeOfGridOPEX and SizeofGridCAPEX measures.

3.02 As explained in the previous chapter, the values of these variables are combined in different ways to construct the unit costs and efficiencies, both total and partial. In turn, these measures also form the basis for the dynamic decompositions into technical progress and catch-up as explained above.

Notation

3.03 The data is defined as follows:

INDEXES

Firm (TSO) index	$f = 1,\ldots, F$
Group index of network assets	$g = 1,\ldots, G$
Network asset index, $a \in A_g$	$a = 1,\ldots, A$
Time index	t or s

PARAMETERS

Total benchmarked OPEX for firm *f* and time *t*	C_{ft}
Investment budget firm *f* and time *t* (local currency)	I_{ft}
Number of assets of type *a* that firm *f* owns at time *s*	N_{fas}
Number of assets of type *a* acquired by firm *f* in period *s*	n_{fas}
Weights for CAPEX, firm *f* asset a	v_{fa}
Weights for OPEX, firm *f* asset a	w_{fa}
Purchasing parity power for firm *f*, time *t*	PPP_{ft}
Purchasing parity power for EURO, time *t*	PPP_{Et}
Consumer price index for firm *f*, time *t*	CPI_{ft}
Consumer price index for NOK, time *t*	CPI_{Et}
Exchange rate between currencies X and Y time *t*	$Exch(X,Y;t)$

VARIABLES

The lifetime of assets in group *g*	T_g
Investment budget (corrected) firm *f* and time *t* (local currency)	$\underline{I}_{ft}$
Investment budget (corrected alt) firm *f* and time *t* (local currency)	$\underline{I}'_{ft}$
Weights (corrected) for CAPEX, firm *f* asset a	$\underline{v}_{fa}$
Weights (corrected) for OPEX, firm *f* asset a	$\underline{w}_{fa}$
Weights (common) for CAPEX, asset a	V_a
Weights (common) for OPEX, asset a	W_a
Country specific weight CAPEX, firm *f*, group *g*	μ_{fg}
Country specific weight OPEX, firm *f*, group *g*	λ_{fg}
Real interest rate	R
Forgiveness factor for time *t*	φ_t

INTERNAL VARIABLES

The weighted average lifetime of assets for firm *f*	$\underline{T}_f$
Annuity factor with *r* and lifetime *T*	$\alpha(r,T)$
Binary asset group indicator, asset *a* and group *g*	x_{ag}

Asset grouping

3.04 The asset grouping can be modeled using a binary variable x_{ag} such that it is 1 if *a* belongs to group g (with asset numbers A_g) and zero else. It is convenient to structure the assets in this manner, as assets in a specific group (say, DC-cables) share common properties (e.g., climate dependency) and characteristics (e.g., life time). The *X*-matrix also enables fast sensitivity analyses and comparisons between benchmarks of different aggregations.

Exchange rates and inflation

3.05 To account for inflation and to make currency corrections to compare long investment streams in different countries, we have adjusted observed investment in TSO f year t by a price indices. Following the previous round of ECOM+ attempts have been made to come up with the most relevant approach.

3.06 Several alternative suggestions like the use of purchasing power parity (PPP) indices has been discarded on conceptual grounds.

3.07 Ideally, one could use indices combining local labor costs with international capital equipment costs, or at least to use price indices for import and the first producer level. Unfortunately, it has not been able to get indices from the national or international statistical bureaus that are comparable and of a sufficiently good quality. Our own attempts to combine labor cost information from ILO and producer price indices from OECD have also not resulted in any convincing constructions.

3.08 Fortunately, the use of alternative indices do not seem to have a huge impact on the TSO ranking, but the spread have often increased compared to the index using in the previous round. We have therefore decided to continue to use the same approach as in the last round, despite of the obvious objections one can make to this. It seems, after all, to be the best alternative available within the limits of this study.

3.09 The index we have used is therefore

$$\text{Index-3}_{ft} = [\text{Exc}(f,\text{NO};t)]\ [\text{CPI}(\text{NO},2000)/\text{CPI}(\text{NO},t)]\text{Exc}(\text{NO},€\ ;2000)$$

This index transforms 1 unit of a local currency in the country of TSO f in year t into a common currency in year t, here Norwegian Crowns. Next, the amount is transformed into year 2000 price level by using the Norwegian price index CPI. Lastly, we transform to Euro.

3.10 The investment of TSO *f* at time *t* adjusted to the price level in year 2000 and calculated in a common currency, namely Euro in year 2000, will be denoted $\underline{I}_{ft}$ below, i.e.

$$\underline{I}_{ft} = I_{ft}\ \text{Index-3}_{ft}$$

Average life lengths

3.11 Using a single lifetime for all assets would arbitrarily favor some investment patterns, without adding relevant information. Here, we have used individual estimates T_g for each asset group in the calculation of the normalized CAPEX. However, since the actual investment streams are not decomposed into assets (or asset groups), a weighted average is used. The average assumes that investments in particular years are equally distributed among the asset groups. Although some variation is present in the sample, the parameter is robust and does not intervene substantially in the rankings.

$$\underline{T}_f = \frac{\sum_g T_g \sum_{a \in A_g} N_{fa} v_{fa} x_{ag}}{\sum_a N_{fa} v_{fa}}$$

Forgiveness factor φ_s

3.12 Assuming that the empirical data may be of different quality in early periods and that the proportion of actual OPEX that refers to early assets can be identified, one may operate with a variable *horizon of interest*, φ_s, where a particular year or period can be excluded from the calculation of the normalized CAPEXs. In the current study, this variable is primarily used for sensitivity analysis

Annuity factor $\alpha(r,T)$

3.13 The actual investment streams I_{ts} after correction for currency and inflation are annualized using a standard annuity factor $\alpha(r,T)$, where r is the real interest rate. The parameters r and T are both subject to sensitivity analysis.

$$\alpha(r,T) = \frac{r}{1-(1+r)^{-T}}$$

CAPEX

3.14 The investment stream is transformed into a constant annuity and this constitutes the standardized CAPEX measure used in the comparisons .

$$CAPEX_{ft} = \sum_{s=t_0}^{t} \varphi_s \underline{I}_{fs} \alpha(r, \underline{T}_f)$$

SizeofGridCAPEX

3.15 The size of the grid from the point of view of necessary capital costs is evaluated using the CAPEX weight that provide medium to medium-high European equipment prices

$$SizeOfGridCAPEX_{ft} = \sum_{s=t_0}^{t} \sum_a \varphi_s n_{fas} v_{fa} \alpha(r, T_a)$$

This cost driver for CAPEX combines the expected prices of installing the equipment v_{fa} and the number of items installed in a given year, n_{fas}. The installation costs driver is transformed into an annuity as the investments were above, and to the extent that we use any forgiveness assumptions, the same years should be excluded in both the investment stream and the investment costs driver.

SizeofGridOPEX

3.16 The size of the grid from the point of view of necessary maintenance and operating expenditures OPEX is evaluated

$$SizeOfGridOPEX_{ft} = \sum_a N_{fta} w_{fa}$$

3.17 This cost driver for OPEX combines the expected prices of maintaining the assets w_{fa} with the number of asset items in use in a given year, N_{fta}.

ECOM+ Unit Cost expression

3.18 The unit cost (UC) expression in ECOM+ is the ratio of actual OPEX, normalized actual CAPEX and the standardized grid cost measure. The unit cost in itself is a standardized cost measure that can reveal operating efficiency, even in the absence of other comparators. The asset weights *w* and *v* (as well as the country specific weights μ and λ) will be the subject of the next chapter. The unit cost expression is an absolute measure and can thus be compared over time and across firms.

$$UC_{ft}(w,v) = \frac{C_{ft} + \sum_{s=t_0}^{t} \varphi_s \underline{I}_{fs} \alpha(r, \underline{T}_f)}{\sum_a N_{fa} w_{fa} + \sum_{s=t_0}^{t} \sum_a \varphi_s n_{fas} v_{fa} \alpha(r, T_a)}$$

ECOM+ Efficiency score

3.19 The unit cost in isolation does not reveal whether a particular TSO is adhering to best practice that may evolve over time and across different operators. Consequently, the unit cost estimate is used in benchmarking by relating it to the least unit cost provider at any given time. We denote the obtained relative efficiency estimate by E_{ft} for firm *f* at time *t*

$$E_{ft} = \frac{UC_{ft}(w,v)}{\min_{f'\in F}\{UC_{f't}(w,v)\}}$$

3.20 The ECOM+ score can then give an estimate of the efficient cost to construct and maintain the actual grid of a given firm, had it been using best practice at the given time. As the unit cost measure both includes OPEX and normalized CAPEX, it avoids the erroneous partial comparisons of OPEX or CAPEX that ignore substitution and activation possibilities.

3.21 The normalization of actual CAPEX has the advantage of rendering the firms' capital cost comparable. In absence of a uniform taxation, depreciation and financing policy, this would otherwise have been misleading. Without normalization, the time effect would also have biased the estimate towards early investments, or necessitated complicated inflation correction of actual depreciation patterns. However, the normalization also has the disadvantage of ignoring the efficiencies of the *grid-financing* role, which has been discussed further in Agrell and Bogetoft (2002).

ECOM+ Unit Cost expression based on common weights and country specifics

3.22 The normalization of actual CAPEX has the advantage of rendering the firms' capital cost comparable. In absence of a uniform taxation, depreciation and financing policy, this would otherwise have been misleading. Without normalization, the time effect would also have biased the estimate towards early investments, or necessitated complicated inflation correction of actual depreciation patterns. However, the normalization also has the disadvantage of ignoring the efficiencies of the *grid-financing* role, which has been discussed further in Agrell and Bogetoft (2002).

The weights

3.23 The OPEX and CAPEX weights shall ideally reflect the minimal construction and maintenance costs of the different assets in the different TSOs:

v_{fa} = CAPEX weight, i.e. the minimal costs of installing one unit of asset a in firm f

w_{fa} = OPEX weight, i.e. the minimal cost of operating and maintaining one unit of asset a in firm f

3.24 If we have such information, we can evaluate the construction, operations and maintenance efficiency of the TSOs even without making comparisons among them as explained above. That is, if the weights reflect ideal minimal costs, the unit costs reflect the actual costs compared to the minimal costs and hence the unit costs give a direct measure of efficiency. A unit costs of 1.2 suggests an overspending of 20% on OPEX and CAPEX. In this case there is no need *per se* to compare the TSOs, or to try to establish a common weight system.

3.25 Unfortunately, we cannot be sure that the weights provided by the TSOs are minimal costs. We shall discuss this in the implementation part.

Estimation of country specific weights

3.26 In the likely case that one cannot get good weights from the TSOs or external sources, one can – as an alternative - try to estimate country specific weights also using a common methodology.

3.27 We can do this for the CAPEX weights by F linear regression analysis, one for each country. The regression for country f is

$$\underline{I}_{fs} = \sum_{a \in A} w_{fa}^{SUMICSID} n_{fas} + \varepsilon_f \qquad s = 1,..,t$$

3.28 That is, for each country we can try to explain the total investment (corrected for inflation and currency) in each year by the physical investments that took place.

3.29 We cannot make a series of similar estimation of the OPEX weights since we only have OPEX costs for a few years. However, we can at least check the consistency by combining the weights supplied with the total reported OPEX in the few years we have, i.e. by comparing for each TSO f

$$C_{fs} \text{ and } \sum_{a \in A} v_{fa} N_{fas} \qquad s = 2000,...,2003$$

3.30 It turns out that these approaches to the estimation of country specific weights does not work well in practice. The regressions often come out with obviously incorrect signs and the consistency check of the OPEX shows – with one exception - very little correspondence between the weights supplied and the OPEX reported.

Common weights and country specific factors

3.31 Given the limited information available, it is natural to impose some restrictions on the weight structure. It is a general econometric principle that the less data available, the smaller should the degrees of freedom in the model be. The latter is in most cases equal to the number of parameters to be evaluated.

3.32 A general restriction structure is to assume that the weights have a part, which is common for all firms, and an individual part, which is specific to the firms:

$$v_{fa} = v_a \lambda_{fg}$$
$$w_{fa} = w_a \mu_{fg}$$

when a is in group g, i.e. $x_{ag}=1$.

3.33 A priori, a natural structure could for example be to assume that the individual parts, the λ and μ, depend only on assets groups like lines, transformers, circuit ends etc. The rationale for such a structure would be that the domestic costs drivers (labor, land, cost increasing work restrictions, environmental constraints etc) may be larger in some groups like lines compared to other groups like transformers, where the international costs drivers may be more significant. This would suggest that the TSO specific factors λ and μ on the first groups might vary much more than the factors λ and μ in the other groups.

3.34 To summarize our discussion of a common weight system modified by TSO specific complicating factor in different asset groups, we observe that the unit costs become

$$UC_{ft}(w,v,\mu,\lambda,x) = \frac{C_{ft} + \sum_{s=t_0}^{t} \varphi_{fs} \underline{I}_{fs} \alpha(r,\underline{T}_f)}{\sum_g \sum_a N_{fa} w_a x_{ag} \mu_{fg} + \sum_{s=t_0}^{t} \sum_g \sum_a \varphi_{fs} n_{fas} v_a x_{ag} \lambda_{fg} \alpha(r,T_g)}$$

3.35 This is the formula we have used to calculate the UC and the resulting efficiencies in the chapters on results and sensitivity analysis.

Direct validation and calibration of weights

3.36 To determine the common weights and the country specifics, it is reasonable to use a three step procedure.

3.37 First, to determine CAPEX weights one can use external experts to validate the costs of constructing (or operating) one asset a* under average European conditions. The weights validated by the technical expertise in this round of the ECOM+ study are described in Chapter 5 and give in Appendix A5 and some of the partially proprietary model background for the individual weights were presented at Workshop 3.

3.38 Second, the OPEX weights can be calibrated by combining the weights suggested by the TSOs with overall cost drivers. It is common to allocate operating costs in relation to capital values. This suggest that the OPEX and CAPEX weight shall be proportional. There is however no reason to assume the same proportionality factor for the different assets groups. Cables for example are very expensive in terms of CAPEX but relative inexpensive in terms of OPEX. One can therefore assume group specific proportionality factors as in

$$w_a = \beta_g v_a$$

when a belong to group g. The proportionality factors β_g can then be set by using the relative OPEX to CAPEX weights suggested by the TSOs. The usefulness of this approach depends of course on the asset groups implemented. The relevant grouping must strike a balance between being detailed and estimated on only few weights stated by the TSOs and being more aggregate with the possibility of extending the use of a given proportionality factor too far. To guide this balance, one can use the relative OPEX weights suggested by the TSOs. If two assets have very different OPEX weight proposals from the TSOs, they should allocated to different groups unless the CAPEX weights have the same differences. While thick line may be substantially more expensive in terms of CAPEX, the extra maintenance costs may not be as high. This would suggest that lines in this calibration should be split in sub-groups. The result of this approach of calibrating against CAPEX weights on the one hand and setting reasonable proportionality groups using relative OPEX weights on the other hand, is reported in APPENDIX A6 below. By comparing the OPEX weights and CAPEX weights, the groups and proportionality factors are revealed.

3.39 Third, country specifics can be introduced. As discussed in the previous round, it is theoretically possibly to make econometric estimation of these factors. In reality, however, the limited data set and the detailed asset specification makes this difficult. A natural procedure is therefore to let the evaluated TSOs submit country claims to the extend that they have evidence of substantial, non-discretionary and permanent extra costs in the construction or maintenance of some of the assets.

4. Implementation

The weights supplied by the TSOs

4.01 The weights supplied by the TSOs have been derived in different ways and their interpretation differs. Some supply only relative weights, some weights are defined per category, some relate to current records, some to new investments.

4.02 However, the clear connection to the accounting for the weights of TSO H and TSO G has been useful in the sensitivity analysis, as the quality of the relative weights of TSO E. That said, the need for consolidation in the weight set is well illustrated in Table 4-1 and Table 4-2 below. In these tables, we have used the weights of TSO E and TSO G, respectively, to evaluate the Unit Costs for themselves and the other TSOs. The comparison is made with the other parameters as in the study, i.e., r = 3.5%, T = 37 yrs. For obvious reasons, each TSO estimates carefully the costs related to the most crucial assets and give little importance to other items.

Table 4-1 Lower bounds on UC using TSO E weights 2000-2003.

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
2000	100%	15%	19%	22%	3%	14%
2001	100%	14%	19%	22%	2%	13%
2002	100%	15%	20%	23%	2%	15%
2003	100%	14%	19%	23%	3%	16%

Table 4-2 Lower bounds on UC using TSO G weights 2000-2003.

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
2000	21%	49%	100%	91%	1%	66%
2001	21%	47%	100%	92%	1%	67%
2002	20%	46%	100%	90%	1%	68%
2003	21%	47%	100%	92%	1%	74%

Weight estimation principles

4.03 As opposed to earlier methods, where the *weight standards* have carried some more or less implicit reference to efficient operations, with all the resulting problems of adjustments to non-optimal conditions etc, we have opted for a techno-economic weight estimation based on average European building and operating conditions. The underlying logic is based on the dual character of the measure; the ECOM score defines best practice among the participants and the unit cost gives performance related to an average standard.

4.04 The estimation of the weights has been managed by the data validation team that has reviewed a number of external sources and cost catalogues, but also performed case studies and analyses of specific investments such as HVDC converter stations and compensating devices. Although a specific cost function has been estimated for each asset or reference, it is not the intention of the project to publish yet another asset catalogue.

4.05 The submitted weights have been used for calibration of the asset categories such that the proportion of costs and asset expenditure are approximated. For certain assets, for which no valid estimates were presented, the submitted weights were directly used in the system.

4.06 Compared to ECOM+2003, the current weight system (cf Appendix A6), has been completely revised with respect to the assets. New categories have been introduced and others have been suppressed, leading to a more useful allocation of the estimation time. Using the new in-depth asset definition (cf. Appendix A14), its has been possible to provide a more solid definition for the weights and their interpretation. The weights of the original ECOM study (Econ, 1998, 2002) are obvious to use also to ensure continuity. Moreover and more importantly, they are considered relevant since they reflect information in the ITOMS study for the OPEX weights and in Norconsult (1998) for the CAPEX weights. For a detailed discussion, see Econ(1998, 2002).

4.07 They are therefore a good starting point, but they have been modified to some extent because of information from other external sources, most notably the studies by ICF Consulting, PB Associates, Hirst (2000) and ELFORSK (cf. references). Regarding these external validations, it is worthwhile to emphasize that technical evaluations are not unique. (This is well known also from other studies, a good illustration of which is the variation of expert evaluations derived by the regulator and the distribution companies in Chile, cf. Agrell and Bogetoft(2003). In fact, they are sometime inconsistent and often relatively uncertain. We have therefore found it useful to combine alternative reports rather than rely on a single extern evaluator (as it has to some part been done in the original ECOM study).

4.08 The OPEX weights in a preliminary release were based on an econometric estimation in each asset group, based on a weighted average ratio OPEX/CAPEX across observations in each group. The approach, an extension of the method in ICF (2002) was judged unsatisfactory and replaced by relative approach, pegged to reference items. Most importantly, the maintenance costs in total and per group were reviewed critically against the average costs of the observations to ensure the definition of *average European* operation.

Average versus extreme conditions

4.09 A common misunderstanding of any normalization system is that it has to represent any asset instance that is present in the data. An tower ratio of 1:10 can easily be insufficient for a section around a city, infrastructure or a topological obstacle. Naturally, this results in objectively measurable costs, *for that segment*, that are superior to the average norm. However, this is inevitable for any average that has to catch deviations both above and below the single estimate. Thus the insistence to admit only adjustments based on estimates for *the entire asset category* as to avoid bias by outliers. The mere existence of higher than average cost drivers does not necessarily imply that the average is violated for the very same asset, when all items and costs are taken into consideration.

4.10 The primary sources used to calibrate the common weights system are a) the relative weights from the TSOs, b) the relative weights from the original ECOM study and c) a series of external validations. We emphasize that the sensitivity of the results are in general not high when it comes to individual weights. This is understandable since many assets affect the total cost norm.

R-factor from ECOM+ 2003

4.11 The relative importance of OPEX to CAPEX, adjusted through a factor R in the ECOM+ 2003 study, has been made redundant by operating directly in comparative units. This has been made possible both by having direct access to ample asset costs and the increased quality of the absolute TSO weights.

4.12 In the results below, we have chosen to avoid this normalization to allow the individual TSOs and regulator to simply compare the unit costs against what they consider to be reasonable OPEX cost for 1 km of circuit length above 350kV. As a guideline, however, we propose that unit costs below 1000 EUR show that the TSO is doing better than an average (European) TSO on the construction, operations and maintenance of the grid.

The index

4.13 It is complicated to compare investment streams over many years due to inflation. It is even more complicated to compare long investments streams in different countries with different developments in exchange rates and purchasing powers. To cope with this we have defined three ways to adjust the investment streams, Index 1, 2, and 3, cf. 3.05. Somewhat unforeseen given the reports we have from the previous ECOM studies, the choice of index has a considerable impact on the results. This is an unfortunate feature of the model structure and the whole evaluation approach that may call for further analysis in subsequent studies. In the present project, the task was to implement in the best possible way the basic ECOM model methodology, and we have therefore relied on sensitive analysis. Fortunately, it turns out that from the point of view of the active TSOs in this project, the results are most favorable under the same index, namely INDEX3. We have therefore chosen to use this, giving the benefit of the doubt to these TSOs.

4.14 An additional motivation for the use of INDEX3 is the continuity in relation to the previous ECOM studies that relied on the same index.

4.15 The relative impact of productivity increases, material and labor cost fluctuations over time has not been modeled in the index. Difficulties related to the disaggregation of historic investment costs onto asset groups, past technologies and the construction of the investment basket make the task highly complex and possibly somewhat arbitrary.

Grouping

4.16 The asset groups are formed using sensitivity analysis as in ECOM+ 2003, where the uncorrected unit cost is shown to be fairly stable with respect to the aggregation policy. However, as a finer disaggregation gives more degrees of freedom to tailor the weights and to capture country specifics, we have chosen to work with a grouping policy such as in Table 4-3.

Table 4-3 Groups and assets used in ECOM+.

Group g	Comment	Asset category
1	Line	10
2	Cable	20
3	Circuit end	30
4	Transformer	40
5	Compensating device	50
6	Series compensation	60
7	Other assets	91

5. Country specific weights

5.01 The ECOM+ benchmarking exercise has a double purpose: to provide frontier unit cost estimates and to provide information for the assessment of the relative efficiency of TSOs in a regulatory context. The latter objective requires the explicit assessment of a set of country specific weights that reflect the exogenous cost drivers for the TSOs.

5.02 The efficiency estimate without country specific weights has some informative value as a measure of social welfare and to assess the relative costs of interacting regulation. However, it does not give a valid estimate of the operating and managerial efficiency of the appointed TSO, if best practice cannot be implemented for various reasons.

5.03 To make sure that all relevant complicating factors are identified, it can be useful to organize them in a hierarchy, where each subsequent level offers more complete, detailed and operational coverage of the preceding level.

5.04 To allow fair comparisons and relevant modeling, we need to account for a range of complicating factors, i.e. factors that the companies do not control and which may have significant impact on the companies ability to perform cost-efficient grid services. The complicating factors could for example reflect:

- the climate and other operating conditions which might render the construction, operation and maintenance more difficult and costly
- the environmental restrictions which may severely limit the firms' choice of technical solutions
- the interconnectedness of the country, which could have a considerable impact on network configuration and operating practice.
- the location of sources of generation and load, which will govern how network configuration and complexity
- the pricing and universal service obligations that are imposed on the different companies
- the country specific and international market structures in generation and consumption that affects the companies and on which they have limited control

5.05 To allow fair comparisons and relevant modeling, we also need to account for a range of complicating properties, i.e. properties that the companies may affect but which are neither inputs nor outputs in the usual sense. Rather, the complicating properties capture different properties of the inputs or outputs. The complicating properties may for example include:

- Differences in energy reliability levels
- Differences in power reliability levels
- Differences in the service restoration (fault detection and correction) levels
- Differences in customer satisfaction

Criteria

5.06 Given the limited number of TSOs in the study and the informational asymmetry inherent in the benchmarking of national monopolies, the ambition in the project is not to exhaustively cover all individual conditions that are, or have been, applicable to the service. Instead, participating TSO have been invited to submit a statement of alleged complicating factors. To qualify for inclusion in the study as a country specific allowance, the cost driver has to have exogenous, durable and sizeable impact on benchmarked cost. In addition, factors that are indeed valid in terms of the relevance criterion, but shared among all participants, are excluded.

Process

5.07 Following the previous round of ECOM+ in 2003, the process of determining country specific adjustments has been improved and implies in this round an systematic and open scrutiny of the claims to avoid information games among project members. In combination with the new weight system based on European standard costs, rather than best-practice, and an augmented asset data base, the role of the country specific has also diminished to primarily regulatory imposed action. For each claim, see Appendix A6, a review was made by the data validation team and the economic team. The proposed decision was communicated for information to respective regulator before communicating it to the submitting TSO.

5.08 By creating a more stringent review of the country specific adjustments, but also opening the definition of the items and the operating cost definition to a consensus among the reporting members, everybody benefits from an improved data and information. As part of the exercise is also to provide information about relative cost differences, without inferring anything about the causal relationships that lead to its incurrence. An abusive use of adjustment factors may unnecessarily complicate the correct estimation of costs, as some of the same assets or conditions may be present at another TSO that did not bother to claim. We believe that a fair application of benchmarking is to construct a model that cover the main cost drivers at a European level without resorting to a process benchmarking level of detail, and then to allow for due adjustments when they drivers are neither picked up by asset categories, nor washed out by averaging other impacts.

5.09 Below, we give some brief review of common cost drivers and their inclusion in the data set.

Equipment and installation standards

5.10 *Motivation*

The choice of steel vs. wooden poles is partially given by environmental regulation, population density and right-of-way legislation. As wood poles are less expensive to buy and install, this affects the comparability of CAPEX across countries. The Data Definition guide operates with steel towers and no submitting party has revealed inferior installation standards.

Landscape

5.11 *Motivation*

Climatic conditions in general, play a central role as determinants of the cost of construction and maintenance of the electrical grid system. Mean temperatures, air salinity and air humidity. The typology and type of landscape in which installations are placed influence construction as well as maintenance costs.

- wooded areas requires recurring tree cutting to keep lines free of branches
- soft underground requires better pole foundations
- cultivated areas calls for special access roads
- mountain areas require a higher number of poles, and the higher load from wind and ice requires more expensive conductors, towers, insulators and fittings
- forest areas and long trees entail that line routes have to be wide and regular patrolling and harvesting

5.12 *Comments*

- Lines are defined for average and alpine conditions, where alpine conditions have an impact both on capital expenditure and operating costs due to access conditions, climate, topology and environmental restrictions. The cost drivers are included in the capital expenditure as 162% on average conditions, based on building standards, ratio of angle towers to suspension towers and construction costs, operating costs follow a progressive scale, i.e 144%, 175% and 180% on average conditions depending on non-proportional costs for fault prevention at higher voltage.

- No specific allowance has been issued, since claims were either partial or covered by the new standards.

Population Density

5.13 *Motivation*

High population density increases the amount of site owners affected by new installations. This results in increased costs due to

- more property purchases and settlements
- more compensation to property owners / higher land prices
- more judicial processes
- noise protection demands
- problems arising from the debate on cancer in relation to magnetic fields
- protective planting
- cosmetic undergrounding of installations to minimize visual and noise related inconveniences
- increased demands for substitution of overhead power lines with cables
- increased amount of poles with multi-line suspension making the maintenance task more difficult and time consuming
- shorter distance to travel because relatively small land area

5.14 *Comments*

All TSOs share some zones of higher density and the effective cost driving effect has been estimated using the ratio of angle and suspension towers, without much differentiation. The landuser compensation problem, addressed already in ECOM+2003, has been resolved by exclusion.

Operating safety regulations

5.15 *Motivation*

Several TSO argued increased costs due to abnormal safety regulations, access rules, delays and permits implying considerable extra costs to the establishing of access roads, payments of damages to site owners, and increased usage of expensive machinery.

5.16 *Comments*
Already the commonality of the claims indicate that the non-uniqueness of the claim. The increased allowance for line maintenance covers this common effect.

Public demands

5.17 *Motivation*
Various demands from the public greatly influences the total cost of new installations and their maintenance:

- Tendency towards substitution of high-wires with dug down ground cables
- Increased tendency towards reconstruction of the grid
- Imposition to paint and repaint poles

5.18 *Comments*

- The ECOM+ measure does not evaluate choice of asset.
- Grid planning is not included
- After verification that the painting frequency indeed surpasses operational needs for corrosion prevention, a significant expenditure and a confirmed regulatory request, TSO may bypass the budget exceeding normal painting incidence.

Regulatory delays and cost-increasing interventions

5.19 *Motivation*
Several TSOs face regulatory regimes and legislations that considerably prolong the grid investment and projection process. Regulatory authorities may also intervene in the process, require costly investigations and statements that do not add to the final value. High costs are incurred by consultants, advisors and lobbyists to promote the construction of new lines and cables.

5.20 *Comments*
Costs related to grid planning are excluded, direct as well as indirect. The indirect impact on investment cost through lags is project start and incurred investment is considered equal among TSO and not estimated.

Quality of supply

5.21 *Motivation*

- Well known trade-off between quality and cost
- Particularly relevant in the countries, where TSOs have high supply reliability record

5.22 *Comments*

Differences in transmission quality (supply reliability) are indeed acknowledged among the participating TSO, but the cost causality to quality and its impact on model parameters are not clear. No evidence has been disclosed to inform the project group on the increases in cost and investment budget due to higher quality. No compensation has been given, pending possible further investigation of regulatory instruments (penalties) that could limit the relevance of quality adjustments in the current benchmark. See also Chapter 12 for a futher discussion.

Summary

5.23 After careful review of submitted documents and the revised weight system. no general country-specific adjustments were implemented for specific assets or categories of assets. Among the specific costs eligible for bypass only tower painting was implemented.

6. Presentation of TSO J

7. Presentation of TSO I

8. Presentation of TSO F

9. Presentation of TSO E

10. Presentation of TSO H

11. Presentation of TSO G

12. Service quality and maintenance

Outline

12.01 This chapter contains a discussion on service quality in transmission and its linkages to construction and maintenance expenditure. The purpose is to provide a word of warning against temptations to use the model or other regulation to provoke short-term cost-cutting with long-term effects. As such it also gives some indications on how not to use the results of benchmarking in regulation.

TSO Regulation and incentives

12.02 As a legal monopoly under the IEM Directive, the transmission system operator is subject to both detailed regulation concerning its organization (unbundling, independence), its behavior and processes (non-discrimination, service objectives, information) as well as its economic conditions (charges, incentives). Whereas the two first issues predominately are implemented as restrictions in the regulation, the last dimension is usually implemented as high-powered regulations of the CPI-X revenue-cap type or similar.

12.03 In the case of a TSO the possible consequences of mis-specified incentives are potentially dramatic as it can have cascading costs in the whole electricity supply chain. The TSO is not a simple production unit transforming inputs to outputs, largely independent of other agents. A TSO is an intermediary in a supply chain and as we know from recent advances in supply chain management, the operation of one stage can have huge chain wide impacts.

12.04 In fact, the special role and position of a TSO has long been acknowledged by lawmakers and TSOs alike and is reflected in the social planner role and the independence that is part of the objective of a TSO. The TSO is a special agent to regulate. It is like a police force or an institution that shall help discipline the production and distribution agents and that shall assist making socially attractive arrangements when private, bilateral arrangements may fail by strategic behavior and the existence of so called public goods and free riding possibilities.

12.05 All of this does not mean that a TSO should not be regulated or benchmarked. An exercise like ECOM+ can help to inform regulatory rulings on TSOs, but a couple of important caveats have to be mentioned as with regard to *service quality* and *scope of regulation*.

Service quality and maintenance

12.06 The ECOM+ is benchmarking the cost consequence of the tasks construction and maintenance under the critical assumption that the service quality is adjusted to a socially optimal level. This does not necessarily equate identical levels of reliability indicators such as ENS (Energy Not Supplied) and SAIFI (System Average Interruption Frequency Index), since the cost vs benefit of meeting such targets may be different in e.g.meshed vs radial grids with different load profiles.

12.07 The ECOM+ unit cost measure *does* provide an incentive in CAPEX for reinforcement through the line measure of circuit length, rather than route length. That means that an increase from an n-1 to n-2 criterion would actually be promoted in ECOM+, which is compatible with the European policy on Transmission System Quality.

12.08 The ECOM+ unit cost measure *does not* provide an incentive for OPEX service quality. Decreasing the operating cost for maintenance will in the model lead to positive effects on the individual unit cost, proportional to the share of operating cost to normalized capital costs, and to competitive effects on the relative score for the other TSOs. This may suggest a *race to the bottom* in the case when a partial measure, like ECOM+, is used mechanically to determine the regulated revenue of an operator.

12.09 Maintenance activities, in particular planned and regular, can be adjusted to arbitrary levels with few or no short-term effects on reliability and operational safety. The medium-term effects may be increases in operating costs, but the effects may also be absorbed by clients interruption times, interruption frequencies or, in general, an increased risk of delivery interruptions.

Strategy 1: Quality indicators

12.10 One potential defense against the risk of quality skimping is to include quality indicators in the measure itself or related documentation. Besides a considerable complexity in finding comprehensive and comparable quality measures, see European projects such as CEER (2001), the approach is unsatisfactory due to the *stochastic* nature of the events recorded for a given periods and the *lack of causality* between the expenditure in a given period and the events in the same period. The two problems suggest that quality indicators should only be used during longer intervals, preferably smoothed over time, and only by carefully verifying that indeed the expenditure pertains to the same equipment. In practice, this translates poorly to a more frequent exercise like the ECOM+ benchmark or periodic regulatory reviews.

Strategy 2: Quality costs

12.11 Another approach is to indeed include a monetary measure for quality costs in the regulation and potentially even in the benchmarked operating cost, as to create a consistent and clear quality provision incentive. Although as ineffective as quality indicators in the short run, it has the advantage of giving long-term incentives that will also give a corresponding result in a partial benchmarking. This approach is operational in e.g. DSO regulation in Norway (CENS regime) and in the UK.

Scope of regulation

12.12 Now, given the extreme information asymmetry and the particular role of a TSO as an intermediary with social obligations in a supply chain, how can we proceed to benchmark the TSO in relevant ways? How should a benchmarking exercise of a TSO deviate from a more traditional benchmarking of distribution companies? We suggest that at least two new – but interrelated - perspectives should be introduced. One concerns delegation and accountability and the other the utilization of a spectrum of internally consistent performance measures.

12.13 In Agrell and Bogetoft (2002), the Charter of Accountability is developed as an overall framework for performance assessment at multiple levels, where ECOM+ is the lowest. At higher levels, one would take into considerations not only the input side of operations, but also the service dimension and the added-value of the TSO activities on e.g. overall social welfare.

The insertion of ECOM+ in regulation

12.14 The mechanic insertion of ECOM+ unit costs or scores in the determination of revenue caps for TSOs is not only limited by quality considerations, but also due to the intricacies of the regulation in itself. Whereas ECOM+ normalizes both operating costs and capital expenditure to a common footing to permit comparison, the regulation and the incumbent revenues of a particular TSO are naturally defined from the book value of the assets. The actual value on the books of an identical asset in service may thus vary considerably among two TSOs, depending also on the institutional solutions for its ownership, national regulation or implemented procedures for the revaluation of assets at the unbundling. Thus, a TSO that has made an efficient investment may in fact charge a higher capital charge than an inefficient investment *at a given time*, simply due to the way investments have been depreciated and or evaluated.

12.15 Another difficulty lies in the treatment of sunk incumbent investments that remain on the books prior to the unbundling. Since the depreciation of these investments is a fixed charge for the TSO, without influence as to improve their efficiency, any statement by the regulator on the value or capital expenditure of these assets is equivalent to a statement about stranded costs. As this may, once again, depend on the institutional solution chosen for the TSO (ownership, procedure for establishing the endowment, independence) there is no general solution.

12.16 A relevant usage of ECOM+ in regulation, compatible with the principles of multi-dimensional performance assessment of the Charter, is then to consider the *dynamic results* as a sign of overall improvement, and in particular to *use contingent runs on the relevant subset of costs* for the individual regulator. Thus, the value-added of an exercise as ECOM+ is partially the mere participation of the TSO, as an act of accountability and learning, partially the database made available for more detailed comparisons.

Summary

12.17 On the one hand, the service quality of transmission system operations has an imperative priority for the electricity system and, in consequence, for its economic regulation. On the other hand, the economic values involved and the mere size of the operators oblige the regulators to create an equitable regulatory pressure also on these operators, including the monitoring of performance information related to the efficiency of subsets of the activities performed.

12.18 ECOM+ is a measure that leverages quality investments on the capital side, but does not gauge whether an observed level of operating cost intensity in compatible with continued service at an optimal quality level. Neither does the score or the unit cost interface with accounting data as to form a proportional factor for a classical revenue-cap regulation. Hence, care should be taken to consider ECOM+ as *one or many* indicators of TSO performance, *to adjust unit costs* to the actual controllable base before making translations to high-powered schemes and *to continuously improve* the data material as to minimize the risks of bias due to lack of comparators or random events.

13. Results

Assumptions

13.01 The main calculations are made using a 3.5% real interest rate, life times 50 years for lines, 45 years for cables and circuit ends and 40 years for all other equipment, no country specific adjustments of capex and the same inflation adjustment as in the previous run. The operating cost used is the reported following definition 2.1 in Appendix A15 as item SUBTOTAL OPEX(A)[1] before allocated administration and overhead expenditure. All these key parameters and assumptions are addressed the following chapter.

Partial measures

13.02 Beginning with the new partial measures introduced in 2.26 and below, the new model permits to draw partial conclusions based on fairly general assumptions of variable returns to scale while maintaining the given intensity of opex or capex.

13.03 The results for operating costs in Table 13-1 below indicate that TSO E, TSO G, TSO I and TSO J are all partially efficient in operating expenditure *at their level of capital expenditure and scale*. The revealed partial inefficiency of TSO F and TSO H are entirely determined by linear combinations of TSO E, TSO I and TSO J, dominating the grids in the two dimensions. TSO G is an auto evaluator, meaning that no other grid can dominate its OPEX performance at a higher level of CAPEX.

Table 13-1 Results partial measures OPEX 2000-2003.

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
2000	100%	69%	100%	59%	100%	100%
2001	100%	62%	100%	57%	100%	100%
2002	100%	93%	100%	56%	100%	100%
2003	100%	81%	100%	52%	100%	100%

[1] Line 69 in OPEX reporting sheet.

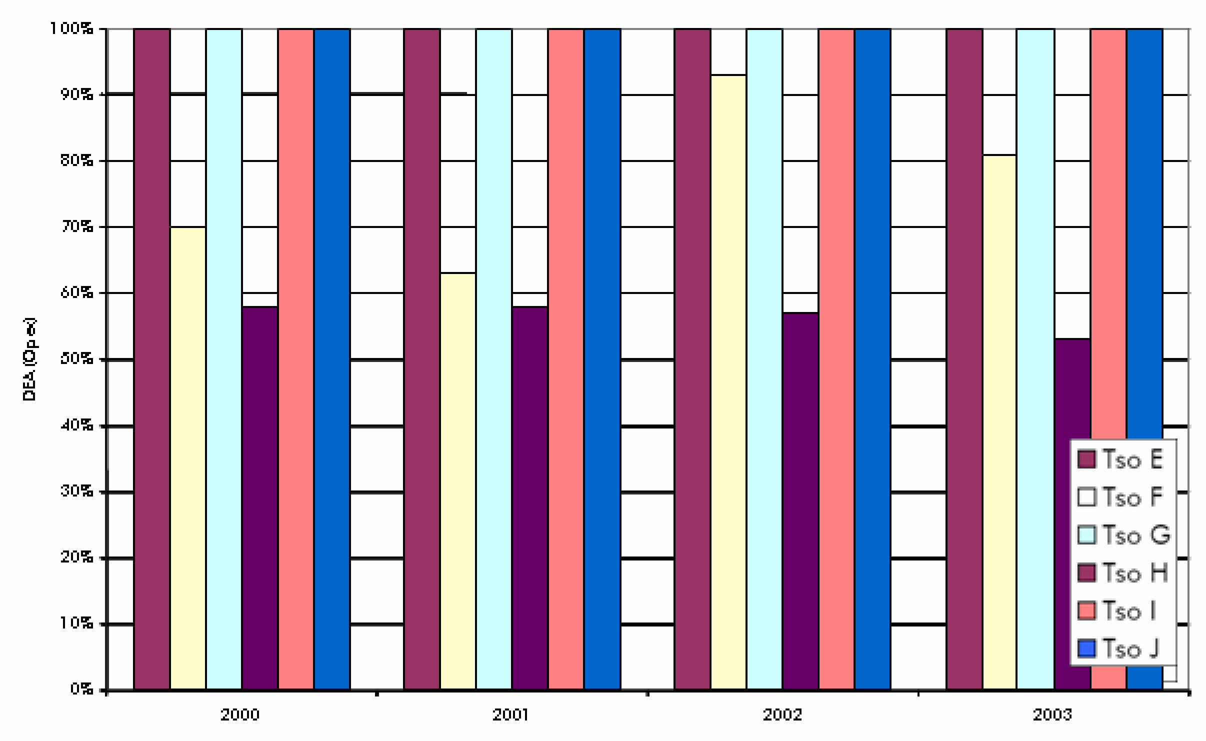

Figure 13-1 Results partial opex for 2000-2003.

13.04 In terms of partial efficiency of capital costs, Table 13-2 below gives a similar picture in that TSO E, TSO G, TSO I and TSOI J are all partially efficient in capital expenditure *at their level of operating costs and scale*. TSO H shows a marginal inefficiency of 3-6% whereas TSO F demonstrates an endemic difference of 35-37% compared to a reference point constituted of TSO E, TSO I and TSO J. In this model, TSO G is part of the comparative unit for TSO H along with TSO E and TSO J.

Table 13-2 Results partial measures CAPEX 2000-2003.

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
2000	100%	65%	100%	94%	100%	100%
2001	100%	64%	100%	95%	100%	100%
2002	100%	64%	100%	97%	100%	100%
2003	100%	63%	100%	95%	100%	100%

13.05 The partial measures, also illustrated in Figure 13-1 for OPEX and in Figure 13-2 for CAPEX already provide reason to moderate the normative conclusions of the study for short-term action. The six TSOs are indeed following somewhat different strategies in both operation and investment, as will be confirmed by the unit cost figures. However, for any partially efficient grid, there are no immediate conclusions to be drawn with respect to the expected level of opex and capex in a given grid.

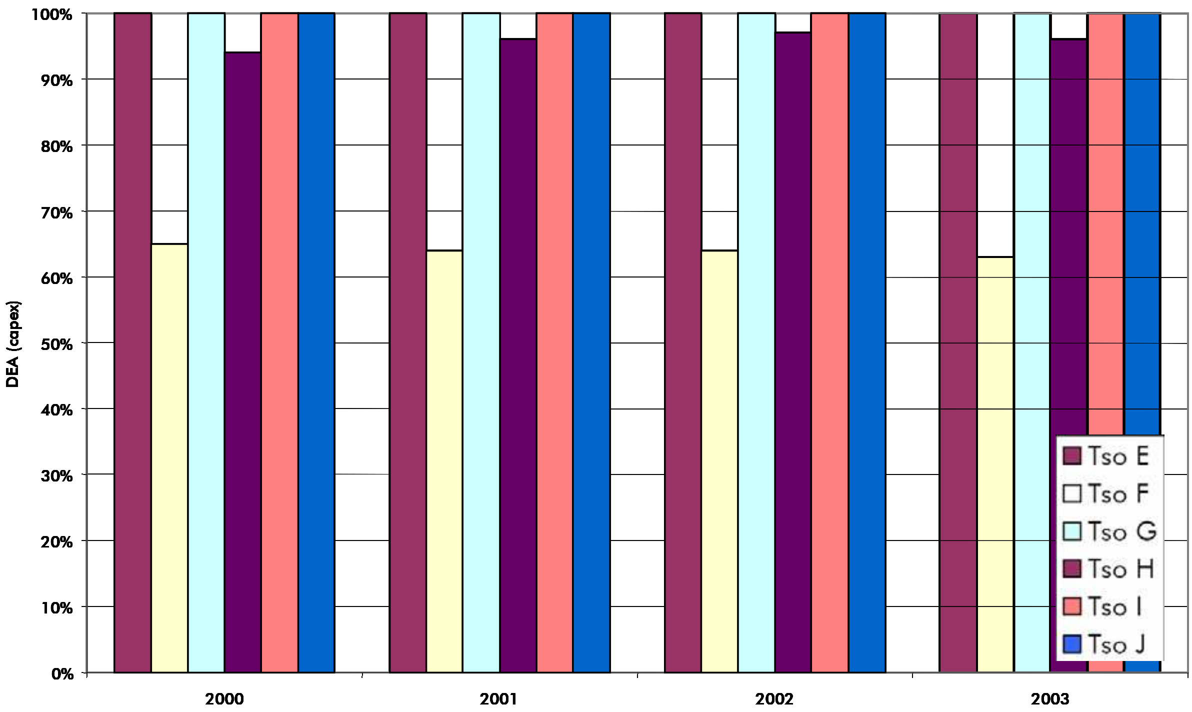

Figure 13-2 Results partial capex for 2000-2003.

Unit cost results

13.06 The unit cost results for the first application of the ECOM+ model are depicted in Figure 13-3 and Table 13-3 below. They indicate a certain span of costs, where TSO E and TSP J set the minimal cost frontier. TSO H and later TSO I approach the European standard, whereas TSO F and TSO G show higher unit costs. The development of unit cost is declining for most countries, with the striking counterexample of TSO I. The unit cost measure in itself denotes the relation to average European costs.

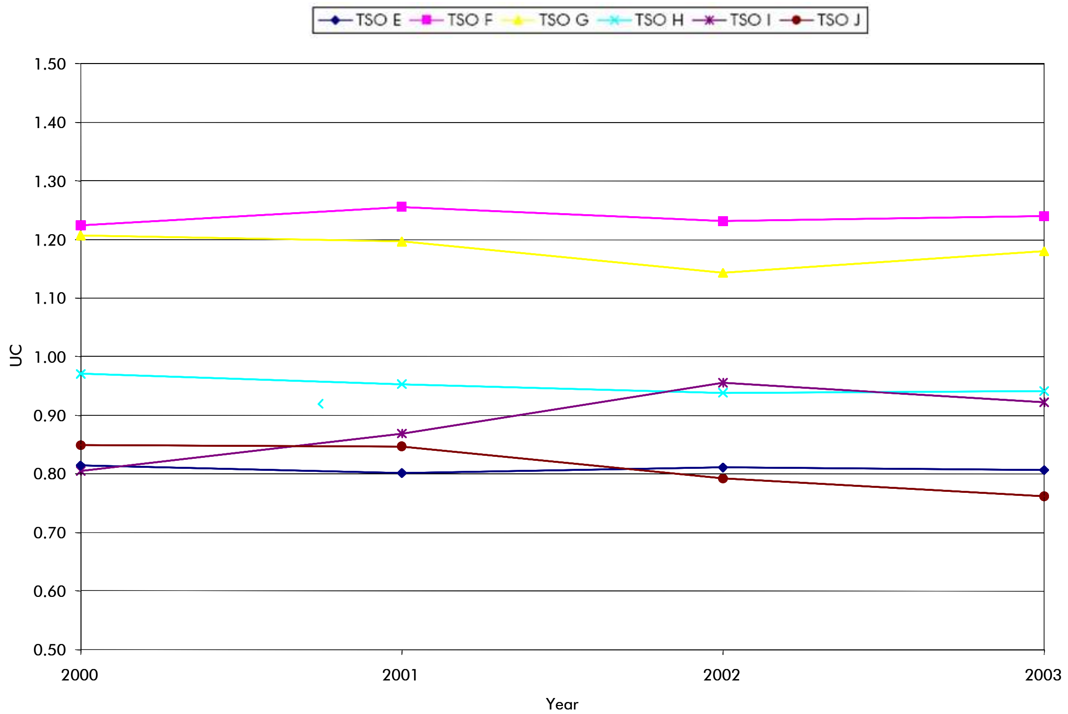

Figure 13-3 Results in Unit Cost 2000 – 2003 excluding administrative OPEX.

13.07 The unit cost measure can, as discussed in Chapter 2, be seen as a special case of partial weighting. As such it is fairly restrictive, but the results are relatively stable and confirm the picture. In particular, it can be noted that the any difference in unit cost efficiency between TSO E and TSO J is determined by some additional assumption regarding the valuation of CAPEX versus OPEX efficiency. Although Table 13-4 does indicate an efficiency margin of up to 6% in three of four years for TSO E, the picture in Figure 13-4 shows a different explanation. Whereas TSO E has a maintained high operating efficiency, it stays proportional to the grid size that increases over the horizon, TSO J decreases total normalized cost from 31,5 M€ to 30 M€ in spite of a comparable proportional increase in grid size. As the UC efficiency is a linear measure, as opposed to the partial measures presented above, these changes have a direct impact on the TSO E target.

Table 13-3 Unit cost results 2000-2003 excluding administrative OPEX.

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
2000	0.81	1.22	1.21	0.97	0.81	0.85
2001	0.80	1.26	1.20	0.95	0.87	0.85
2002	0.81	1.23	1.14	0.94	0.96	0.79
2003	0.81	1.24	1.18	0.94	0.92	0.76

13.08 The sudden appearance of TSO I at the efficiency scene in 2000 is due to an exceptionally low operating cost of M€, increased to more than the double (M€) the following year. This peculiar condition might have been a reason to worry, had not TSO E been very close (99%) in unit cost to back up the feasibility of this cost level. Note, however, that TSO I's <specific> costs are indeed included in the operating cost figures.

Table 13-4 Results E(f,t) 2000-2003 excluding administrative OPEX.

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
2000	99%	66%	67%	83%	100%	95%
2001	100%	64%	67%	84%	92%	95%
2002	98%	64%	69%	84%	83%	100%
2003	95%	61%	65%	81%	83%	100%

Figure 13-4 Results in efficiency E(f,t) for 2000 – 2003.

Decomposition of results

13.09 The information value of the final results, unit costs in Table 13-3 and relative efficiency scores in Table 13-4 is increased with the decomposition of the nominator and the denominator offered in Table 13-5 for 2000 etc. Here, the components of the measure can be studied separately to understand the sources of non-standard cost and investments. Below, we make a short comment on each of the participants along with a cone analysis of the country specific weights that may define the span of efficiency estimates. However, we note the already the close correspondence between the estimated operating costs for TSO H and TSO G, whereas the common weights give a large superiority in operating costs to TSO E. For TSO J, it is the opposite phenomenon, with the actual capital costs well below the estimated European level.

Table 13-5 Decomposition of costs 2000 (kEUR).

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
OPEX (EUR)						
CAPEX						
OPEX+ CAPEX						
SizeOfGrid OPEX	31 391 911	12 489 713	22 175 358	14 570 168	2 460 595	5 765 042
SizeOfGrid CAPEX	160 509 850	71 484 207	74 370 381	71 810 288	29 493 074	31 287 058

Table 13-6 Decomposition of costs 2001 (KEUR).

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
OPEX (EUR)						
CAPEX						
OPEX+ CAPEX						
SizeOfGrid OPEX	31,468,939	12,489,713	22,243,777	15,064,114	2,551,938	5,938,735
SizeOfGrid CAPEX	160,810,117	71,484,207	74,670,105	73,795,084	29,974,326	32,159,777

Table 13-7 Decomposition of costs 2002 (KEUR).

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
OPEX (EUR)						
CAPEX						
OPEX+ CAPEX (LRAC)						
SizeOfGrid OPEX	31,660,717	12,489,713	22,268,767	15,995,053	2,623,921	5,999,588
SizeOfGrid CAPEX	161,541,940	71,484,207	74,781,720	78,239,467	30,261,997	32,262,049

Table 13-8 Decomposition of costs 2003 (KEUR).

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
OPEX (EUR)						
CAPEX						
OPEX+ CAPEX (LRAC)						
SizeOfGrid OPEX	32,410,372	12,583,011	22,387,683	16,662,822	2,623,921	6,165,879
SizeOfGrid CAPEX	164,518,885	71,815,182	75,125,726	81,808,461	30,261,997	33,188,030

Dynamic results

13.10 We have analyzed the efficiency development using the Malmquist approach described in Chapter 2. Our analyses has been done using both the total unit costs, the naïve and the refined partial measures. The relatively few observations and the stochasticity in the OPEX numbers from one year to the next makes the use of Malmquist, in particular on the partial measures, problematic. We conclude from these calculations that there are too few data and two much variation to make reasonable Malmquist evaluations of the partial measures. We suggest that it is more reasonable to take a general view of the measures over the four years.

13.11 As a middle approach, we have calculated the Malmquist index and decompositions taking into account total costs but acknowledging the different importance of OPEX and CAPEX in the different TSOs. The models are calculated using linear programs like in the case of partial measures except that we have only used one input, the total costs equal to the sum of (normalized) OPEX and CAPEX.

13.12 The results are now more stable although the year to year variations are non-trivial. In terms of overall productivity there seems to be no significant improvements year by year. Still, there seems to be a small technological progress (frontier shift) which however in some cases are counteracted by a small negative efficiency chance (catch-up), i.e. a fall-back in terms of the frontier. In particular, and as one can see from the aggregate numbers as well, TSO I seems to fall back from 2001 to 2002 while TSO F and TSO G experience some – although smaller - regress between 2002 and 2003. In average terms, the dynamic development is primarily problematic for TSO I that experience a yearly regress of about 4%. These results are shown in Table 13-9 below.

Table 13-9 Total cost dynamic results (average over years)

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
Malmquist_total	1.005	0.996	1.008	1.011	0.957	1.037
Frontier Shift	0.998	0.978	1.000	1.003	0.967	1.015
Catch Up	1.008	1.019	1.008	1.008	0.990	1.022

Decompositions

13.13 Below in Table 13-10 the detailed norm per asset group is listed, showing exactly how the size of the grid has been estimated in CAPEX. The relative shares of the norm for the asset groups are given in Table 13-11.

Table 13-10 CAPEX norm per asset group and TSO (2003, annuities, kEUR).

Asset group g	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
10						
20						
30						
40						
50						
60						
91						
CAPEX norm						

Table 13-11 Share of CAPEX norm per asset group and TSO.

Asset group g	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
10	55%	53%	56%	50%	7%	38%
20	12%	1%	0%	0%	71%	11%
30	19%	18%	24%	32%	11%	13%
40	14%	28%	19%	18%	3%	13%
50	0%	0%	0%	0%	0%	0%
60	0%	0%	0%	0%	0%	0%
91	1%	0%	0%	0%	7%	25%

13.14 Below in Table 13-12 the detailed operating cost norm is broken down per asset group, which gives an idea about the annuities estimated for each type of asset.

Table 13-12 OPEX norm per asset group and TSO (2003, annuities, kEUR).

Asset group g	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
10						
20						
30						
40						
50						
60						
91						
OPEX norm						

13.15 The relative shares of OPEX per TSO are presented in Table 13-13.

Table 13-13 Share of OPEX norm per asset group and TSO.

Asset group g	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
10	39%	30%	51%	49%	20%	23%
20	7%	0%	0%	0%	23%	8%
30	30%	24%	28%	24%	27%	18%
40	22%	45%	22%	27%	10%	20%
50	1%	0%	0%	1%	0%	2%
60	0%	0%	0%	0%	0%	0%
91	2%	0%	0%	0%	21%	30%

TSO G

13.16 For TSO G, the OPEX efficiency is relatively high, even without ad hoc corrections, norm matches fairly closely the actual OPEX (cf. Table 13-5 etc), with a positive trend for the period until 2002. The total cost score is thus entirely attributable to the CAPEX term, where the norm is 20 MEUR less than the normalized annuity. Compared to the result in ECOM+, we note actually that a positive revaluation net of the correction factor for lines in 2003.

13.17 TSO G is relatively insensitive to the valuation of the alpine line group (the allowances 1.62 and 1.80 for mountain lines are always included) in a window [0.9, 2.0]. The reference unit cost of 1000 is reached for 1.47. This means that TSO G to be ranked European average cost would need an additional 47% adjustment to all its line assets. Figure 13-5 shows also that no adjustment within this interval is sufficient to achieve full efficiency.

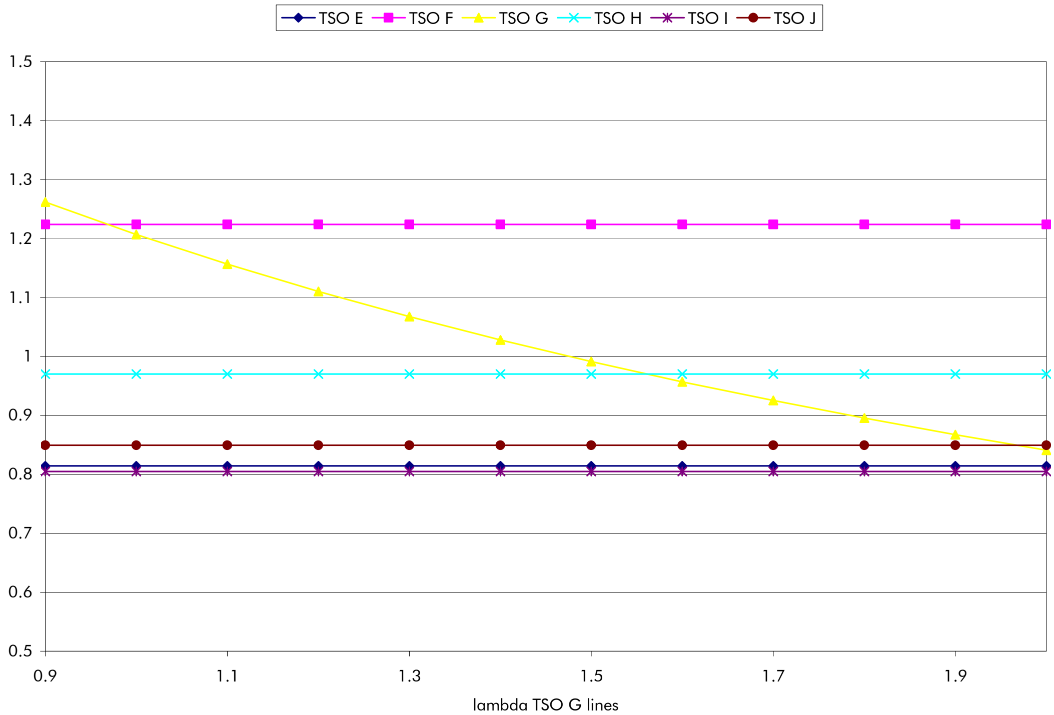

Figure 13-5 UC as a function of $\lambda_{TSO\ G}$ (lines).

13.18 The sensitivity concerning the CAPEX valuation of the alpine lines is illustrated in Figure 13-6 below for an interval [0.9, 2.0]. Given that the alpine lines constitute a limited segment, it is hardly surprising to see that a full 1.8 is needed to reach reference cost for TSO G, implying a CAPEX weight of 2.92 compared to normal 380 kV lines. This is not in line with any documented cost function.

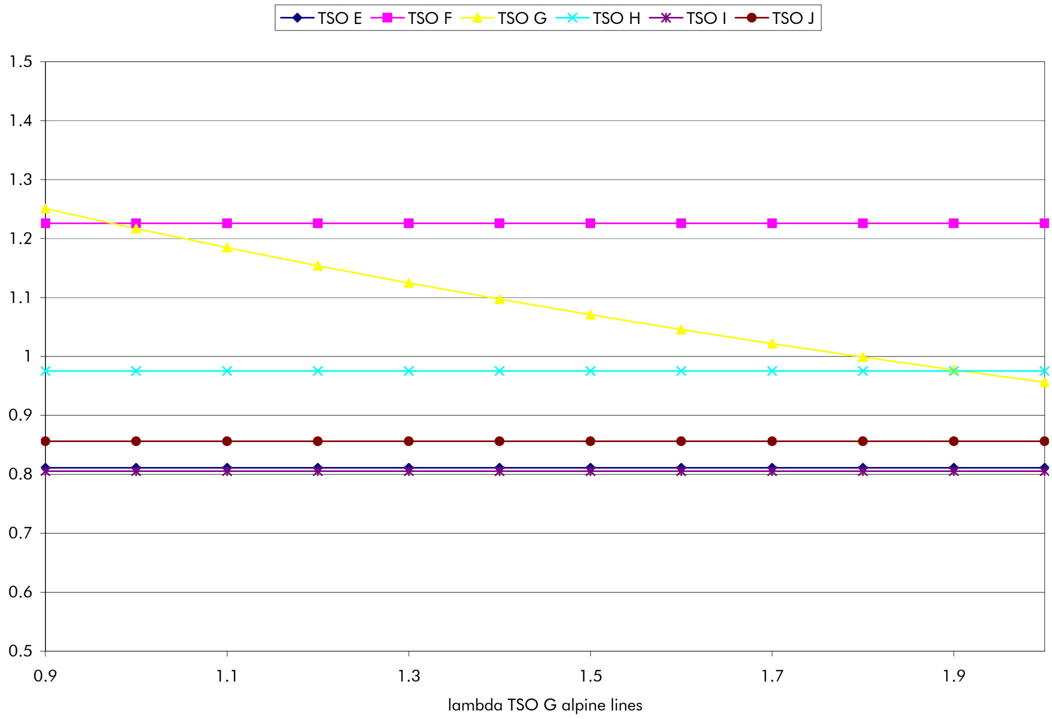

Figure 13-6 UC as a function of $\lambda_{TSO\ G}$ (alpine lines).

13.19 The operating cost sensitivity for lines for TSO G is illustrated in Figure 13-7, where reference cost is reached at 2.7, meaning an additional 170% on operating cost per circuit km. The ranking seems relatively stable from this perspective.

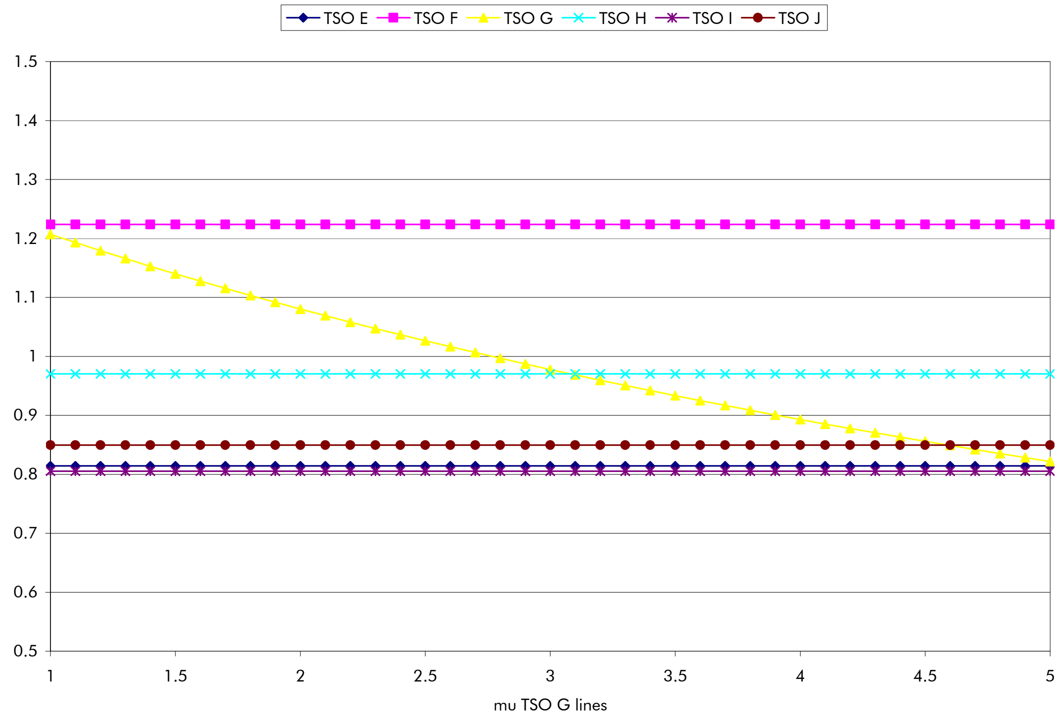

Figure 13-7 UC as a function of of $\mu_{TSO\ G}$(lines).

13.20 A similar exercise for OPEX on alpine lines in Figure 13-8 reveals a rank reversal with TSO H at an adjustment of 4.1, i.e. 310% addition.

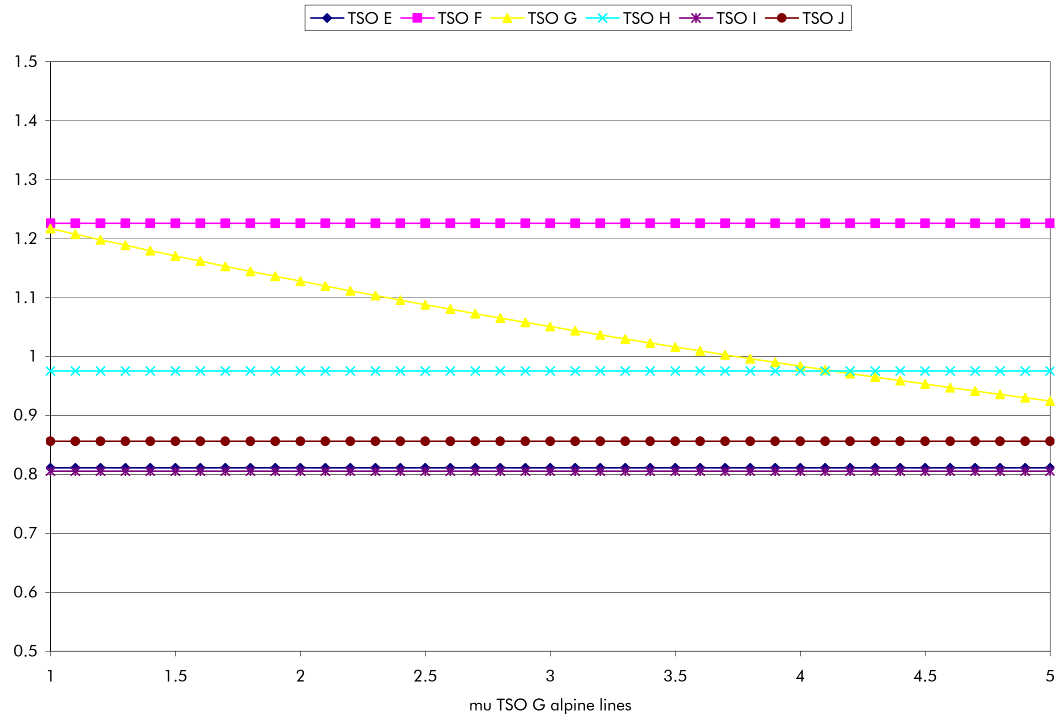

Figure 13-8 UC as a function of $\mu_{TSO\ G}$(alpine lines).

TSO H

13.21 TSO H exhibits detailed data with high confidence, showing performance around European average cost. However, a comparatively higher proportion of lines with lower cross-section dimension in the 250 – 400 kV area gives some lag in the operating cost efficiency. The sensitivity of the capital cost for the line assets is depicted in Figure 13-9 below. We note that TSO H would need a 1.5 adjustment to define best practice and 1.35 to reverse the order with TSO J.

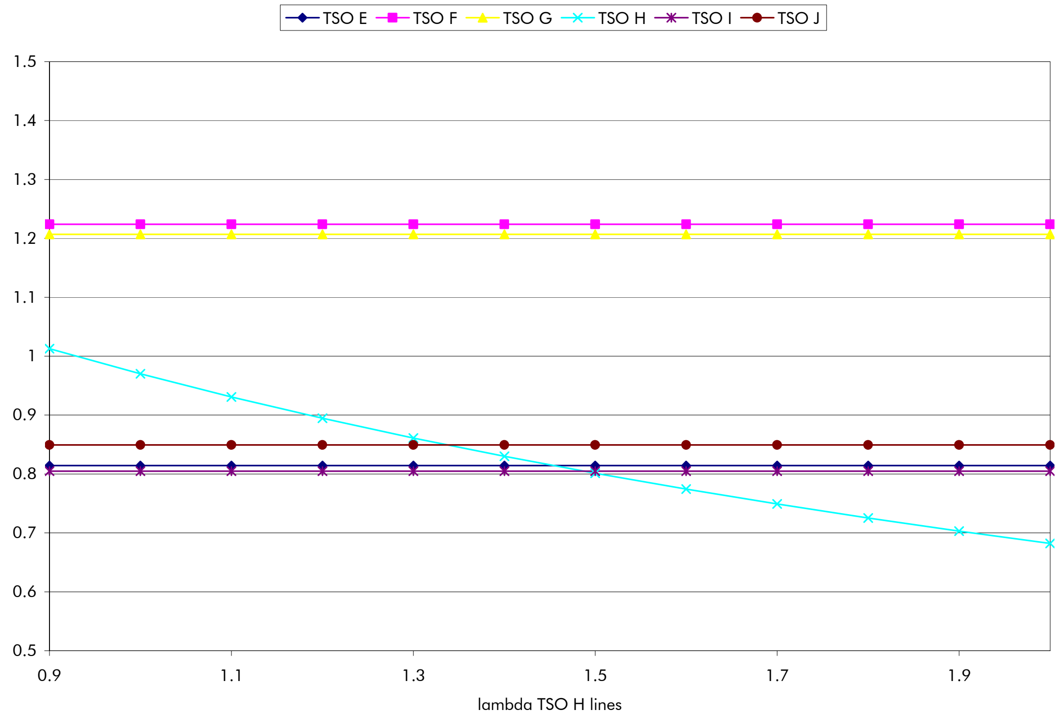

Figure 13-9 UC as a function of $\lambda_{TSO\ H}$(lines).

13.22 Considering the operating cost, here TSO H starts better that European average, but stays in rank in the window [1, 2.6], which seems highly plausible.

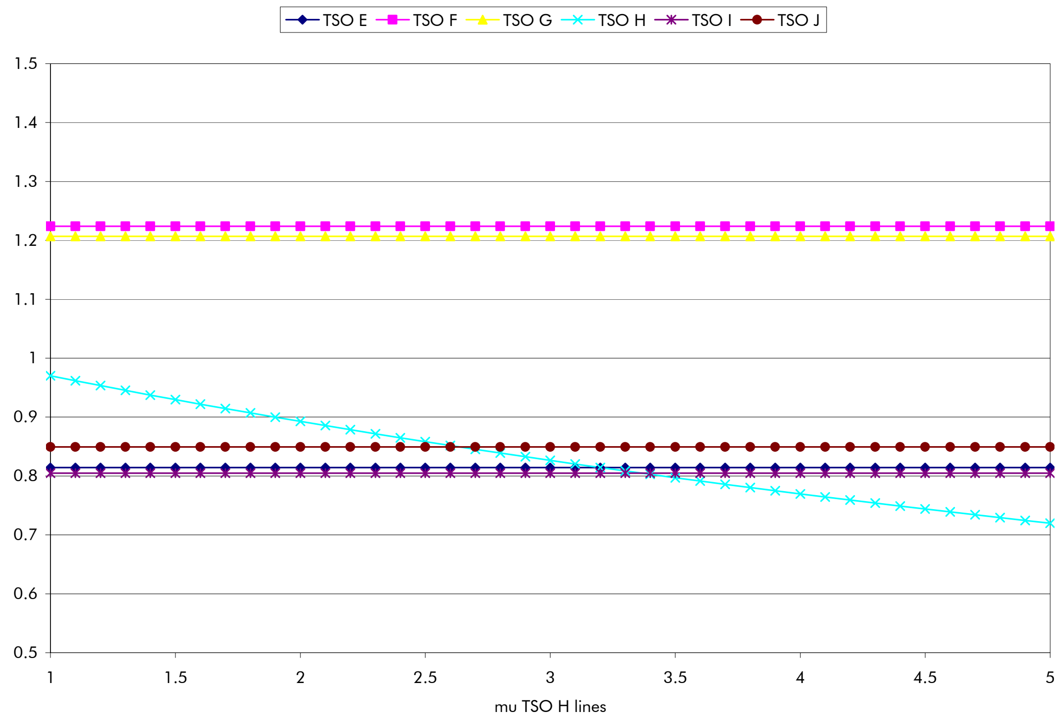

Figure 13-10 UC as a function of $\mu_{TSO\ H}$(lines).

TSO F

13.23 TSO F, enjoying less adjustments than in the previous round, shows an relative advantage in the operating cost this run compared to European average, thanks to increased allowance. However, the capital intensity is still higher than any comparable measures [UC] and considerably higher than the grids in the reference set [E].

13.24 The inefficiency of TSO F is thus supported both by high absolute and relative costs on both OPEX and CAPEX. The estimate is reasonably stable as TSO F has no unique assets and the compensation factors for environmental and urban complexity are clearly less than the identified window [1.0,1.5] for UC=1 and [1.0,>2.0] for full efficiency.

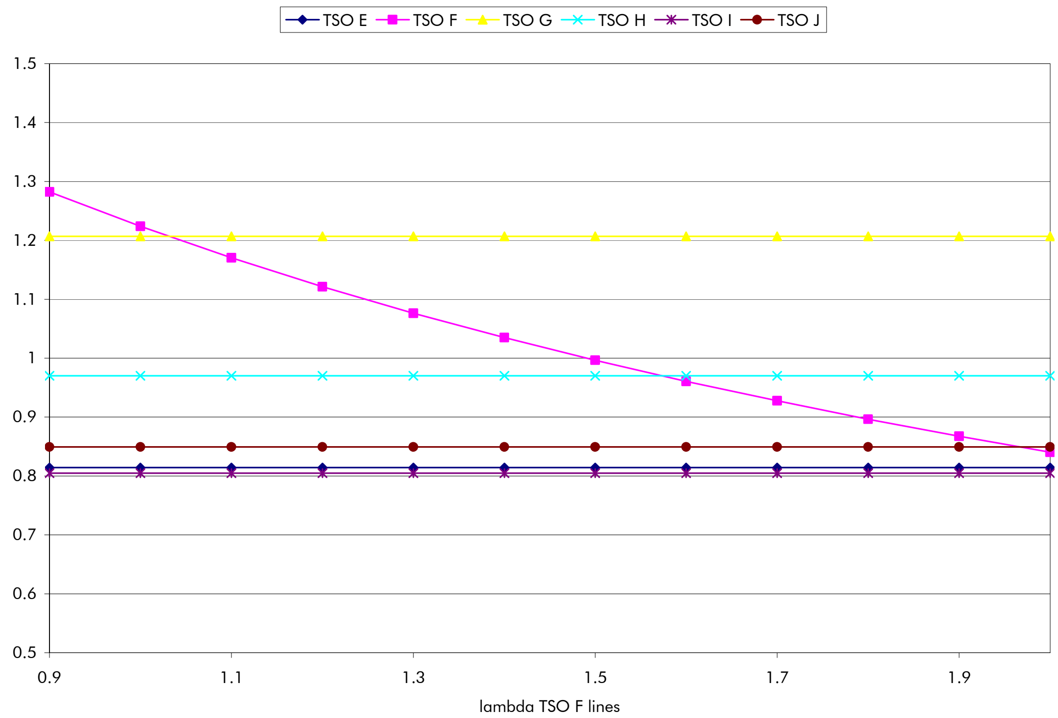

Figure 13-11 UC as a function of $\lambda_{TSO\ F}$(lines).

13.25 In terms of OPEX, TSO F without the administrative costs is already some 25% below norm, but burdened by the heavy CAPEX, Figure 13-12 shows no hope for rank reversal within a large interval.

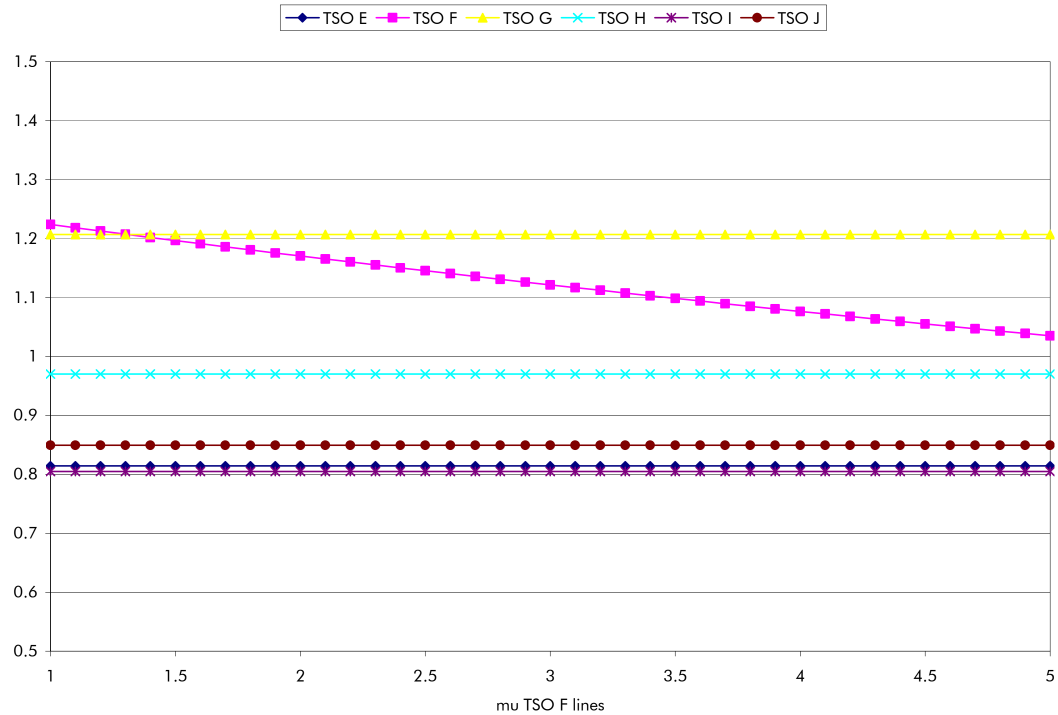

Figure 13-12 UC as a function of $\mu_{TSO\ F}$(lines).

TSO J

13.26 The investment efficiency of TSO J is striking both on average and detail, being 24% below the norm for a network characterized by an unusual proportion of cables and other installations. However, validation with other sources for the HVDC stations has shown competitive costs. The weakness of TSO J is in the operating cost, where both relative and absolute numbers (with or without administration) reveal higher than average costs.

13.27 Some sensitivity analysis for TSO J is made in Figure 13-13 below, where the specific CAPEX weight for the lines is on the X-axis for the year 2000. We see that TSO J stays behind notably TSO E until 1.2 is achieved in this factor, which seems unlikely.

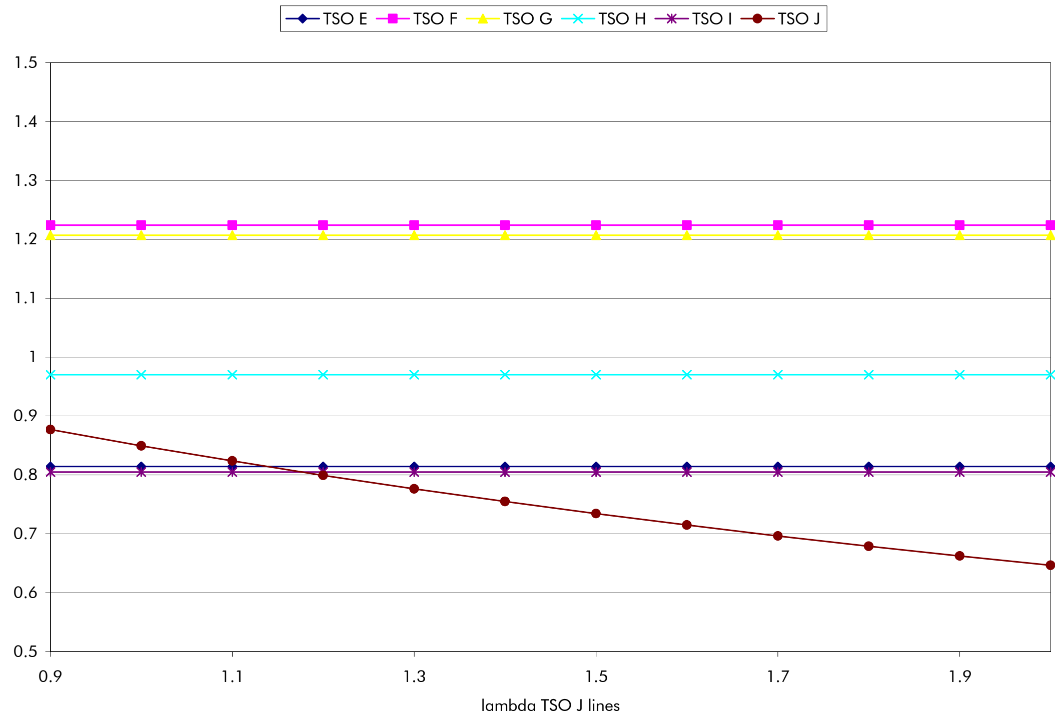

Figure 13-13 UC as a function of of $\lambda_{TSO\ J}$(lines).

TSO E

13.28 TSO E, who got good scores also in the first ECOM round, scores well even without the previous adjustment factor. As shown in Figure 13-14, a country specific adjustment on lines generally of around 1.07 suffices to make TSO E the benchmark for all years but 2003, where 1.12 is needed. As mentioned above, the target is the TSO J asset base in the unit cost measure. However, in the partial measures, TSO E surfaces as reference unit in both OPEX and CAPEX, although this is also an effect of size in a model of variable returns to scale.

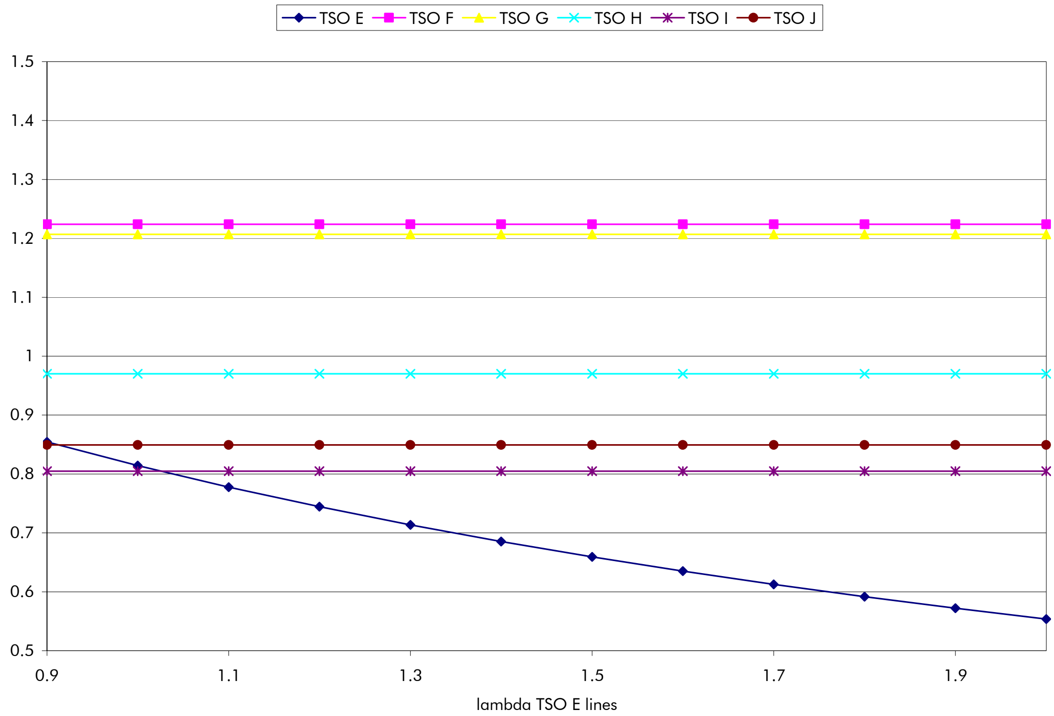

Figure 13-14 UC as a function of $\lambda_{TSO\ E}$(lines).

13.29 As with regards to alpine lines in Figure 13-15, the conclusion is similar to the situation for general lines, with a somewhat higher correction factor due to the limited asset base.

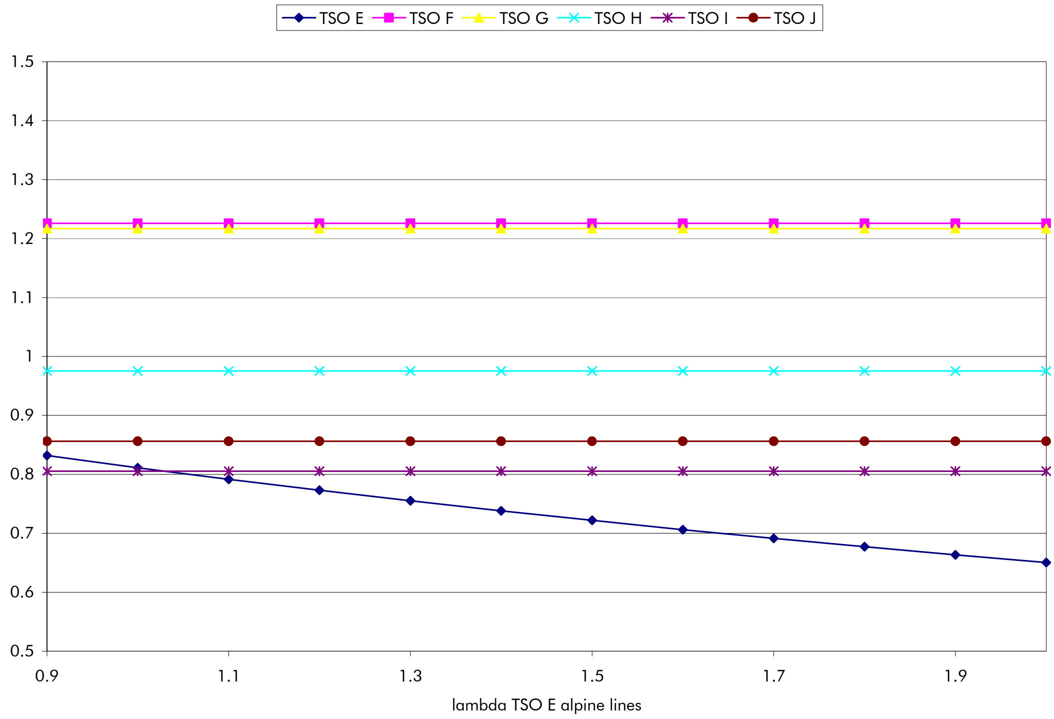

Figure 13-15 UC as a function of $\lambda_{TSO\ E}$(alpine lines).

13.30 TSO E shows an unsurpassed strength in operating cost in the sample and compared to the revised European standard. Although calibrated against external data and the average of the sample, TSO E is at around 50% of the expected norm for operating expenditure. Further investigations would be interesting (for the other TSOs) to find in what subprocesses TSO E can realize these gains. Figure 13-16 and Figure 13-17 give some idea about the sensitivity for this parameter in 2000, requiring some 30% additional adjustment to become unit cost master. However, this would drive the cost norm to an unrealistic level at decomposition.

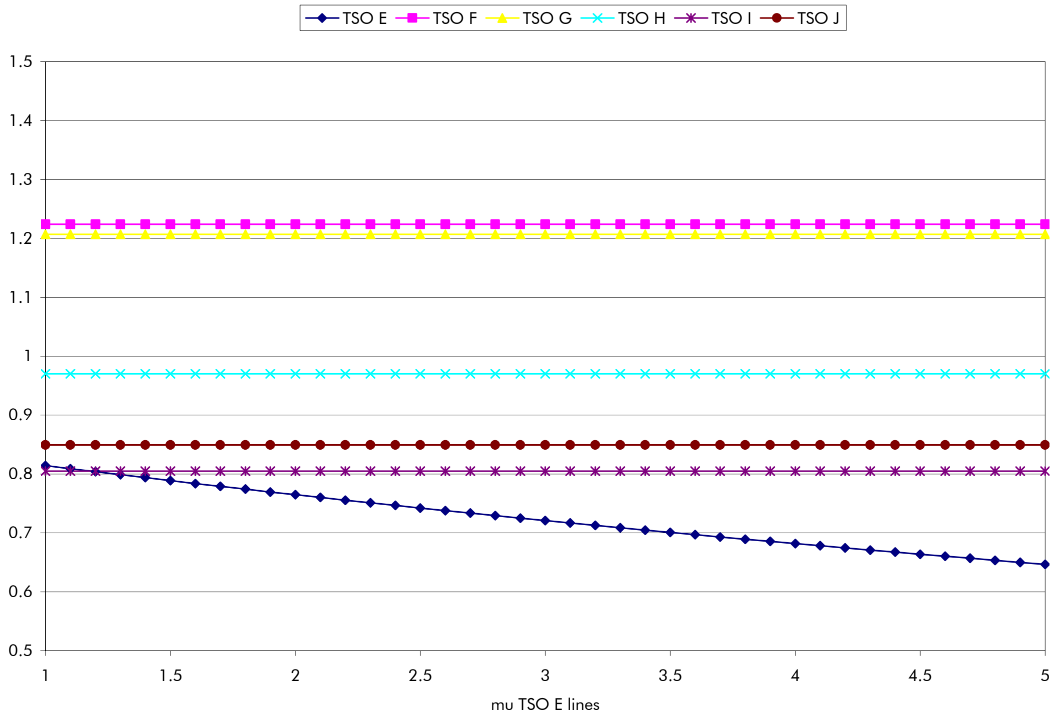

Figure 13-16 UC as a function of $\mu_{TSO\ E}$(lines).

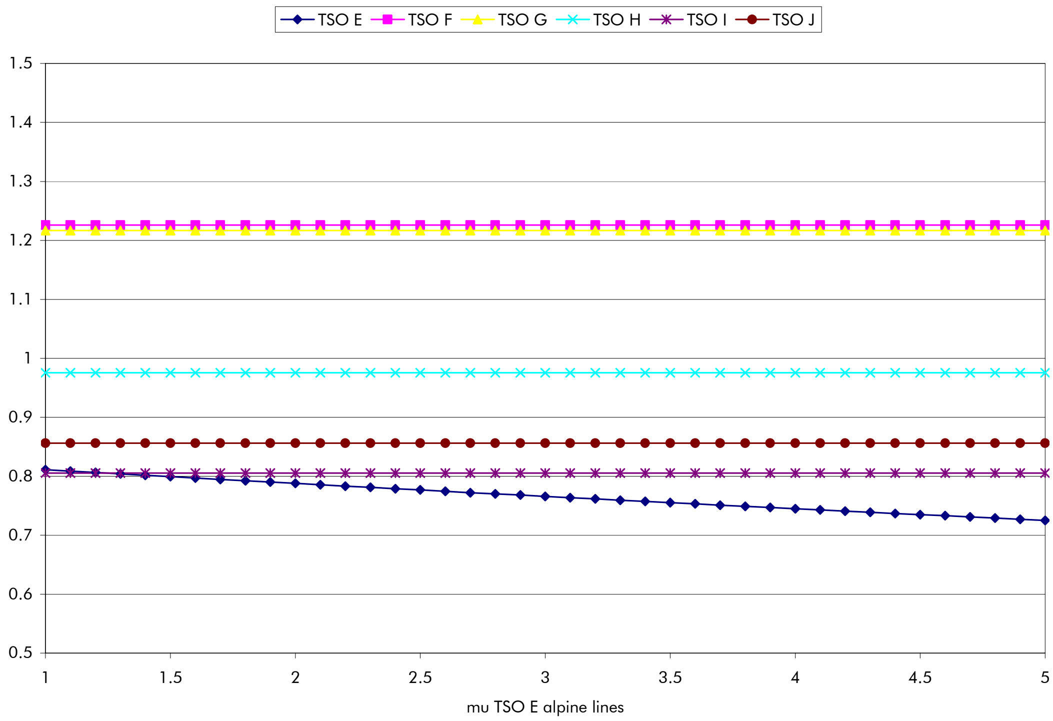

Figure 13-17 7 UC as a function of $\mu_{TSO\ E}$(alpines lines).

13.31 deleted.

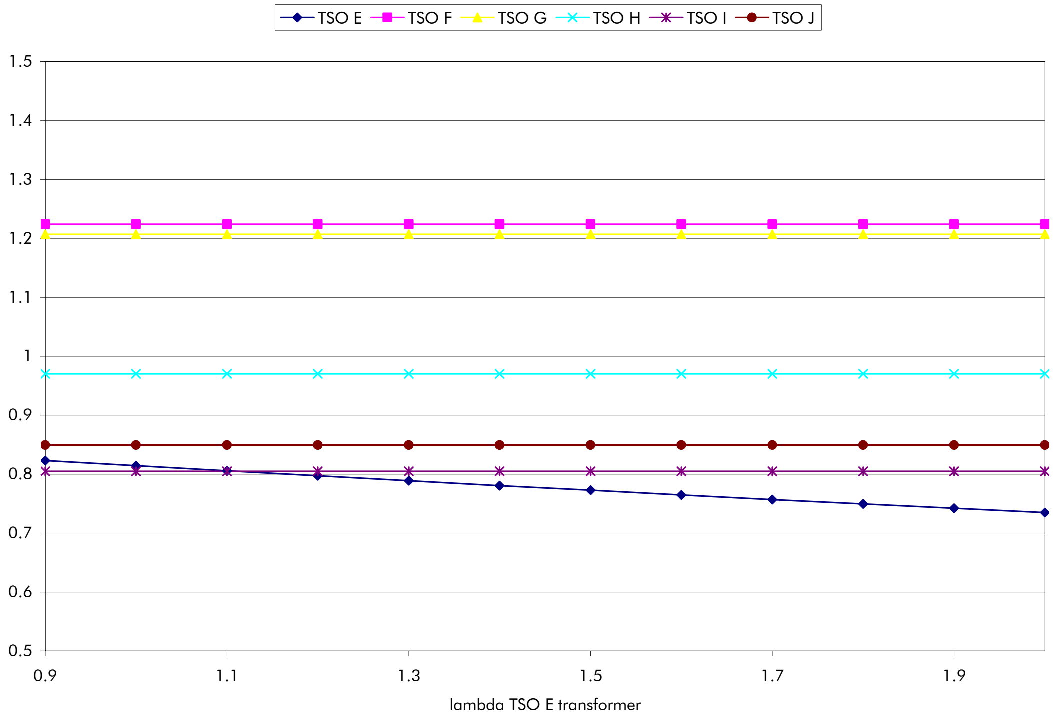

Figure 13-18 UC as a function of $\lambda_{TSO\ E}$(transformers).

TSO I

13.32 The TSO I shows a declining efficiency during the period and increasing unit costs, allegedly due to punctual and unforeseen costs for recovery and repair of sea cables. In terms of CAPEX, TSO I shows a good fit with the CAPEX norm, suggesting closer adherence to the given valuation. As shown in Figure 13-19, the sensitivity to the line CAPEX valuation is low for TSO I, basing the efficiency essentially on the OPEX term.

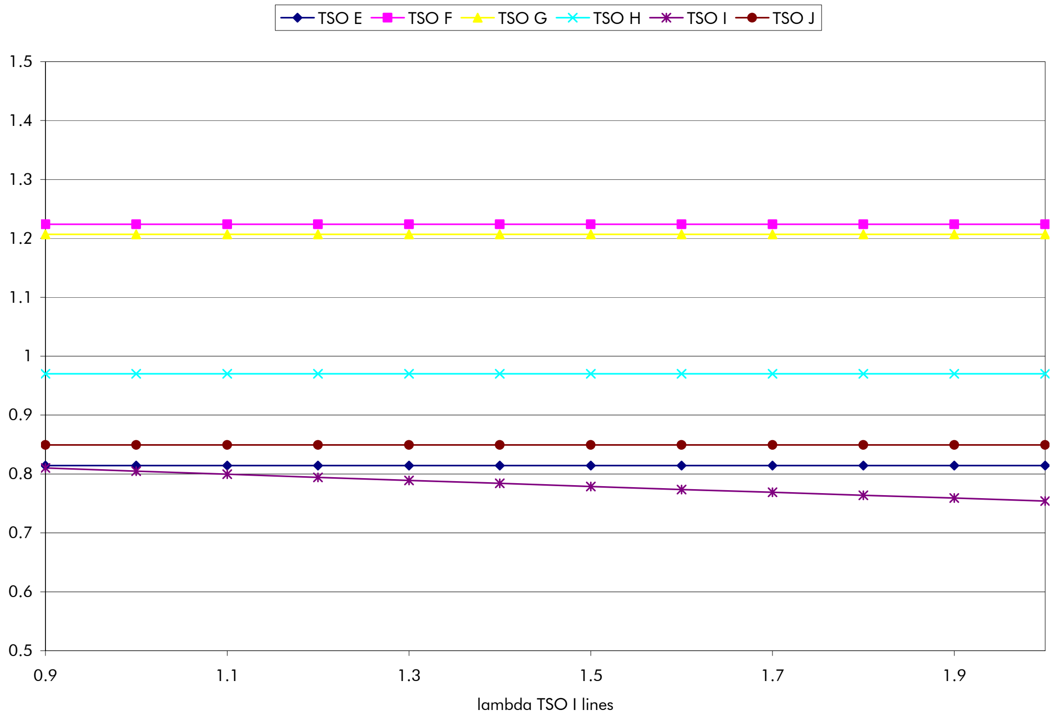

Figure 13-19 UC as a function of $\lambda_{TSO\ I}$(lines).

14. Sensitivity analysis

Interest rate r

14.01 The sensitivity of the results to changes in the real interest rate *r* is rather low, except for the ranking of TSO J and TSO E at around 2.5%. We note that a higher interest rate would make TSO E and others less competitive as it changes the balance between OPEX and CAPEX, whereas TSO J would gain in unit cost advantage. The chosen real interest rate of 3.5% corresponds to earlier studies (ECON, 1999) and reflects the low risk in the industry.

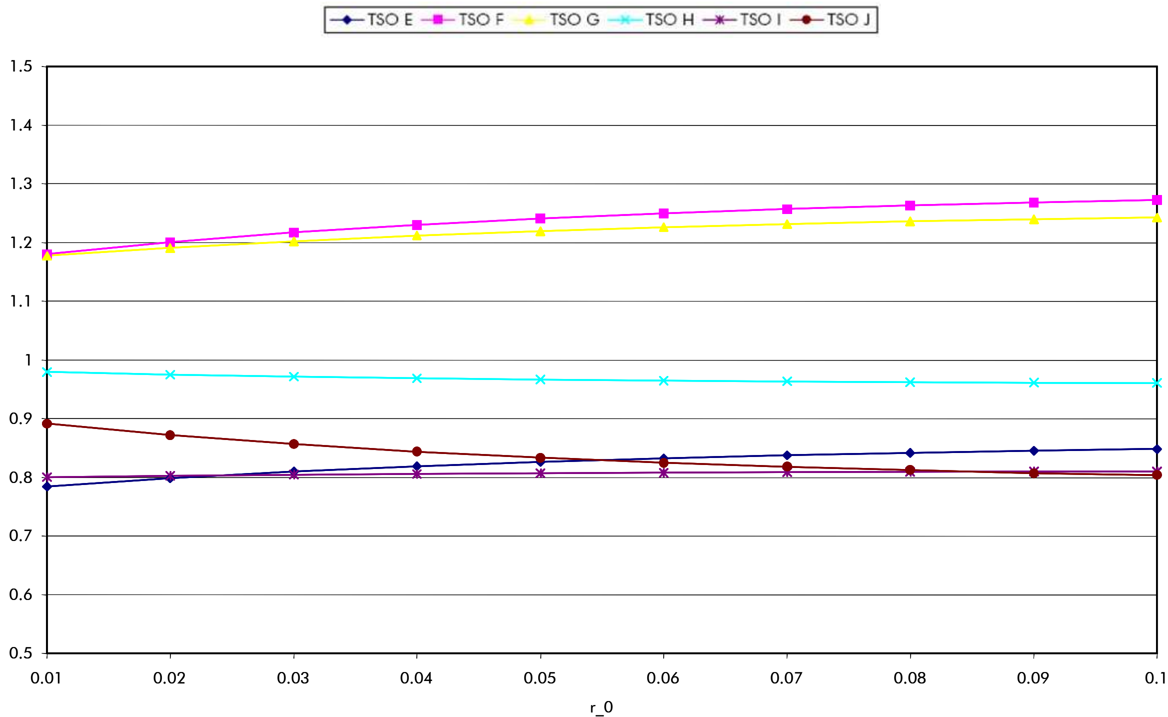

Figure 14-1 UC as a function of real interest rate *r*, example year 2000.

Forgiveness factor φ

14.02 As discussed and shown in the ECOM+ 2003 report, the horizon of interest has a major impact on the result, since the operating cost cannot be decomposed onto past and current investments. Since this would render the exercise arbitrary, the entire database is used in the current run and this corresponds to the real value of assets in operation.

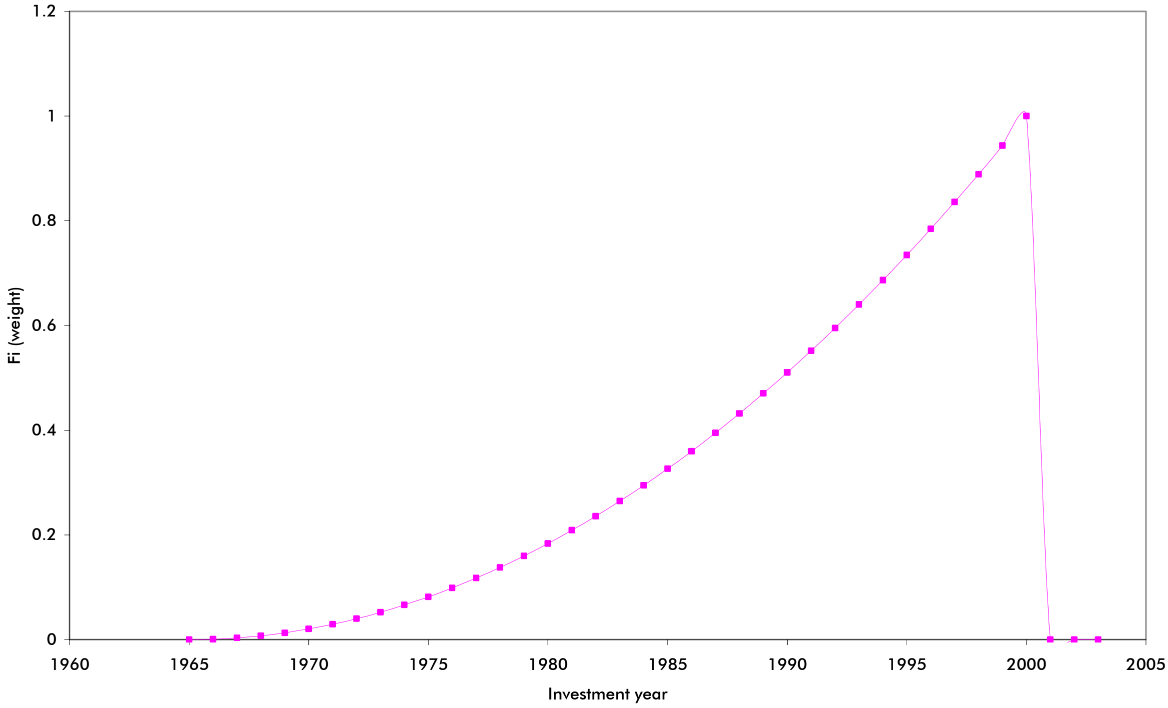

Figure 14-2 Forgiveness factor φ = 2

14.03 The forgiveness factor has a considerable impact and relevance to the individual regulators for reasons explained in Chapter 12. In Figure 14-2 an example is given of a progressive forgiveness factor that corresponds to a half-life of an investment at about 14 years. The results in Figure 14-3 over the parameter β, expressing the progression of the forgiveness factor (β = 1 is linear and β = 0 is the flat line) show an interesting pattern between TSO J and TSO E, where TSO E of course gains considerably in unit cost when the older assets are ignored and the opposite with TSO J. The curve for TSO is not relevant, as the asset ages are already taken into account at the reevaluation exercise.

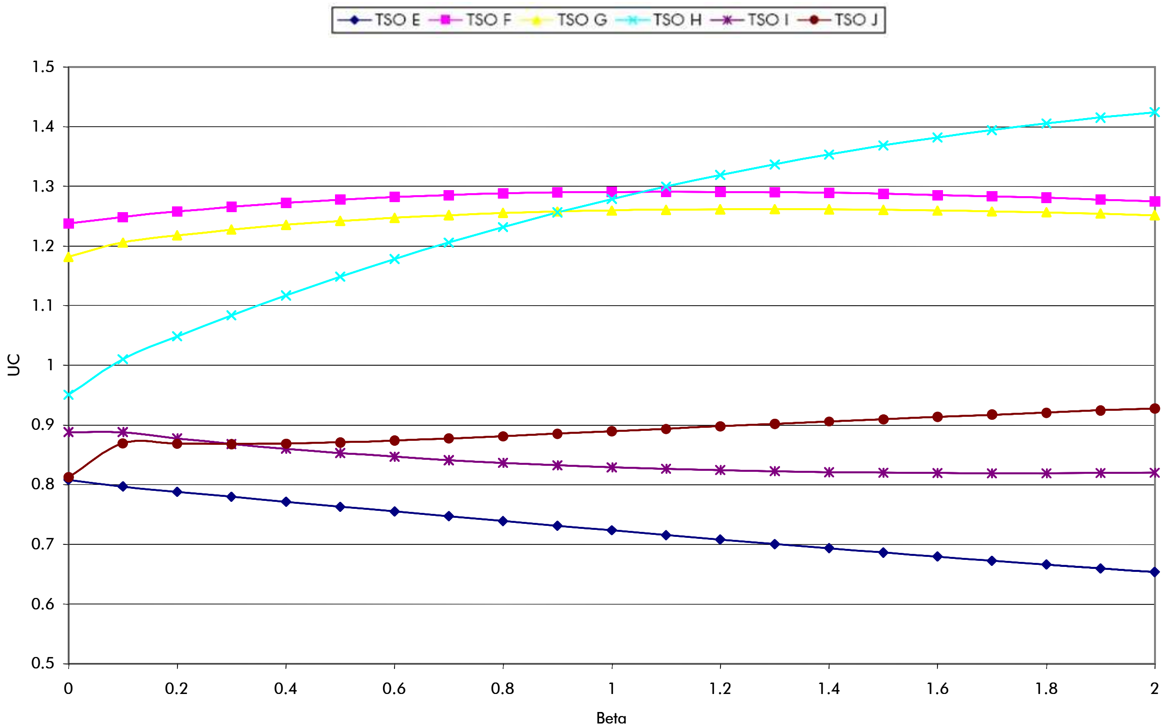

Figure 14-3 Results for φ = 0, ..., 2.

Asset life length

14.04 The life times of the assets have been estimated using multiple sources for each asset group. In particular for lines, Hildewall and Westberg (1999) has shown that the life length under continental climatic conditions can be extended almost indefinitely with preventive maintenance. PB Associates (1999) argue using statistical data and references to OFGEM in the UK that the effective life length in-land is 70 years. A detailed analysis of the impact on unit cost of line life length is depicted in Figure 14-4. Here, a very small impact is detected, depending on how assets are procured in time. UA similar graph for cables is found in Figure 14-5. Here, the overall impact is minimal and it was decided to use the life times 50, 45 and 40 years for lines, cables and stations/transformers, respectively.

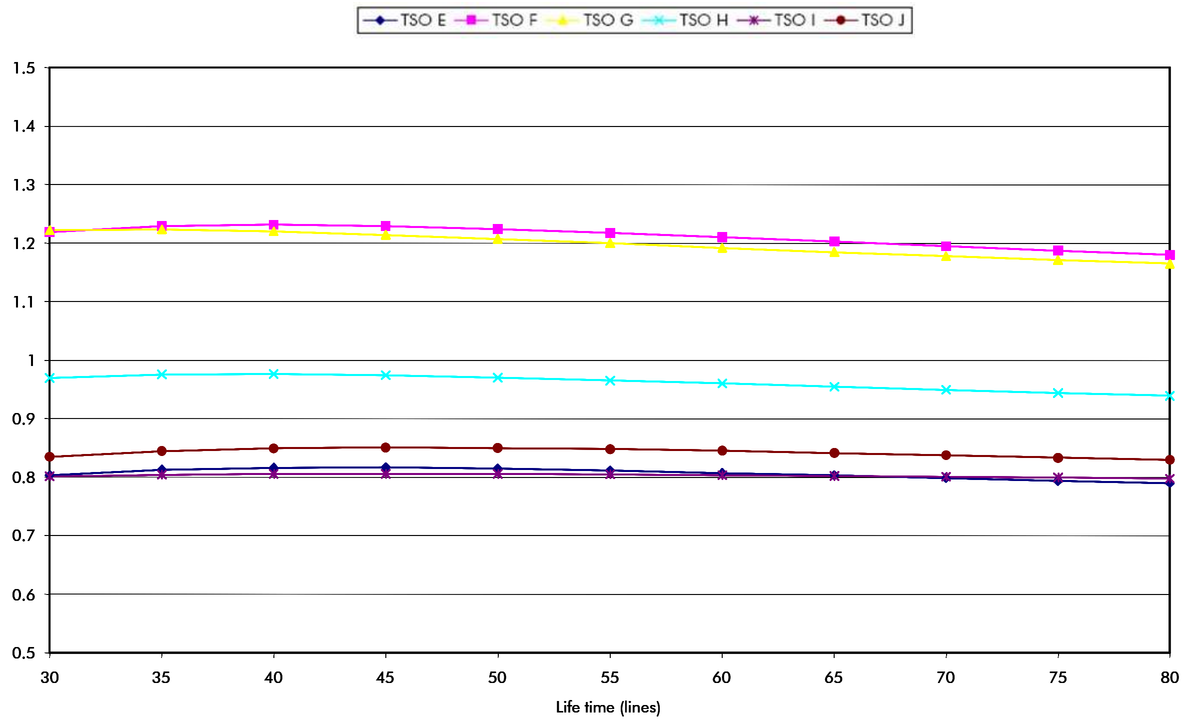

Figure 14-4 UC as a function of life time (lines).

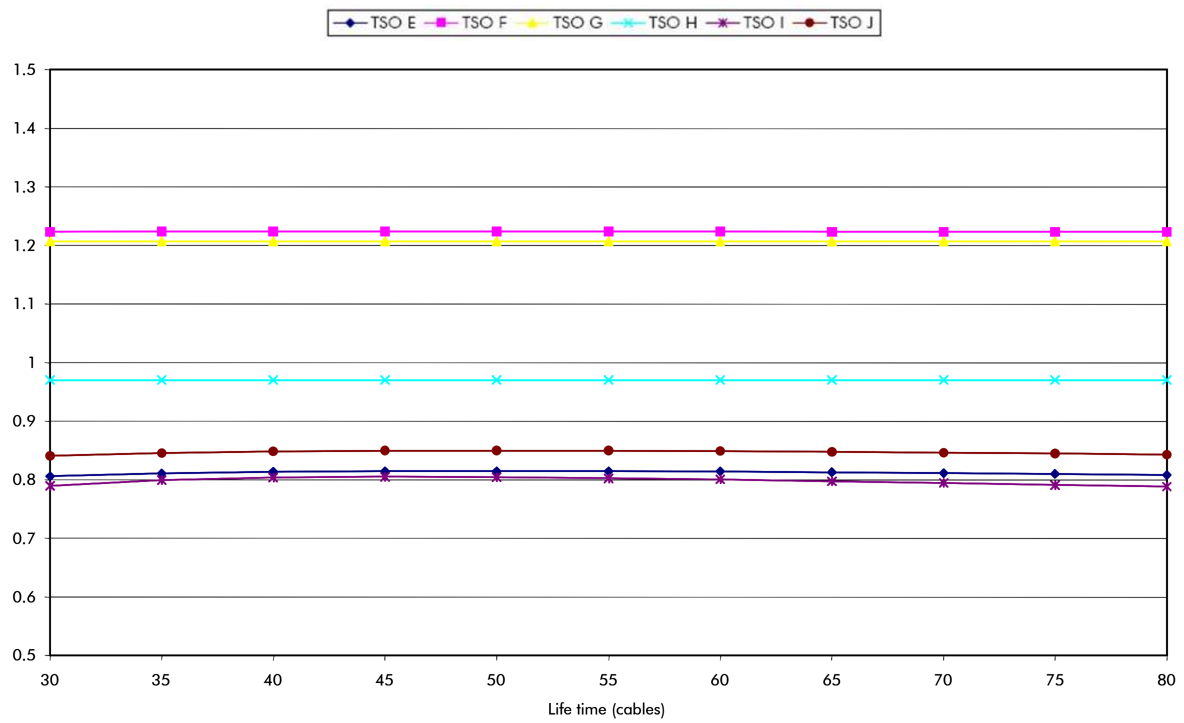

Figure 14-5 UC as a function of life times (cables).

Administrative OPEX

14.05 The intention in the operating cost guide (2.1, appendix A15) was to include a relevant and standardized share of administrative costs as to create a comparable base. The results and reported data are given in Table 14-1 through Table 14-5. Several indications contributed to our not using these data in spite of the original intention.

Table 14-1 Unit cost results 2000-2003 including administrative OPEX.

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
2000	0.83	1.28	1.26	1.08	0.81	0.88
2001	0.82	1.31	1.25	1.03	0.87	0.88
2002	0.82	1.28	1.18	1.02	0.96	0.82
2003	0.81	1.29	1.20	1.03	0.93	0.80

Table 14-2 Decomposition of costs 2000 including administrative OPEX.

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
OPEX (EUR)						
CAPEX						
OPEX+ CAPEX						
SizeOfGrid OPEX	31,391,911	12,489,713	22,175,358	14,570,168	2,460,595	5,765,042
SizeOfGrid CAPEX	160,509,850	71,484,207	74,370,381	71,810,288	29,493,074	31,287,058

Table 14-3 Decomposition of costs 2001 including administrative OPEX.

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
OPEX (EUR)						
CAPEX						
OPEX+ CAPEX (LRAC)						
SizeOfGrid OPEX	31,468,939	12,489,713	22,243,777	15,064,114	2,551,938	5,938,735
SizeOfGrid CAPEX	160,810,117	71,484,207	74,670,105	73,795,084	29,974,326	32,159,777

Table 14-4 Decomposition of costs 2002 including administrative OPEX.

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
OPEX (EUR)						
CAPEX						
OPEX+ CAPEX (LRAC)						
SizeOfGrid OPEX	31,660,717	12,489,713	22,268,767	15,995,053	2,623,921	5,999,588
SizeOfGrid CAPEX	161,541,940	71,484,207	74,781,720	78,239,467	30,261,997	32,262,049

Table 14-5 Decomposition of costs 2003 including administrative OPEX.

	TSO E	TSO F	TSO G	TSO H	TSO I	TSO J
OPEX (EUR)						
CAPEX						
OPEX+ CAPEX (LRAC)						
SizeOfGrid OPEX	32,410,372	12,583,011	22,387,683	16,662,822	2,623,921	6,165,879
SizeOfGrid CAPEX	164,518,885	71,815,182	75,125,726	81,808,461	30,261,997	33,188,030

14.06 First, as seen in Table 14-6 below, the total joint cost for payroll, services and expenditure varies considerable among the TSO in proportion to operating expenditure. Attempts to clarify some of these differences with regard to the definitions issued have not been successful due to a lack of response. As the differences affect units classed as efficient, a further analysis was made

14.07 Second, analysis of some particular defined items, e.g. 4.10 in A15, direct deduction for salary and payroll costs for CEO and board, reveals cost differences between 0 and 5.1 M€ per year! Clearly, this does not correspond to the intended purpose of the item. This, in combination with the fact that the administrative cost allocation involved ambiguities also for units ranked as peer or best-practice, concluded the prematurity of using the administrative cost in this run.

Table 14-6 Share of administrative cost to OPEX(A)

Share Admin/OPEX	2000	2001	2002	2003
TSO G	22%	22%	23%	11%
TSO J	13%	15%	23%	32%
TSO I	5%	4%	2%	2%
TSO F	55%	38%	46%	42%
TSO H	58%	47%	49%	53%
TSO E	15%	20%	13%	10%

15. Further work

15.01 Several important improvements have been implemented on the method since the previous run in 2003. Besides standardized definitions of assets and operating cost reporting, a completely revised weight validation and new scale-corrected partial measures and dynamic indicators of efficiency, the processes of result dissemination, country specific claims and TSO referral have also been improved. However, regulatory benchmarking of an activity as complex as transmission system operations remains both a practical and methodological challenge for which there still is room for improvements.

15.02 The unit cost measure UC as an absolute measure can be used as an informative measure of cost development, even with a small sample size. Possible improvements in this direction would be centered around the possible creation of new asset groups and selective revision of certain weights. The impact of such changes compared to their relative cost in time and resources might be relatively modest, though.

15.03 The relative efficiency measure E would naturally call for an enlargement of the pool of participating TSO to cover the span of operating efficiency. The larger the sample, the more information could be obtained endogenously through econometric treatment of the data. This in its turn improves the comparability of weights and standards and may smoothen the results. In our sample, the need for more TSOs with dense grids is particularly obvious, especially in the light of poor documented data on density measures. In our opinion, this avenue is the most promising and cost-efficient, also with background of the positive discussions held with some TSOs not currently in the sample. As previously agreed, any addition of a new member using the same data would be disseminated to all current members without any extra cost.

Reporting standards

15.04 Although considerable progress has been made in operating costs reporting, both data definitions and quality, the submitted data still shows differences in quality and precision. In particular grids that use organizational models involving non-regulated tasks show widely varying results depending on the definition of joint costs. Although the current version without administration stays consistent with the previous run, we consider it an area of future improvement to be able to address a higher proportion of the variable cost base. For this to succeed, more work has to be made on reviewing the underlying processes and their reporting.

Delays

15.05 The current project is reported in October 2005, almost four months and an extra workshop later than the original project plan. It is evident and a shared experience among the consultants and the TSOs that sufficient time needs to be devoted to both data collection, compilation and analysis. Clearly, this requires both a realistic time plan from the provider side *and* a common commitment from the reporting side to become reality.

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Appendixes

A1 Agenda ECOM+ Workshop 1

A2 Agenda ECOM+ Workshop 2

A3 Agenda ECOM+ Workshop 3

A4 Agenda ECOM+ Workshop 4

A5 ECOM+ Information Log

A6 ECOM+ Asset weights

A7 ECOM+ Country specifics

A8 Statement TSO J

A9 Statement TSO I

A10 Statement TSO H

A11 Statement TSO E

A12 Statement TSO F

A13 Statement TSO G

A14 Data definition guide, version 1.6

A15 Cost reporting guide, version 2.1

A1. First ECOM+ Workshop

Per AGRELL – Peter BOGETOFT 2004-11-26

Brussels,
Jolly Hotel du Grand Sablon , rue Bodenbroek 2/4, B-1000 Brussels.

	Friday November 26	
10.00	Welcome and Introductions	Agrell
10.05	*Benchmarking of TSO* TSO benchmarking, European regulation and evolving roles in the market.	Agrell
10.30	*ECOM+ model* - logic and components The mechanics and usage of the ECOM model in the Charter context.	Bogetoft
11.15	Example V: Maintenance evaluation	SUMICSID
12.00	Lunch	
13.00	Example V: Maintenance evaluation debrief	SUMICSID
13.30	*ECOM+ model* - data and weight specifications The data and weight requirements, country specifics	Deuse
14.30	*ECOM+* - recent model developments Dynamics in the ECOM+ model, how to catch a fleeing target.	Bogetoft
15.00	Coffee break	
15.30	*ECOM+ data collection procedure* Plans, procedures and contacts for the *ECOM+* project, discussion.	SUMICSID
16.00	Closing remarks and comments	Agrell

A2. Second ECOM+ Workshop

Per AGRELL – Daniele BENINTENDI 2004-11-09

	Friday November 19	
10.00	*Welcome, round table presentation and organization*	Agrell
10.15	*The ECOM+ Model: Introduction* Current state of the process, model components, agenda.	Agrell
11.00	*Data Validation: Asset data base* Comparative results, reporting assumption and discussion.	discussion
12.00	*Data Validation: Investment stream data* Comparative results, reporting assumption and discussion.	discussion
12.30	Lunch	
14.00	*Data Validation: Cost reporting* Comparative results, reporting assumption and discussion.	Benintendi
14.30	*ECOM+ Weight elicitation system* Principles, examples and mechanics	Agrell
15.30	*ECOM+ Country specifics and reference level validation* Austrian situation, data and availability	discussion
16.30	*ECOM+ Summary: Project Plan* Future activities, plan of action, coordination	Benintendi/Agrell
17.30	Closing of the workshop	

A3. Third ECOM+ Workshop

Per AGRELL – Peter BOGETOFT 2005-05-03

Sheraton Hotel, Brussels Airport, Zaventem.

	Friday May 6	
09.00	*ECOM+ status report* Introduction to the workshop, progress in the project, objectives.	Agrell
09.30	*Concerns and limitations* Discussion on site-visit findings, methodological debate.	Agrell
10.00	*Specific claims: Asset, group and country* Status, preliminary observations and suggestions.	Agrell
10.30	Coffee break	
11.00	*CAPEX model* - logic and components Asset valuation, assumptions, details, asset and category specifics	Deuse
12.30	Lunch	
13.30	*OPEX model and parameters* - logic and components Indexation, discounting, opex weights	Bogetoft
14.00	*ECOM+ results* - snapshot General results, observations and comments	Agrell
15.00	Coffee break	
15.30	*ECOM+ dynamics* Efficiency development results, including decompositions.	Bogetoft
17.00	Summary and next steps	Agrell

A4. Fourth ECOM+ Workshop

Per AGRELL – Peter BOGETOFT **2005-06-23**

Hilton Copenhagen Airport Hotel

	Thursday June 23	
10.00	*ECOM+ status report* Introduction to the workshop, objectives.	Agrell
10.15	*Introduction to the Cost reporting guide* System description, principles and details.	Agrell
11.00	*Discussion on to the Cost reporting guide* - Chapter 2-3	
11.30	*Discussion on to the Cost reporting guide* - Chapter 4 Understanding and applicability.	
12.15	*Summary of changes* Implementation of changes, types and information	Bogetoft
12.30	Lunch	
13.30	*Introduction to the OPEX reporting format* Logic and components.	Agrell Bogetoft
14.00	*Discussion on the OPEX reporting format* General results, observations and comments	
14.30	*Summary and next steps* Revision of the project plan and further planning.	
15.00	*Closing of the Workshop*	

A5. Information Log

A6. ECOM+ Weights

Asset *a*	Category	Voltage	Cross-Section	Group *g*	OPEX weight *w*	CAPEX weight *v*
1	AC Lines Average Condition	<150 kV	<250 mm	10		
2	AC Lines Average Condition	<150 kV	250-400 mm	10		
3	AC Lines Average Condition	<150 kV	400-700 mm	10		
4	AC Lines Average Condition	<150 kV	700-1500 mm	10		
5	AC Lines Average Condition	150 kV-220 kV	400-700 mm	10		
6	AC Lines Average Condition	150 kV-220 kV	700-1500 mm	10		
7	AC Lines Average Condition	150 kV-220 kV	>1500 mm	10		
8	AC Lines Average Condition	220 kV-350 kV	400-700 mm	10		
9	AC Lines Average Condition	220 kV-350 kV	700-1500 mm	10		
10	AC Lines Average Condition	220 kV-350 kV	>1500 mm	10		
11	AC Lines Average Condition	>350 kV	<250 mm	10		
12	AC Lines Average Condition	>350 kV	700-1500 mm	10		
13	AC Lines Average Condition	>350 kV	>1500 mm	10		
14	AC Lines Alpine Condition	<150 kV	<250 mm	10		
15	AC Lines Alpine Condition	<150 kV	250-400 mm	10		

16	AC Lines Alpine Condition	<150 kV	400-700 mm	10
17	AC Lines Alpine Condition	150 kV-220 kV	400-700 mm	10
18	AC Lines Alpine Condition	220 kV-350 kV	400-700 mm	10
19	AC Lines Alpine Condition	220 kV-350 kV	700-1500 mm	10
20	AC Lines Alpine Condition	220 kV-350 kV	>1500 mm	10
21	AC Lines Alpine Condition	>350 kV	700-1500 mm	10
22	AC Lines Alpine Condition	>350 kV	>1500 mm	10
23	DC Lines Average Condition	<150 kV	400-700 mm	10
24	DC Lines Average Condition	220 kV-350 kV	400-700 mm	10
25	DC Lines Average Condition	220 kV-350 kV	700-1500 mm	10
26	AC Land Cable	<150 kV	250-400 mm	20
27	AC Land Cable	150 kV-220 kV	400-700 mm	20
28	AC Land Cable	150 kV-220 kV	700-1500 mm	20
29	AC Land Cable	>350 kV	400-700 mm	20
30	AC Land Cable	>350 kV	700-1500 mm	20
31	AC Land Cable	>350 kV	>1500 mm	20
32	AC Sea Cable	<150 kV	250-400 mm	20
33	AC Sea Cable	<150 kV	400-700 mm	20
34	AC Sea Cable	<150 kV	700-1500 mm	20
35	AC Sea Cable	220 kV-350 kV	400-700 mm	20
36	AC Sea Cable	220 kV-350 kV	700-1500 mm	20
37	AC Sea Cable	>350 kV	700-1500 mm	20
38	DC Land Cable	<150 kV	250-400 mm	20
39	DC Land Cable	220 kV-350 kV	400-700 mm	20
40	DC Land Cable	220 kV-350 kV	700-1500 mm	20
41	DC Land Cable	>350 kV	>1500 mm	20
42	DC Sea Cable	220 kV-350 kV	400-700 mm	20
43	DC Sea Cable	220 kV-350 kV	700-1500 mm	20
44	DC Sea Cable	>350 kV	700-1500 mm	20
45	DC Sea Cable	>350 kV	>1500 mm	20

46	Circuit end; single, open, air	<150 kV	-	30
47	Circuit end; single, open, air	150 kV-220 kV	-	30
48	Circuit end; single, open, air	220 kV-350 kV	-	30
49	Circuit end; single, open, air	>350 kV	-	30
50	Circuit end; single, open, metal	>350 kV	-	30
51	Circuit end; single, closed, air	<150 kV	-	30
52	Circuit end; single, closed, air	220 kV-350 kV	-	30
53	Circuit end; single, closed, air	>350 kV	-	30
54	Circuit end; single, closed, metal	<150 kV	-	30
55	Circuit end; single, closed, metal	150 kV-220 kV	-	30
56	Circuit end; single, closed, metal	>350 kV	-	30
57	Circuit end; double, open, air	<150 kV	-	30
58	Circuit end; double, open, air	150 kV-220 kV	-	30
59	Circuit end; double, open, air	220 kV-350 kV	-	30
60	Circuit end; double, open, air	>350 kV	-	30
61	Circuit end; double, closed, air	<150 kV	-	30
62	Circuit end; double, closed, metal	<150 kV	-	30
63	Circuit end; double, closed, metal	150 kV-220 kV	-	30

64	Circuit end; double, closed, metal	220 kV-350 kV	-	30
65	Circuit end; double, closed, metal	>350 kV	-	30
66	Transformer; no OLTC; no phase shift	<150 kV	-	40
67	Transformer; no OLTC; no phase shift	150 kV-220 kV	-	40
68	Transformer; no OLTC; no phase shift	220 kV-350 kV	-	40
69	Transformer; no OLTC; no phase shift	220 kV-350 kV	-	40
70	Transformer; no OLTC; no phase shift	220 kV-350 kV	-	40
71	Transformer; no OLTC; no phase shift	>350 kV	-	40
72	Transformer; no OLTC; no phase shift	>350 kV	-	40
73	Transformer; no OLTC; no phase shift	>350 kV	-	40
74	Transformer; no OLTC; phase shift	220 kV-350 kV	-	40
75	Transformer; no OLTC; phase shift	>350 kV	-	40
76	Transformer; OLTC; no phase shift	<150 kV	-	40
77	Transformer; OLTC; no phase shift	<150 kV	-	40
78	Transformer; OLTC; no phase shift	150 kV-220 kV	-	40
79	Transformer; OLTC; no phase shift	150 kV-220 kV	-	40
80	Transformer; OLTC; no phase shift	220 kV-350 kV	-	40

81 Transformer; OLTC; no phase shift	220 kV-350 kV	-	40
82 Transformer; OLTC; no phase shift	>350 kV	-	40
83 Transformer; OLTC; no phase shift	>350 kV	-	40
84 Transformer; OLTC; phase shift	220 kV-350 kV	-	40
85 Transformer; OLTC; phase shift	>350 kV	-	40
86 Autotransformer; no OLTC; no phase shift	220 kV-350 kV	-	40
87 Autotransformer; no OLTC; no phase shift	220 kV-350 kV	-	40
88 Autotransformer; no OLTC; no phase shift	>350 kV	-	40
89 Autotransformer; no OLTC; no phase shift	>350 kV	-	40
90 Autotransformer; no OLTC; no phase shift	>350 kV	-	40
91 Autotransformer; no OLTC; phase shift	>350 kV	-	40
92 Autotransformer; OLTC; no phase shift	150 kV-220 kV	-	40
93 Autotransformer; OLTC; no phase shift	220 kV-350 kV	-	40
94 Autotransformer; OLTC; no phase shift	>350 kV	-	40
95 Autotransformer; OLTC; no phase shift	>350 kV	-	40
96 Compensating devices; Bank, fixed, capacitive	<150 kV	-	50
97 Compensating devices; Bank, fixed, capacitive	220 kV-350 kV	-	50

98	Compensating devices; Bank, fixed, capacitive	>350 kV	-	50
99	Compensating devices; Bank, fixed, inductive	<150 kV	-	50
100	Compensating devices; Bank, fixed, inductive	150 kV-220 kV	-	50
101	Compensating devices; Bank, fixed, inductive	220 kV-350 kV	-	50
102	Compensating devices; Bank, fixed, inductive	>350 kV	-	50
103	Compensating devices; Banks, fixed, capacitive and inductive	220 kV-350 kV	-	50
104	Compensating devices; Banks, adjustable, inductive	>350 kV	-	50
105	Compensating devices; SVC, adjustable, capacitive	>350 kV	-	50
106	Compensating devices; SVC, adjustable, inductive	220 kV-350 kV	-	50
107	Compensating devices; SVC, adjustable, inductive	>350 kV	-	50
108	Compensating devices; Synchronous compensator, adjustable, capacitive	<150 kV	-	50
109	Compensating devices; Synchronous compensator, adjustable, capacitive	>350 kV	-	50
110	Series compensation, discrete fixed	220 kV-350 kV	-	60
111	Series compensation, discrete fixed	220 kV-350 kV	-	60

112	Convert Station	>350 kV	-	91
113	HVDC Converter Bridge	>350 kV	-	91
114	Fjord Crossing	>350 kV	-	91
115	Converter station,270MW	>220-350kV	-	91
116	Control center HVDC	>350 kV	-	91
117	Ground Connection	<150 kV	-	91
118	Converter station, 500MW	>220-350 kV	-	91

A7. Submitted claims for country specific factors

A8. Statement TSO J

A9. Statement TSO I

A10. Statement TSO H

A11. Statement TSO E

A12. Statement TSO F

A13. Statement TSO G

A14. Data definition guide 1.6

A15. Cost reporting guide 2.1

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