Electricity distribution losses

A consultation document

January 2003 03/03

Summary

Electrical losses are an inevitable consequence of the transfer of energy across electricity distribution networks. On average, around 7 per cent of electricity transported across local distribution systems in Great Britain is reported as electrical losses.

The level of reported losses in any given year will be influenced by a number of factors, both technical and operational. It is Ofgem's aim to ensure that industry parties face the appropriate incentives to manage these factors and thus treat losses in the most efficient and effective way. The overall purpose of this document is therefore to consider whether the current incentive mechanism achieves this aim and, if not, what alternative arrangements might be put in place. Furthermore, the document invites views of interested parties on the issues raised.

The document examines the current level of losses on the distribution networks and the extent to which the Distribution Network Operators (DNOs) can influence this level. There appears to be scope through the decisions of DNOs on design, operation and investment for them to further reduce losses as a share of units distributed. It is therefore important that they face appropriate incentives so that the costs and benefits of reductions and increases in losses are valued appropriately.

The document explores the factors that need to be considered in designing an incentive framework on distribution network losses within the context of the price control. In particular, it is important that the overall balance of incentives in the price control is correct. Three alternative options are proposed:

- modifying the parameters of the current incentive scheme
- introducing a scheme based on the National Grid Company's System Operator incentive model, and
- making DNOs responsible for the purchase of electricity to cover losses.

The project has important links with a number of other pieces of work currently being carried out by Ofgem and the Department of Trade and Industry (DTI). These include the:

- development of technical arrangements for the connection of distributed generation

- development of the price control framework for monopoly networks
- introduction of competition in the provision of electricity connections, and
- review of the structure of electricity distribution charges.

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1. Rationale

Introduction

1.1. Ofgem's principal statutory objective is to protect the interests of consumers, wherever appropriate by promoting effective competition between persons engaged in, or commercial activities connected with, the energy industry. Many areas of the energy industry are subject to, or in the process of being opened to, competition. Where competition has been introduced, Ofgem will continue to monitor these markets to ensure that they operate effectively and deliver ongoing benefits to consumers.

1.2. There are some areas of the energy industry where companies retain an effective monopoly since it may not be possible or appropriate to introduce competition. This applies to the transportation of energy to consumers using the national and local networks of wires and pipes. In these circumstances, Ofgem has put in place price controls and other incentive regimes to protect the interests of consumers. Within the context of this regulatory framework, network businesses operate and maintain their networks. It is important to strike the right balance between the different incentive mechanisms to ensure that the overall package of incentives encourages network companies to take appropriate decisions.

1.3. There are presently 14 licensed distribution network operators (DNOs) in Great Britain. Each of these distribution businesses owns and operates one or more networks and sets charges for connection to and use of their networks. Each distribution network comprises of overhead lines, cables, transformers and switchgear to facilitate the transfer of electricity from the transmission system and distributed generators to customers' premises. The package of incentives faced by DNOs will influence the way that they utilise their existing assets and make investment decisions over the short, medium and longer-term. These decisions will influence the overall performance of the distribution network and may impact on the level of electrical losses.

Issue

1.4. Electrical losses are an inevitable consequence of the transfer of energy across electricity distribution networks. On average, around 7 per cent of electricity transported across local distribution systems is reported as electrical losses. The level of reported losses in any given year will be influenced by a number of factors, both technical and operational. It is important that industry parties face the appropriate incentives to manage these factors and thus optimise the level of losses in the most efficient way.

1.5. DNOs presently face a financial incentive to reduce the overall proportion of energy lost during transportation across the distribution system. The present incentive regime encourages DNOs to take operational and investment decisions to reduce losses by rewarding out-performance and penalising under-performance based on a target level of losses derived from historic performance.

Table 1.1: Development of losses

DNO	1990/91 (%)	1995/96 (%)	2000/01 (%)
Eastern	7.0	6.9	7.1
East Midlands	6.6	6.1	6.0
London	7.8	6.7	7.3
Manweb	9.8	8.8	9.1
Midlands	6.2	5.5	5.4
Northern	7.5	6.8	6.6
Norweb	7.1	4.8	6.2
Seeboard	7.9	7.1	7.6
Southern	7.1	7.2	7.2
South Wales	8.9	6.7	7.2
South Western	8.6	7.2	7.9
Yorkshire	6.3	6.5	6.6
ScottishPower	8.5	6.7	7.2
Hydro Electric	9.3	8.9	9.1
Average	**7.6**	**6.7**	**7.0**

1.6. Table 1.1 above illustrates the variability in the performance of DNOs since privatisation. There are many inherent differences in the design and load characteristics of each DNO. Nevertheless, it is not clear that these differences are sufficient to account for the variable performance of distribution companies. Anecdotal evidence suggests that DNOs have not considered the impact of their decisions on the level of electrical losses to an appropriate degree. This may reflect the strengthening of other incentives on DNOs to improve operating and capital efficiency. In light of this, it is important to consider whether DNOs face the appropriate balance of incentives across all outputs, including those in respect of losses.

1.7. The government's climate change commitments place greater emphasis on managing electrical losses and improving energy efficiency. While losses occur on the distribution networks, the financial costs of electrical losses are borne by suppliers and their customers. The environmental impact of losses is also borne by society as a whole. Nevertheless, neither suppliers nor consumers presently face significant incentives to invest resources into reducing electrical losses or improving energy efficiency, as the benefits from such efforts are largely smeared across all parties. It is important that those best placed to take actions face appropriate incentives to encourage those actions. Failure to do so may result in an inappropriate allocation of resources. In light of this, it will be important to consider whether suppliers and their customers should face stronger incentives to manage energy consumption efficiently.

1.8. In total 20 TWh of electrical energy is lost during its transportation across local distribution networks. This imposes a substantial financial cost on society both in terms of the costs of producing the electricity that is lost and the costs of transporting these units over the transmission and distribution networks.

1.9. In addition, the production and transportation of additional energy has a significant environmental impact both in terms of the production of climate change gases and in the investment in more infrastructure to accommodate the transport of this energy. Ofgem estimates that a reduction in losses from the current level of 7 per cent to 6 per cent might contribute to 4 per cent of the government's target reduction in CO_2 emissions by 2010.

1.10. However, it is important to note that there are other environmental impacts from electricity generation. All combustion-based generation can result in the emission of local air pollutants (particles and oxides of sulphur and nitrogen). Nuclear generation gives rise to health risks and waste-disposal problems. Even renewable generation has some impact on the surrounding environment; a hydro plant might cause changes to the surrounding ecosystem and wind farms can have visual and noise impacts. A reduction in electricity lost will help reduce the amount of electricity production required to meet demand and this will have wider environmental benefits.

1.11. As set out in appendix 3, our initial estimates suggest that each unit of electricity lost costs around 3.0 – 3.6p/kWh (including an estimate of the environmental impacts of 0.5 – 1.1p/kWh). This implies that the total cost of losses across all distribution systems is approximately £600 - £720m, or around 5 per cent of the typical electricity bill.

1.12. Electrical losses are undesirable and costly. They account for a considerable amount compared to the distribution businesses' allowed revenues and they are a cause of unwanted environmental effects. A change in losses of only 0.1 per cent of demand may have financial and environmental impacts valued in excess of £8m a year. The direct costs that Ofgem will incur in undertaking this project are relatively small by comparison to its importance and the final prices faced by consumers. Ofgem’s budget for this project is £300,000, which incorporates an allowance for consultancy support. This is equivalent to less than one penny per electricity consumer.

1.13. Undertaking this review of the approach to losses is fully consistent with the social and environmental guidance issued by the Secretary of State to the Gas and Electricity Markets Authority (“the Authority”) on 21 November 2002. The guidance invites the Authority, in exercising its functions, to have regard to the desirability of reducing the amount of energy losses on gas and electricity networks.

Objective

1.14. Undertaking this project to evaluate the performance of local networks in respect of electrical losses should help:

- protect the interests of consumers by developing appropriate incentive regimes to ensure that the financial and environmental costs of losses are at an efficient level, and
- encourage regulated companies to provide appropriate incentives on users of the network to encourage efficient use of their local systems.

1.15. The project will also consider the potential contributions of distributed generation to the management of electrical losses. This may help facilitate further advances in the competitive market for both the generation and supply of electricity.

Policy

1.16. Three broad approaches to this review have been considered. One option would be to remove the losses incentive mechanism within the DNO price controls and focus on encouraging generators and suppliers to manage the cost of losses effectively. However, electrical losses have a significant impact on the long-term interests of consumers and, given that the current scheme does not seem to offer sufficiently strong incentives on DNOs, to remove it would not be an appropriate solution.

1.17. An alternative is to maintain the existing incentive framework for distribution businesses and focus attention on providing appropriate incentives on consumers to enhance energy efficiency. However, this would not seem to deliver significant benefits in terms of reductions in electrical losses and is not considered to address the issue appropriately, especially given the concerns that the incentive currently is too weak.

1.18. The framework of incentives imposed on DNOs is likely to focus on the delivery of outputs. It is therefore important to re-evaluate the balance of incentives faced by DNOs and the potential utilisation of distributed generation. In light of this, Ofgem's favoured approach is to undertake a high level review of the incentive framework with respect to losses in parallel to the work already being undertaken. This will enable the development of a balanced package of incentives that encourages DNOS, generators, suppliers and consumers to recognise the impact of their decisions on losses.

2. Timetable

Purpose and structure of this document

2.1. The overall purpose of this document is to consider whether the current incentive mechanism achieves the aim of ensuring that losses are given appropriate consideration by DNOs and, if not, what alternative arrangements might be put in place.

2.2. Chapter 1 of this document sets out the rationale of this review.

2.3. Chapter 3 sets out a brief background of how losses have been treated in the price controls.

2.4. Chapter 4 examines the current level of losses on the distribution networks and the extent to which the Distribution Network Operators (DNOs) can influence this level.

2.5. Chapter 5 explores the factors that need to be considered in designing an incentive framework on distribution network losses within the context of the price control and proposes three alternative options.

Project timetable

2.6. Ofgem met with the DNOs in October 2002 to discuss the overall performance of distribution businesses, the financial and environmental costs of electrical losses, whether it is appropriate to change or strengthen the incentive and, if so, how the incentive should be structured. A brief summary of the discussions is included in appendix 1.

2.7. Ofgem intends to establish a small working group with interested parties to take forward key aspects of the work relating to this project. The purpose of the working group will be to provide a forum for informal discussion of many of the key issues identified in this document and to assist Ofgem in developing its ideas. The working group will not act as a decision making body and will not preclude a full consultation of the issues at an appropriate stage.

2.8. Ofgem intends to hold further workshops as the project progresses. These will provide interested parties with an opportunity to discuss the project in an open forum. The timing and scope of these workshops may vary depending on the interactions with other Ofgem projects and the level of interest in the issues to be discussed.

2.9. The table below sets out the timetable for the review of electricity distribution losses:

Table 2.1: Outline project timetable

Deliverable	Objective	Deadline
Meeting with DNOs	Discuss issues in preparation for the Initial Consultation.	October 2002
Initial Consultation Paper (This document)	Set out thinking and invite comments.	January 2003
Possible Industry Workshop	Further develop thinking.	March/ April 2003
Further Consultation Paper	Set out developed thinking and invite comments.	Approx. May 2003
Decision Paper	Set out Ofgem's final decisions.	Approx. August 2003

Interaction with other projects

2.10. The project has important links with a number of other areas of work, including the work being carried out by:

- the Department of Trade and Industry (DTI), Ofgem and the industry on the technical arrangements for the connection of distributed generation
- Ofgem on the development of the price control framework for monopoly networks
- Ofgem in relation to the introduction of competition in the provision of electricity connections, and
- Ofgem on the structure of electricity distribution charges.

Responding to the document

2.11. It would be helpful to hear from those with an interest in the issues raised in this paper, including distribution businesses, suppliers, distributed generators, customers and their representatives. Views are invited by **24 February 2003**. Where possible, responses should be sent electronically to:

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2.12. All responses will normally be published on the Ofgem website and held electronically in the Research and Information Centre unless there are good reasons why they must remain confidential. Consultees should try to put any confidential material to appendices in their responses. Ofgem prefers to receive responses in an electronic form so they can easily be placed on the Ofgem website.

2.13. Should you have any questions regarding the issues raised in this document, please contact Lars Rognlien on the above number.

2.14. A copy of this document and other Ofgem publications are available from the Ofgem website (www.ofgem.gov.uk).

3. Background

Previous price controls

3.1. The initial distribution price controls put in place at privatisation provided the DNOs with an incentive to reduce electrical losses on their networks by adjusting price control revenues for differences in the level of losses compared to the historic level. The approach was successful in encouraging DNOs to manage electrical losses.

3.2. The 1995 OFFER Distribution Price Control review considered several options for achieving further reductions in losses, including:

- increasing the proportion of efficiency gains from a reduction in losses that is retained by the companies
- requiring the distribution companies to invest in low loss equipment, by making it a requirement in the planning standards and building in an appropriate allowance when setting the new price control, and
- transferring the costs of distribution losses from the supply business to the distribution business.

3.3. The price control proposals chose to increase the financial rewards and penalties of the incentive from 1.5 to 3.0 pence per kWh. The aim of this increase was to give DNOs greater incentive to reduce losses and save energy. The incentive mechanism was also extended to the two DNOs in Scotland.

3.4. These arrangements were augmented by applying a one-off adjustment of 1/4 per cent of base price control revenue where companies out/underperformed against predetermined outputs.

4. The current level of losses and the ability to control it

4.1. Each licensed distribution business owns and operates one or more distribution network. These distribution networks comprise overhead lines, cables, transformers, switchgear and other equipment to facilitate the transfer of electricity to consumers' premises from the transmission system and generators connected directly to the distribution network. Most consumers are supplied at low voltage (LV), which is defined as a voltage less than 1 kV, with domestic customers typically supplied at 230V. Larger commercial and industrial customers are typically supplied at high voltage (HV), which is defined as a voltage of 1 kV or greater, with the largest customers supplied at extra high voltage (EHV), which is defined as a voltage greater than 22 kV.

4.2. While there are many similarities in the distribution networks operated by each distribution business, there are some important differences, including:

- geographical size of the area where the network is located
- number of customers connected to the network
- quantity of electricity distributed
- degree of dispersion of customers across the network
- proportion of different types of customers connected to the network, and
- the amount of underground cables compared to overhead lines.

In addition, the DNOs have historically adopted different design, operating and investment principles, which have led to very different network configurations. Some of the differences are illustrated in Table 4.1 below.

Table 4.1: Characteristics of individual DNOs

Distribution company	Area (Sq. km)	Customers (000's)	Circuit length (km)	Prop. of circuits under-ground	Quantity distributed (GWh)	Prop. LV	Prop. HV	Prop. EHV	Losses 2000/01 (GWh)
Eastern	20300	3322	89747	61%	34217	74%	24%	2%	7.1%
East Midlands	16000	2300	67751	64%	28187	60%	37%	3%	6.0%
London	665	2011	30160	100%	25518	74%	24%	2%	7.3%
Manweb	12200	1393	45313	53%	16941	60%	26%	14%	9.1%
Midlands	13300	2260	63802	60%	27216	60%	37%	3%	5.4%
Northern	14400	1451	43937	61%	16687	63%	22%	15%	6.6%
Norweb	12500	2140	58772	76%	25216	65%	31%	3%	6.2%
Seeboard	8200	2126	44773	73%	20745	78%	13%	9%	7.6%
Southern	16900	2652	71934	61%	32320	67%	26%	7%	7.2%
South Wales	11800	980	32873	43%	12518	55%	22%	24%	7.2%
South West	14400	1344	48009	39%	15116	71%	24%	4%	7.9%
Yorkshire	10700	2088	54268	71%	24074	60%	34%	6%	6.6%
ScottishPower	22950	1870	64396	62%	22561	69%	22%	10%	7.2%
Hydro-Electric	54390	640	44113	31%	8407	81%	14%	5%	9.1%
Average	**16336**	**1898**	**21161**	**61%**	**22123**	**67%**	**27%**	**7%**	**7%**

4.3. In assessing DNOs' performances in reducing distribution losses over the 12 years since privatisation, it is useful to form some view of what might be considered an optimal or efficient level. The factors mentioned above will influence these considerations for each network and arriving at such an estimate is therefore difficult. In addition, there are problems in measuring losses due to errors in the settlement process and other non-technical issues, such as the illegal abstraction of electricity and errors in unmetered supplies.

4.4. It may therefore be important to consider whether losses are above or below what is optimal and whether DNOs are managing losses effectively. Despite technological advancements that have reduced the costs of producing lower loss assets, it is very unlikely that benefits from reducing losses will be strong enough to justify premature replacement of assets. However, as networks are extended and assets are replaced, consideration of the cost of losses might affect the design and investment decisions. Given the long lives of network assets, often more than 40 years, a distribution network typically remains in a steady state. In light of this, the losses may be optimal given past investment decisions, but higher than the longer term goal.

4.5. The International Energy Agency publishes electricity statistics for a range of countries, including data on transmission and distribution losses. Although the methodology behind their estimates is not entirely transparent, they are reported on a consistent basis across the countries. Table 4.2 below summarises transmission and distribution losses for countries that may be compared to the UK. The table shows that the UK has higher losses than countries such as Germany, France, Italy and United States, but lower losses than Spain, Canada and Ireland.

Table 4.2 Transmission and distribution losses in selected countries

Country	1980	1990	1999	2000
Finland	6.2	4.8	3.6	3.7
Netherlands	4.7	4.2	4.2	4.2
Belgium	6.5	6.0	5.5	4.8
Germany	5.3	5.2	5.0	5.1
Italy	10.4	7.5	7.1	7.0
Denmark	9.3	8.8	5.9	7.1
United States	10.5	10.5	7.1	7.1
Switzerland	9.1	7.0	7.5	7.4
France	6.9	9.0	8.0	7.8
Austria	7.9	6.9	7.9	7.8
Sweden	9.8	7.6	8.4	9.1
Australia	11.6	8.4	9.2	9.1
United Kingdom	**9.2**	**8.9**	**9.2**	**9.4**
Portugal	13.3	9.8	10.0	9.4
Norway	9.5	7.1	8.2	9.8
Ireland	12.8	10.9	9.6	9.9
Canada	10.6	8.2	9.2	9.9
Spain	11.1	11.1	11.2	10.6
New Zealand	14.4	13.3	13.1	11.5
Average	**9.5**	**9.1**	**7.5**	**7.5**
European Union	**7.9**	**7.3**	**7.3**	**7.3**

4.6. By comparing the development in losses since vesting across DNOs[1], it seems evident that some companies have been more successful that others in reducing losses. Although inherent differences between the companies result in different scopes for reductions in losses, this does not seem to justify why some companies have reported significant reductions in the rate of losses while others have not.

[1] See table 1.1

4.7. Variable losses[2] on a network are approximately proportional to the square of the current. This means that, for a given capacity, a 1 per cent increase in load will increase losses by more than 1 per cent. Therefore, greater utilisation of the network's capacity has an adverse impact on losses. Consequently, there is a trade-off between the cost of financing surplus capacity and the cost of losses. An appropriate investment decision would reflect a minimum life-cycle cost of assets, including both the capital costs and the cost of losses. Research by UMIST[3] has suggested that a distribution network that takes appropriate account of losses by adapting an approach of minimising the life-cycle cost of the networks will be running at a very low utilisation rate. Several parties have commented that DNOs focus on 'sweating' the assets to get as much utilisation of the assets as possible subject to constraints provided by the security requirements. This arises from the incentive to increase capital efficiency. The work by UMIST has found that the minimum life-cycle methodology will generally satisfy the current security requirements at no further costs.

4.8. Although UMIST's findings should be read with caution as they are based on a simplified model of the real distribution networks with stylised assumptions, the resulting utilisation percentage was found to be lower than what is typical for networks in Great Britain. This suggests that the existing distribution networks are not designed to optimise the level of losses with respect to the rate of utilisation, and that losses are above the optimal level.

4.9. In October 2002, Ofgem issued an information request to DNOs inviting comments on their approach to managing losses. The responses revealed that losses are not considered to an appropriate degree when operational and investment decisions are made. Four DNOs explicitly stated that they do not consider electrical losses in their investment appraisals.

4.10. Further indications that the losses incentives do not have a significant impact on DNOs' behaviour are found in the fact that many DNOs have moved away from reactive power charges. Reactive power flows reduce the effective capacity of the surrounding network and therefore cause higher losses. The effective capacity as a share of installed capacity is called the power factor. A consumer

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[2] See paragraph 4.17 for an explanation of variable losses.
[3] "Effect of losses in design of distribution circuits", S. Ćurčić, G. Strbac and X.P. Zhang, IEE Proc. Gener. Transm. Distrib., Vol 148, No. 4, July 2001.

can take actions to reduce its creation of reactive power by installing certain correcting equipment, but has no incentive to do so unless it is charged for the low power factor, either by a specific charge or via a charge for actual rather than effective capacity. While at the time of vesting all DNOs levied a specific charge for the resulting low power factors, many have now ceased these charges. If reducing losses featured highly on DNOs agendas, they would be keen to encourage the installation of power factor correcting equipment and would therefore levy such a charge. There is the problem, however, that not all suppliers identify this charge on the bills to their customers, but little effort seems to have been spent on the DNOs' part to encourage suppliers to do so.

4.11. A similar argument can be applied to the issues of illegal abstraction of electricity and unmetered supplies. Generally, the incentives on DNOs to detect and combat theft of electricity[4] and to audit the inventories of unmetered supplies are weak. Both of these efforts would result in a reduction in recorded losses. If the current incentive mechanism was effective, one might expect to have seen more effort in these areas.

4.12. Although there are difficulties both in measuring actual losses and in estimating what level of losses is optimal or efficient, there seems to be many indications that several DNOs are not taking full account of losses. Based on the above, Ofgem believes that there most likely is scope for further reduction in distribution losses in Great Britain. It is important to ensure that the incentives on losses are set so that DNOs spend an appropriate effort on evaluating possible actions that can be taken to reduce losses.

DNOs' ability to control losses

4.13. For an incentive mechanism to have an effect, DNOs must be able to control the losses on their network to some extent. The level of losses on a network is driven by a number of factors and the DNOs' ability to control these, as well as the associated costs, will largely determine the scope for the incentive mechanism to reduce losses.

[4] While DNOs have a licence obligation to report suspected theft to suppliers, the obligation to take steps to investigate and prosecute lies on suppliers.

4.14. The losses figure recorded in the price control is deduced from the number of units entering and the number of units exiting a network. Distortions to either of these figures will therefore affect the recorded level of losses.

4.15. The recorded losses can be broken down into three main categories; variable losses, fixed losses and non-technical losses. Variable losses, often referred to as copper losses, occur mainly in lines and cables, but also in the copper parts of transformers and vary in the amount of electricity that is transmitted through the equipment. Fixed losses, or iron losses, occur mainly in the transformer cores and do not vary according to current. Both variable and fixed losses are technical losses, in the sense that they refer to units that are transformed to heat and noise during the transmission and therefore are physically lost. Non-technical losses, on the other hand, comprise of units that are delivered and consumed, but for some reason are not recorded as sales. They are lost in the sense that they are not charged for by neither the suppliers nor distribution businesses.

4.16. This review of distribution losses is concerned with ensuring that losses in all three categories are at efficient levels and any proposed remedy will therefore seek to encourage efforts in keeping both technical and non-technical losses down. Therefore, for the purpose of this review, it is appropriate to refer to the losses recorded in the price control as *distribution losses*, although not all of these units are physically lost.

Variable losses

4.17. Variable losses vary with the amount of electricity distributed and are, more precisely, proportional to the square of the current. Consequently, a 1 per cent increase in current leads to an increase in losses of more than 1 per cent. Between 2/3 and 3/4 of technical (or physical) losses on distribution networks are variable. The paragraphs below set out how the level of variable losses on distribution networks can be influenced.

Utilisation of capacity

4.18. Because of the proportionality between losses and the square of the current, the level of losses on a network will be affected by the utilisation of its capacity. By increasing the cross sectional area of lines and cables for a given load, losses will fall. It is clear that this leads to a direct trade-off between cost of losses and cost of capital expenditure. It has been suggested that optimal average utilisation rate on a distribution network that considers the cost of losses in its design could be as low as 30 per cent.

Higher voltages

4.19. Because at higher voltages a lower current is required to distribute the same amount of electricity, moving to higher voltages will reduce utilisation and therefore losses on the networks. Several DNOs have suggested that the secondary voltage level 6.6 kV can be replaced by 11 kV. Midlands is in the process of replacing its 33 kV voltage level with 66 kV and 132 kV and this has been a contributing factor to Midlands having the lowest rate of losses recorded amongst the DNOs.

Shorter or more direct lines

4.20. Apart from capacity and voltage levels, the configuration of the network may have an effect on losses in terms of the length of the wires. As the customer base develops independently of the network, the resulting configuration of a network that has been constructed over 40 years will most likely not be the optimal one. There might therefore be some scope for reducing losses by reconfiguring the network, for example by providing more direct lines to where demand is currently situated. Similarly, the location of open points on a circuit can affect the distance electricity is transported.

Demand management

4.21. Because variable losses increase over-proportionally to the current, distributing an additional 1 GWh in peak times will result in a greater increase in losses than 1 GWh in off-peak periods. Therefore, if DNOs can structure their tariffs in a way that encourages customers to smooth demand, the peaks on the distribution network can be reduced and losses will fall.

Balancing 3 phase loads

4.22. DNOs sometimes act to balance loads on 3-phase networks. This may only be carried out at particular locations when it is necessary to avoid voltage or capacity limits being exceeded. However, balancing 3-phase loads periodically throughout a network can reduce losses significantly. It can be done relatively easily on overhead networks and consequently offers considerable scope for cost effective loss reduction, given suitable incentives.

Fixed losses

4.23. Fixed losses do not vary according to current. These losses take the form of heat and noise and occur as long as a transformer is energised. Between 1/4 and 1/3 of technical losses on distribution networks are fixed. Fixed losses on a network can be influenced in the ways set out below.

Quality of transformer core material

4.24. The level of fixed losses in a transformer is largely dependent on the quantity and quality of the raw material in the core. Transformers with more expensive core materials, such as special steel or amorphous iron cores, incur lower losses. There is again a direct trade-off between capital expenditure and cost of losses.

Eliminating transformation levels

4.25. Fixed losses can also be reduced by eliminating transformation levels. Midlands' removal of the 33 kV and 66 kV voltage levels on a large proportion of their network, leaving a direct 132/11 kV transformation, has reduced the amount of transformation necessary to distribute electricity from the Grid Supply Point (GSP) to the consumers. Although there may have been some offsetting increase in variable losses on the 11 kV network, these are clearly outweighed by the reductions. DNOs have indicated that between 6 and 10 per cent of losses occur at this transformation level. However, distributed generation that cannot connect at 11 kV would have to connect at 132 kV, which may lead to higher connection costs for such generators.

Switching off transformers

4.26. Another method of reducing fixed losses is to switch off transformers in periods of low demand. If two transformers of a certain size are required at a substation during peak periods, only one might be required during times of low demand so that the other transformer might be switched off in order to reduce fixed losses. This will produce some offsetting increase in variable losses and might affect security and quality of supply as well as the operational condition of the transformer itself. However, these trade-offs will not be explored and optimised unless the cost of losses are taken into account.

Non-technical losses

4.27. Non-technical losses comprise of units that are delivered and consumed, but are not recorded as sales. Consequently, they show up as losses in the price control returns. In the case where consumption is significantly over-recorded, non-technical losses can be negative. The following discusses causes of non-technical losses and how they might be remedied.

Meter errors

4.28. Statutory requirements[5] are for meters to be within an accuracy range of + 2.5 per cent and – 3.5 per cent. Old technology Ferraris meters normally started life with negligible errors, but as their mechanisms aged they slowed down resulting in under-recording. Modern electronic meters do not under-record with age in this way. Consequently, with the introduction of electronic meters, there should have been a progressive reduction in meter errors. Increasing the rate of replacement of mechanical meters should accelerate this process.

Measurement errors in the settlement system

4.29. There are a number of measurement errors within the settlement system that may distort the recorded losses. In 1999/00, supercustomer billing was introduced as a method of estimating customers' consumption. In some areas, large errors associated with the meter data collection and aggregation process surfaced during the first couple of years under the new methodology. This led to substantial distortions to the recorded units distributed and thus to recorded losses. Elexon continues to work with the industry under the BSC to reduce the

[5] Regulations under Schedule 7 of the Electricity Act 1989.

inaccuracy of data going into settlement. A large part of these errors seems to have been removed, but there are still concerns regarding the accuracy of the billing process. Approximation processes, such as estimated average consumption and annualised averages, profiling errors and meter reading errors still contribute to some extent to distort the losses figures.

Unmetered supply

4.30. Errors in inventories of unmetered supply constitute a second contributor to non-technical losses. For practical reasons, some electrical installations, such as street lighting, are not metered. Customers with unmetered supplies keep inventories of the equipment and estimated usage. DNOs and suppliers bill based on these estimates.

4.31. If additional equipment is added, such as traffic cameras or mobile masts, or if the consumption of the existing equipment changes, these inventories should be changed accordingly to allow for accurate billing. When some of these inventories have been audited by DNOs, they have turned out to be incomplete, usually due to lack of updating after such changes described above. A similar problem arises when photo cells controlling lights do not switch off the lighting during daylight hours, either because they are faulty or because of overgrowing trees. In addition, recent work by the Load Research Group of the Electricity Association has identified inaccuracies in the load profile of particular types of street lighting. Work is continuing on other types of street lighting to ensure that accuracy of its load profiling.

4.32. Often, actual consumption has turned out to be significantly higher than the estimates. DNOs therefore suspect that several of these estimated unmetered supplies are erroneous, causing units to be recorded as losses rather than consumption. Both DNOs and suppliers would derive benefits from correcting this problem.

Illegal abstraction of electricity

4.33. Other sources of non-technical losses include illegal abstraction of electricity. This mainly consists of tampering with meters and illegal connections. It is not currently possible to gauge the exact extent of illegal abstraction, as a proportion of this is likely to be undetected.

4.34. Some suppliers and DNOs have expressed concern that the incentives and obligations on participants to reduce the illegal abstraction of electricity are not correct. In response to these concerns, Ofgem will be consulting on the issue of the illegal abstraction of electricity during 2003. Ofgem will ensure the internal co-ordination of these two work areas.

4.35. It is difficult to measure non-technical losses accurately. Estimates from four DNOs, however, indicate that non-technical losses account for about 3 to 9 per cent of total losses on GB networks. A further two DNOs stated that non-technical losses accounted for considerably less than 20 per cent of total losses. The UK Revenue Protection Service has estimated the cost of illegal abstraction to the industry at £100m per year.

Other possible loss reducing measures

4.36. Low power factors, as described in paragraph 4.10, also contribute to losses. If DNOs levy charges for low power factors, customers will be encouraged to take measures to improve their power factors, which will lead to reduced losses. However, it is necessary to consider this in relation to suppliers' behaviour in passing such charges on and identifying them on the bills to consumers. This is an area of wider concern that is being considered by Ofgem under a separate project[6].

4.37. An area that is strongly associated with efficiency of the energy industry in Great Britain is distributed generation. While its main benefits are cleaner and more efficient generation and location of generation closer to demand, distributed generation also has an effect on losses. In simple terms, locating generation closer to demand will reduce distribution losses as the distance electricity is transported will be shortened, the number of voltage transformation levels this electricity undergoes is lessened and the freed capacity will reduce utilisation levels. However, much depends on whether generation is situated close to, or

[6] Structure of electricity distribution charges.

remote from loads of similar size on distribution networks. In some cases, distributed generation may increase losses, for example where generation is located at the end of a network or is connected via long feeders.

4.38. The losses incentive will encourage DNOs to take appropriate account of losses when setting charges for distributed generators and they can to some extent influence where these are located. Issues regarding developing appropriate charging methodologies for distributed generators are also dealt with in a separate project[6].

Views invited

4.39. Views are invited on the issues raised in this chapter and in particular on the following:

- **Are there any other areas in which losses can be reduced?**
- **What is the scope for further reducing losses on the 14 DNOs in England, Scotland and Wales?**
- **Is Ofgem's view that the current incentive on distribution losses is too weak and losses are currently higher than what is optimal the correct one?**
- **Which specific efforts are likely to be overall cost effective, bearing in mind that the cost of losses may be 3p/kWh?**

5. How to encourage efforts to achieve an efficient level of losses

5.1. Without any regulatory intervention with regards to losses, there would be weak incentives on distribution companies to reduce them and they would definitely be above what is an efficient level. The question is then; how should DNOs be encouraged to spend effort in reducing losses where the associated benefits to society exceed the costs?

5.2. The existing incentive mechanism does reward DNOs for reducing losses. However, because of reasons set out in chapter 4, Ofgem believes that there most likely is further scope for reductions in losses and that the current incentive mechanism might be failing to give sufficient incentives to the DNOs. The discussion below sets out factors that need to be considered in constructing an incentive mechanism and sets out three alternative options in the light of these factors.

Cost of losses

5.3. The full cost of technical losses on a network consists of the value of the electricity lost, the cost of providing the additional transportation capacity on the transmission and distribution networks and the costs of the environmental impacts associated with the additional generation that is needed to cover losses.

5.4. The values of all three components vary according to time of day and time of year. The value of a unit of electricity is much higher in times of high demand than when demand is low. Similarly, it is predominantly during periods of high demand that the existence of losses leads to higher capacity requirements on transportation networks. As marginal generators tend to have higher emission rates than the average generator, a similar profile exists for environmental costs.

5.5. As a consequence, allowing a fixed value per unit of reduction in losses will not provide the correct incentives. Some efforts largely affect losses in off-peak periods, such as switching off transformers in periods of low demand. Other efforts will reduce losses in peak periods, such as smoothing demand. The incentive mechanism will not encourage the correct trade-offs between the costs and benefits of such efforts unless it reflects the profile of cost of losses. A similar argument applies to allocating the appropriate costs to customers that cause losses at times of different levels of demand.

5.6. Based on estimates of half-hourly GSP and consumption data provided by one DNO, it has been possible to perform a broad analysis of the cost of losses stemming from each of these three sources outlined above. The estimated average cost of losses was calculated to be about 3.0 - 3.6 p/kWh. This varies from just above 2p/kWh during the night to almost 6p/kWh during the afternoon peak. Further details of the analysis performed can be found in appendix 3.

5.7. Any incentive mechanism should reflect the cost of losses. In assessing the merits and demerits of an incentive mechanism, it should therefore be considered to what extent it reflects the actual cost of losses as well as the profile of these costs.

Balance of incentives

5.8. However the incentive is structured, there would be a balance to strike in terms of the share of the costs and benefits of changes in losses that should fall to consumers and to DNOs respectively. Currently, a permanent reduction in losses will reward the DNO with 2.9p/kWh in the first year. The reward then falls in a straight line over ten years. This amounts to about 12.5p on a net present value basis. The net present value of the benefit to society of the same reduction, assuming a 40-year asset life, is 41p. In effect, this provides DNOs with about 30 per cent of the benefits, while consumers receive the remainder. A larger share to DNOs will increase the strength of the incentive. However, it is essential that customers will receive a significant share of efficiency savings.

5.9. It is equally important to achieve an appropriate balance between the different incentives that are part of the price control. In many situations, a DNO will face conflicting incentives on losses, capital efficiency, operating efficiency and quality of supply. It is therefore important to consider the level of these incentives to ensure that they give the correct balance.

Trade-off: Capex and opex efficiency v losses

5.10. The price control gives an allowance for capital expenditure (capex) and operating expenditure (opex). The presumption is that the allowed expenditure is the efficient one overall, including any necessary expenditure to ensure that losses are at an efficient level. The mechanisms of the price control then reward DNOs for efficiency gains in capex and opex spending by allowing them to retain a share of the benefits from efficiency savings compared to the allowance. Although the allowance should include for appropriate expenditure on losses, for example for installing low-loss transformers, the companies have an incentive to reduce expenditure by investing in conventional transformers in order to retain a share of the savings. To avoid this, it is necessary to ensure that DNOs face the correct incentives on loss reduction. This can be done by an incentive mechanism on losses.

5.11. Since only a proportion of a saving in expenditure is retained by the DNOs, or equivalently, only a proportion of an additional cost is paid for by the DNOs, the incentive mechanism should aim to transfer to the DNO the same proportion of the costs (benefits) of increasing (reducing) losses. This should ensure the correct balance between the expenditure efficiency and losses incentives.

Trade-off: Quality of supply v losses

5.12. Ofgem has put in place an incentive scheme on DNOs to meet targets on number and duration of interruptions to supply. The scheme rewards and penalises DNOs by up to 2 per cent of base price control revenue based on the performance of the companies compared to the targets.

5.13. There are circumstances where the incentives on losses conflict with the incentives on quality of supply, eg in relation to the location of system open points. It is therefore necessary to ensure that the incentives are correctly balanced.

Balance of resources

5.14. It has been argued that instead of encouraging DNOs to spend efforts on reducing losses, resources would be better spent on improving energy efficiency of customers. By improving energy efficiency, demand will be lower than it otherwise would and losses would thus be lower.

5.15. Ofgem and DEFRA have implemented a scheme committing suppliers of gas and electricity to improve the energy efficiency of consumers' homes. Each company has an energy savings target, totalling 62TWh, which it must achieve between 2002 and 2005 by installing energy efficiency measures in homes. This can be achieved by installing or encouraging efficiency measures such as boiler replacement, insulation and energy efficient light bulbs and appliances. Estimates by DEFRA predicts that energy companies will spend roughly £500 million over these three years in order to meet their targets. This shows that efforts are spent in improving energy efficiency.

5.16. Nevertheless, whether or not DNOs should be incentivised to rectify inefficient investment signals with respect to losses should not be dependent on whether or not suppliers spend efforts in other areas. The different incentives schemes on DNOs, however, need to be balanced.

Regulatory certainty of the incentive scheme

5.17. Given the long-term nature of investment decisions on distribution network assets, it is important that it is clear what benefit or penalty a DNO will receive from its performance. The benefits are currently given on a sliding scale over ten years, but the incentive mechanism has been amended every five years. If the DNOs suspect that an incentive mechanism will change at the next price control, they will probably assign less importance now to any benefit or penalty due after that time.

5.18. As this review is examining losses more thoroughly than has been done before, it will therefore be important to ensure that an incentive scheme is put in place that can avoid as much uncertainty as possible.

Flexibility of an incentive scheme

5.19. An incentive mechanism calibrated to reflect the real costs of losses in 2005 might not be very accurate 5 years later. While the transportation part of the costs of losses is relatively stable over time, the energy cost is not. One option is to allow the incentive to reflect the variations in the cost of generating electricity so that the incentive would better reflect the costs of losses over time. However, this would add uncertainty to the future revenue stream from the incentive.

5.20. Likewise, including environmental costs in the incentive would internalise the costs of carbon emissions, but an introduction of a carbon tax or trading scheme would undermine the rationale of this approach. If environmental costs of carbon emissions were included, it would be appropriate to allow these to be removed from the incentive if a carbon tax or trading scheme is implemented.

Input v output based incentive mechanism

5.21. An economist's solution to the problem of missing incentives could be to set an incentive mechanism that internalises DNOs' benefits. This rationale has led to the current incentive mechanism, where a fiscal benefit is given per unit that losses are reduced.

5.22. However, views have been expressed that an output based incentive mechanism, such as the one currently in place, is not well suited to encourage DNOs to spend appropriate effort in reducing losses. It has been proposed that the incentive should be placed on inputs rather than outputs, eg by compensating DNOs directly for the benefits of choosing a low-loss transformer rather than a low cost transformer.

5.23. An input based mechanism has appealing advantages. By estimating the contribution to loss reduction from a particular piece of equipment compared to the one most commonly installed, DNOs could be given this sum to encourage the installation of such equipment. This would avoid the problem with measuring losses, which is one of the difficulties with an output based incentive mechanism. Instead, the number of, eg, transformers installed in a year would need to be recorded. The incentive would in this case be closely linked to the effort spent and would be focused on areas where DNOs can control losses.

5.24. Another advantage of such a system is that all the benefits from reductions in losses are given in the same year as the equipment is installed. This would make the trade-off between different types of equipment easier to make for DNOs and it would reduce any uncertainty regarding future incentives.

5.25. However, there are serious shortcomings to an input based incentive. Firstly, it would be necessary to assess a wide range of equipment and a large number of models and then form a judgement of how much each type contributes to reduce losses. This would amount to a massive and very costly administrative task. Secondly, the measure of reduction in losses attributable to any kind of equipment would be difficult to calculate as the achieved reduction will be dependent on factors such as load profile, utilisation and other characteristics in the area of the network where the equipment is installed.

5.26. Furthermore, DNOs would only be incentivised to spend efforts in reducing losses in areas where inputs can be measured with a reasonable accuracy. It would be difficult to encourage efforts in areas such as achieving an efficient utilisation level, redesigning networks and increasing voltages. It would also be difficult to encourage operating decisions that may affect losses, such as load management and reactive power charges. Finally, it assumes that reductions in non-technical losses should not be incentivised. Even if some of non-technical losses cannot be controlled by DNOs, efforts from DNOs may help reduce measurement errors, illegal abstraction and errors in unmetered supply.

5.27. Because of the factors outlined above, Ofgem believes that an output based incentive mechanism is preferable to input based. An output based incentive that transfers the appropriate cost of losses to DNOs will leave it for the companies to develop and decide on ways to reduce losses. As the incentive is given irrespectively of how the reductions are achieved, it encourages the least costly measures to be implemented.

5.28. Measurement errors will be an issue, but when measuring performance over a number of years, the trend in losses should be clearer and the performance related revenue adjustments should be correct in the longer term.

Alternative incentive schemes

5.29. As explained in chapter 3, two general incentive schemes have applied to DNOs since privatisation. Since 1990/91, a marginal incentive has rewarded DNOs (since 1995/96 for the two Scottish DNOs) per kWh that losses have been reduced compared to a ten-year average. In addition, a within-range adjustment was applied when setting the base price control revenue in the

2000/01 - 04/05-price control. This rewarded DNOs with relatively good performance and penalised DNOs with a relatively poor performance in losses in the last price control. This review will consider the merits of these two mechanisms as well as other alternative structures for the incentive scheme to be applied from the 2005/06-price control. Three options are set out below.

Option 1 – Adjusting the current incentive scheme

5.30. The marginal incentive currently in place can easily be modified in several ways. Firstly, the revenue adjustment per kWh can be increased or decreased to better reflect the costs of a unit lost on the distribution network. The level of incentive could be adjusted to incorporate some measure of the environmental damage associated with losses. In the longer term, as these impacts become internalised in the electricity price through the imposition of environmental taxes or trading schemes, they could be removed. Initial analysis on the costs of losses, described in appendix 3, indicates that the loss-weighted cost of 1 kWh is around 3.0-3.6p (this includes an estimate of the costs of environmental impacts of 0.5 - 1.1p). Providing a more robust estimate can be calculated, it might be appropriate to set the unit revenue adjustment at a level reflecting the loss-weighted unit cost of losses.

5.31. Secondly, the length of the period over which rewards and penalties are given can be adjusted. The incentive can be strengthened by structuring the mechanism such that the rewards and penalties are given over 20 years rather than 10, or by providing a fixed benefit rather than on a sliding scale. If the incentive was fixed for five years, it would yield approximately the same benefit to the DNOs as the current scheme. It would reduce the uncertainty and would coincide with the five-year horizon of the expenditure efficiency incentives.

5.32. Thirdly, the incentive mechanism might be changed to allow for the difference in the cost of losses at different points in time. Similarly to how line loss factors are applied, a different p/ kWh could apply to losses occurring in peak and off-peak hours and in winter and summer periods.

5.33. Finally, the benchmark used will affect the proportion of the costs and benefits of changes in losses retained by DNOs. Currently, the benchmark is based on historic performance. Alternatively, an estimate of the efficient level of losses in each area can be used as a benchmark. The move to the efficient level may be done on a stepwise basis.

Option 2 – the NGC approach

5.34. The current NGC System Operator (SO) external cost incentive scheme includes a component for transmission losses. Actual losses are measured against a benchmark level of 5.05 TWh and the difference is valued at a reference price of £18.5/MWh. The benchmark level and reference price is reviewed within the parameters of each SO external incentive scheme. The SO external cost incentive scheme, of which losses is one component, is a sliding scale or profit sharing scheme which has a target, upside and downside sharing-factors, and a cap and floor.

5.35. In the NGC Transmission Owner (TO) price control, there is no losses incentive mechanism.

5.36. It would be possible to adopt a similar approach for DNOs by setting a fixed benchmark with caps and collars and a sharing factor. The benchmark might be set at the 10-year average or at an estimate of efficient level of losses.

Option 3 – DNOs purchasing electricity to cover losses

5.37. The most intuitive approach to allocating the cost of losses to DNOs is to require that they purchase electricity to cover the losses on their own networks. This would assign the correct energy and transportation costs for losses at every half-hour and therefore provides optimal investment and operating signals to DNOs.

5.38. This scheme can be structured in several ways. The DNOs might purchase electricity directly from the generators and on the wholesale market. By forecasting losses, DNOs could cover these by combinations of contracts and wholesale purchases. This would require the businesses to establish an electricity purchasing capability. The DNOs might establish trading desks or they might assume the role of consumers and contract a supplier to deliver the necessary amount of electricity. Alternatively, a separate market could be established, for example an auction market, for DNOs to purchase electricity. This would avoid excessive balancing costs.

5.39. This approach would be combined with an allowance for efficient purchasing costs, which could be based on yardstick competition. In addition, an incentive mechanism could be retained to ensure that the DNOs face the appropriate environmental costs. However, if energy for losses had to be delivered by a supplier, then the Renewables Obligations might apply. The effect of this would be that a proportion of energy for losses had to be from renewable sources.

5.40. Although the intuitiveness of this approach is very convincing, it has some caveats. DNOs' presence in energy market might not be without problems. They might be relatively large players in the short-term market, leaving it open to manipulation. Other consequences of such a dual role of DNOs need to be examined further.

5.41. For such a scheme to work, it must be possible to forecast and measure losses with a reasonable degree of accuracy. Otherwise, the DNOs or the suppliers might face an excessive amount of balancing costs. In the last few years, there have been problems with measurement errors, but there seems to be a consensus that the more significant of these have been sorted out. It is worth bearing in mind that the measurement errors that affect the recorded level of losses also affect the numbers on which DNOs and suppliers billings are based on.

5.42. Alternatively, it might be possible to construct a proxy of purchasing losses. By measuring losses by each half-hour, an incentive scheme that reflects the half-hourly wholesale price can be put in place. This system would avoid some of the problems above and has the added benefit that losses occurring at times of high demand and thus high prices are valued accordingly. In effect, this approach is in many ways similar to the broad structure of option 1.

Views invited

5.43. Views are invited on the issues raised in this chapter and in particular on the following:

- **What is the appropriate valuation of losses? Is it appropriate to include a value for environmental impact and, if so, is the method and level used in this document the appropriate?**

- **What are the important factors in assessing the merits and demerits of alternative incentive schemes?**

- **What are the merits and demerits of an input based versus an output based incentive scheme?**

- **What are the merits and demerits of the alternative options for incentivising losses?**

- **Would it be appropriate to introduce an incentive scheme that differentiates between variable, fixed and non-technical losses? Would it be appropriate to introduce an incentive scheme that differentiates between losses occurring at different points in time?**

Appendix 1 – Summary of October briefing

1.1 This briefing was attended by Ofgem staff, an external speaker and representatives from all distribution network operators (DNOs). The topics covered at the briefing included:

- a discussion of whether losses on electricity distribution networks are currently at sub-optimal levels
- evaluating the cost of losses
- the scope for reducing losses
- possible methods of loss reduction
- the measurement difficulties posed by non-technical losses
- possible methods of redesigning the losses incentive, and
- environmental aspects of losses.

Are losses at an optimal level?

1.2 Anecdotal indicators were put forward in support of the claim that the current rate of electricity distribution losses is higher than the optimal level. These included:

- the stagnation of the overall average rate of losses since 1995/96
- that losses on British distribution networks appear to be higher than the levels recorded on networks in comparable countries
- the wide range of loss percentages reported by DNOs – between 5 and 9 per cent of units distributed
- the perceived adoption by DNOs of a minimum investment cost replacement strategy that does not take proper account of the cost of losses in investment decisions. Consequently, utilisation rates were alleged to be significantly higher than the levels that would be associated with a minimum

life cycle cost strategy that would consider the costs of operating expenditure, capital investment and losses, and

- the encouragement to concentrate on capital efficiency and security of supply that regulatory incentives provide to DNOs. These include the IIP scheme and the failure of Ofgem's consultants to sufficiently weight loss-reduction investment when setting the RAV in the price control review.

1.3 It was noted that losses are an inevitable cost legitimately incurred in the distribution of electricity across a network and that it is difficult to identify the optimal level of losses. In addition, it can be difficult to compare the performance of networks because of their different characteristics, particularly the different composition of demand across HV and LV networks. A DNO representative commented that current utilisation levels on 11kV circuits might not be much higher than the reported rates that would be associated with a minimum life cycle cost strategy. Concerns were expressed that if a greater emphasis is placed on losses, other areas, such as quality of service, might be undermined.

Evaluating the cost of losses

1.4 When assessing the cost of losses, one speaker stated that fixed losses should be valued by a time-weighted average price of electricity. However, considerable variations in unit costs mean that a demand squared weighted average price should be created to evaluate the cost of variable losses.

1.5 Distribution assets are long-lived and therefore it is necessary to estimate the likely prices and demand for the next 40 years in considering the trade-off between capital efficiency and loss reduction. It was claimed that, unless there is a paradigm shift in patterns of electricity consumption, reasonable approximations of future demand and prices could be produced. It was noted that using future values might lead to a divergence from short-term estimates of costs and benefits.

Scope to reduce losses

1.6 It was noted that the need for replacement of major parts of the network over the next 20 years offers a significant opportunity to act to reduce the rate of losses. However, there was a discussion about whether the consideration of the cost of losses was ever pivotal in DNO investment decisions, except possibly concerning marginal projects.

Methods of technical loss reduction

1.7 During the briefing, various methods of reducing technical losses on distribution networks were discussed. These included:

- the installation of low-loss transformers
- operating transformers at efficiency-maximising utilisation rates
- expanding the capacity of wires and cables on the network. This can be achieved by increasing the quantity or cross-sectional area of wires and cables. This may occur as the result of duplication carried out to improve system security of supply
- network reconfiguration. This can take various forms, such as shortening the distances between entry and exit points, reducing the number of transformation levels and taking higher voltages nearer to end users, and
- the improvement of power factors.

Measurement

1.8 It was stated that it was important for all stakeholders to adopt a consistent definition and method of measuring losses. It was noted that measurement errors should be minimised to protect the interests of legitimate customers.

1.9 It was broadly agreed that the measurement of losses became more accurate over a longer time frame. However, one DNO representative claimed that there were significant variations in the recorded loss percentage, even when measured on a monthly basis.

1.10 Because the number of units entering the network is accurately known, difficulties in measuring losses appear to be driven by errors in measuring units distributed. The sources of these errors include:

- meter under-recording. One speaker commented that this might be the consequence of a legal requirement that biases meter tolerance against over-recording
- theft, including meter tampering and illegal connections
- unmetered consumption
- the meter reading cycle. It was suggested that an incentive could be introduced to encourage remote metering for hard to access properties, and
- profiling errors.

1.11 It was asserted that DNOs have only limited influence over the magnitude of non-technical losses because the resources to tackle profiling and metering errors fall outside the control of the DNOs. Furthermore, some DNO representatives stated their belief that it was very difficult to act to reduce theft, especially in the light of new draft supply regulations under which DNOs can only object to connections to their network on safety grounds.

1.12 The extent of potential measurement errors was highlighted by the fact that Elexon is reported to tolerate a 1.5 per cent error in settlement data. Furthermore, it was argued that Elexon are reluctant to punish suppliers that provide poor quality data because suppliers are stakeholders in Elexon. Settlement errors do not appear to be diminishing and were recognised to have broader implications beyond the measurement of losses.

1.13 There was a discussion about the issue of theft of electricity from distribution networks. It was claimed that an appropriate incentive on losses would encourage the DNOs to take measures to reduce theft.

1.14 Some DNO representatives commented that it might be appropriate to return responsibility for revenue protection policy to the distribution section of Ofgem. They claimed this would increase its profile, which would help the tackling of problems building up in this area. One DNO representative also suggested that the consultation on revenue protection, which has been delayed, should be incorporated within the consultation on distribution losses.

1.15 Unmetered inventories were identified as a significant source of non-technical losses. This was claimed to be the result of the responsibility for updating inventories being assigned to customers. Audits have typically resulted in increase in registered consumption of over 10 per cent. However, the DNO has to fund the audit if the inventory is approved. Proposed solutions to improve the accuracy of registered consumption of inventories included:

- the encouragement of joint action by DNO and suppliers because both parties benefit if the audit results in an increase in registered consumption
- deeming growth in the absence of an audit, and
- differential tariffs for unaudited inventories.

Environmental aspects of losses

1.16 There were mixed views of the environmental benefits of reducing electrical distribution losses. One DNO representative stated that because the current incentive is too weak to stimulate direct efforts to reduce either GSP input or capital efficiency, loss reduction will primarily consist of measures to decrease non-technical losses. This may not be directly associated with a fall in the demand for electricity generation. One DNO representative expressed his belief that reductions in non-technical losses made the primary contribution to the decline in the loss percentage between 1990 and 1995.

1.17 There was some discussion of how resources should be allocated in order to meet government targets for reductions in the emission of carbon dioxide. While some delegates claimed that reducing distribution losses has a legitimate place in the overall strategy of reducing emissions across the electricity system, others noted that there might be more efficient methods of reducing carbon dioxide emissions from electricity generation. These include improving generator and consumer efficiency and decreasing the demand of the end user.

1.18 The view was expressed that the strength of the incentive should be linked to the energy efficiency standards placed on suppliers and other emission-reduction initiatives in order to achieve the minimum cost of carbon reduction. One DNO representative claimed that the current losses incentive is the same strength as the energy efficiency standards.

Ways forward

1.19 It was seen as crucial that Ofgem clearly sets out its objectives in reviewing the losses incentive. Two possible objectives were suggested – minimising the economic costs of losses and helping to achieve environmental targets.

1.20 It was also felt to be important that Ofgem targets the behaviour of the correct groups within the DNO framework.

1.21 It was noted that any policy should represent an improvement on the current incentive. Whilst it was acknowledged that the current incentive scheme is clear, well understood and consistent across DNOs, the following criticisms were expressed:

- uncertainties over movements in factors that drive losses make it difficult to fund investment on the basis of an expected return through the losses incentive, and
- the value of the incentive is too low.

1.22 Proposed options for redesigning the losses incentive included:

- increasing the share of benefit from loss-reduction retained by DNOs
- ensuring that marginal profit rates are the same from loss reduction as from efficiency savings in opex and capex. This may incorporate the retention of benefit from loss reduction and greater capital efficiency for a fixed period rather than just until the end of the price control period. It was noted that this approach has been considered in Australia and by Ofwat and mitigates the problem of network companies postponing investment until the start of a price control period

- giving a greater weight to high-cost loss-reduction investment within the capex allowance

- making the DNOs responsible for the purchase of the lost units of electricity. This would reflect the fact that DNOs are responsible for the transport of electricity between the GSP and the end user

- incentivising DNOs to behave as if they were purchasing losses. The DNOs are rewarded or punished according to their performance against a set threshold of losses. It was noted that this proxy option was similar to the approach used by the Central Electricity Generating Board (CEGB), which resulted in the development of networks with a rate of loss higher than current levels. However, it is unclear how accurately the bulk supply tariff used by the CEGB reflected costs

- focusing on target reductions in certain areas. This would encourage DNOs to design tariffs that contain sharper cost signals, such as a power factor levy or higher NGC charges to encourage distributed generation. However it was noted that distributed generation could be associated with increased losses and it was argued that power factor charges are not clearly identified by suppliers on their bills to customers, and

- input-based incentives. These would avoid the problems of trying to accurately measure output and reflect the fact that there is broad confidence in the methods of reducing technical losses. However, several people commented that it would be very difficult to devise a suitable and practical input-based incentive that would not discourage innovative approaches to loss reduction. In addition, the appropriate range of an input incentive is unclear – eg whether it should cover subsidies of customer equipment. Ofgem representatives expressed their views that Ofgem should avoid becoming involved in micro-regulation.

1.23 DNO representatives expressed concerns about the implications of the introduction of an incentive that made DNOs responsible for purchasing losses. The arguments put forward are outlined below.

- It would be inappropriate for short-term wholesale energy prices to drive long-term investment decisions

- DNOs would need to be able to exert greater influence on industry agreements, such as CUSC and BSC

- DNOs could distort the supply market because they would be large purchasers of electricity, and

- Significant costs will be incurred in developing the skills to participate in electricity trading. One example given was an increase in the cost of capital as a reflection of the risks involved in electricity trading. These risks include the problem that DNOs may simply be purchasing settlement errors rather than lost units.

1.24 However, it was noted that the entry of well-informed purchasers could improve liquidity in a market where current participants have not always performed strongly. There will be no change in the overall amount of electricity purchased. Furthermore, the level of risk could be reduced by the introduction of yardstick competition, which might involve the retrospective comparison of the costs of purchasing electricity.

List of Attendees

Cathie Hill	SP Transmission & Distribution
Andy Phelps	Aquila Networks
Richard Smith	Aquila Networks
Rob McDonald	Scottish & Southern Energy
Paul Eveleigh	East Midlands Electricity
Andrew Neves	East Midlands Electricity
Joe Hart	Northern Electricity Distribution/Yorkshire Electricity Distribution
Nigel Turvey	Western Power Distribution
Mike Boxall	United Utilities
Jonathan Purdy	SEEBOARD Power Networks
Matthew Hays-Stimson	Eastern Power Networks/London Power Networks
Ralph Turvey	London Business School
Richard Ramsay	Ofgem
Lars Rognlien	Ofgem
Colin Green	Ofgem
Gary Keane	Ofgem
Gail Crick	Ofgem
Min Zhu	Ofgem
John Costyn	Ofgem
John Benson	Ofgem
Sarah Samuel	Ofgem
Steve McBurney	Ofgem

Appendix 2 – Summary of responses to information request

Introduction

2.1 Below is a summary of responses by Distribution Network Operators' to an information request in November 2002. The summary is structured according to the responses to the following questions:

- Which factors drive losses on your network? In your view, what is the scope for reducing losses associated with each factor?
- To what extent does your business have the ability to control these factors?
- Could you please provide an estimated breakdown of losses into the driving factors?
- In your view, how much of what is currently recorded as losses in your price control returns are due to theft and measurement errors respectively?
- To what extent does your business consider losses when making operating and investment decisions?
- In your view, how does the losses recorded in your price control returns reflect actual losses on your network?

Summary of responses

Which factors drive losses on your network? In your view, what is the scope for reducing losses associated with each factor?

Table 1: Summary of factors driving losses

Factor	Control / scope for reduction
	Technical losses
Low loss distribution transformer	Six distributors stated that replacing old transformers with low loss transformers was an option, but that it would need to be a long-term commitment. One of these stated that it was not cost or resource reflective.
Direct 132/11kV transformation	One distributor suggested the elimination of 33kV. However, there would be a long lead-time and it would only be beneficial in urban areas.
'Oversized' cables	Seven distributors put forward the option of introducing larger cables onto the networks. One said they would install larger cables if the incentive were greater. Another estimated that increasing the cross sectional area of cables and lines could reduce losses by up to 335 GWh p.a. One said this would be expensive and would have a low impact on losses on its network. Three distributors claimed that this would conflict with the licence obligation to design an efficient network.
Primary distribution voltage	Two companies put forward the option of increasing operating voltages. One stated that a 1% increase would lead to a 2% losses reduction. The other suggested that it could replace 66kV with 132kV.
Secondary distribution voltage system – uprate 6.6kV to 11kV	One distributor estimated that uprating could reduce losses by 75 GWh p.a. Another company is already uprating its system, and this will be completed in two years.
Shorter feeding distances	One distributor said that it could move the normal system open points, although this may conflict with targets set in the information and incentives programme.
Manage load	Four distributors suggested managing load could help reduce losses. One of these suggested reducing the lighting load by providing low energy light bulbs. However, this can create problems with harmonic currents. Two distributors suggested that encouraging customers to use electricity more wisely and encouraging power factor improvement could have a great effect on losses.
Connect fewer	Two distributors suggested that this could be beneficial in terms of

Factor	Control / scope for reduction
	Technical losses
customers to each cable/line	reducing losses. One said this would be achievable, particularly in rural areas, where another option would be to install additional primary substations.
Distributed Generation	Two companies suggested identifying zones where distributed generation would impact on losses.
Outages	One distributor said that it could reduce outage durations or alter their timing. It also suggested de-energising transformers during certain outages.
HV customer base	One distributor stated that the relative number of HV customers compared to LV customers would affect the level of losses, as eg HV/LV transformers are not used in delivering electricity to HV customers.

Factor	Control / scope for reduction
	Non-technical losses
Replace induction disc meters	One distributor estimated that this could reduce non-technical losses by 23 GWh p.a.
Registration issues	A problem identified by one distributor was that the number of customers not included in settlements has increased. However, new distributions licences and competition in connections should help.
Illegal abstraction	Three distributors suggested that revenue protection could help prevent and detect theft. Two said that this be viewed as more generic, covering a broad range of activities that ensure the electricity used by customers is correctly accounted for and entered into the settlement process.

To what extent does your business have the ability to control these factors?

2.2 There were five direct responses to this question. All felt that current characteristics of the network, and historic investment decisions are outside the control of distributors, but they have more control over future investment. They have little control over theft.

2.3 One company pointed out that on overhead systems additional losses occur from imbalance within transformers. In some cases rebalancing the system may be more cost effective than lower loss transformers.

Can you please provide an estimated breakdown of losses into the driving factors?

Table 2: Breakdown of losses (in per cent of total losses)

Company	A			B			C			D		
Losses	**Fix**	**Var**	**Tot**	**Fix**	**Var**	**Tot**	**Fix**	**Var**	**Tot**	**Fix**	**Var**	**Tot**
132kV network	1	8	9	1	8	9						
132/ 33kV transformers	4	4	8	6	4	10						
33kV network	1	10	12	0	6	6						
33/ 11 & 6.6kV transformers	4	4	8	5	4	8						
11kV network	1	18	19	0	10	10						
11&6.6kV/ LV transformers	10	6	16	18	6	24						
LV circuits & Services	3	23	26	0	31	31						
Meters & T-Sw's				3		3						
Total technical losses	**23**	**73**	**97**	**33**	**68**	**100**	**24**	**67**	**91**	**> 35**	**> 55**	**> 80**
Non-technical losses			*3*						*9*			*< 20**

- Non-technical losses reported as being considerably less than 20 per cent

In your view, how much of what is currently recorded as losses in your price control returns are due to theft and measurement errors respectively?

2.4 Most companies stated that it was difficult to quantify the proportion of losses due to theft. Three companies were of the opinion that theft accounted for only a small part of total losses, ranging from 0.2 to 1.5 per cent of units supplied.

2.5 Most distributors said that also measurement errors are difficult to quantify. One distributor pointed out that measurement errors can be either positive or negative, and different types of error might tend to net-off (e.g. faulty and 'slow running' meters counterbalanced by 'fast running' meters and excessive EACs / AAs[7]).

2.6 Four distributors pointed out that as old meters are replaced with new electromechanical meters, metering inaccuracies should reduce.

2.7 Two companies said that measurement errors accounted for only a small proportion of total losses. One of these said that a worst case would be an underregistration of 0.5 per cent of units supplied.

[7] Estimated Average Consumption/ Annualised Averages.

2.8 One company noted the reliance on suppliers and the settlement processes for the data that forms the basis of both the DUoS billing and the regulatory returns.

To what extent does your business consider losses when making operating and investment decisions?

2.9 Nine distributors stated that they did consider losses and low loss options when making investment decisions. The other five said that considering losses in modern investments is not viable.

2.10 Seven distributors stated that ‘low loss’ options are generally not justifiable in the current regulatory regime and that the current incentive is too small. Five stated that there might be conflicts in interest with the IIP security of supply incentives. For example, transformers will be kept energised to maintain security of supply, when they may otherwise have been switched off to reduce losses.

2.11 Three distributors have a strategy for deciding which equipment should be installed. One company said that generally ‘low loss’ options were unjustifiable following this strategy.

2.12 Four distributors work with performance parameters that provide cost-effective options, taking into account the loss incentive. This analysis determines the unit with the lowest overall cost, which does not usually favour low loss equipment. However, the analyses of three of these appear to be flawed. Two other distributors stated that they currently specify transformers for use at distribution voltages whose losses performance is broadly in the middle of the range that is available.

In your view, how does the losses recorded in your price control returns reflect actual losses on your network.

2.13 One company stated that losses recorded in price control returns reflect actual losses on the network quite accurately while three distributors stressed that every effort is made to ensure a realistic estimate of actual system losses is reflected in the price control returns.

2.14 One company said that the losses stated in 1999/00 and 2000/01 price control returns were a best estimate of actual system losses, and were not calculated as GSP Units less Actual Billed Units.

2.15 Two distributors said they were unable to accurately quantify the difference between recorded losses and actual network losses.

2.16 Two distributors stated that inaccuracies in the data at final reconciliation as a result of non-technical errors are primarily a consequence of problems with the stage two settlement process and are thus outside the control of distributors.

2.17 One company commented that the calculation of losses is inevitably an imprecise exercise, given the reliance on infrequent meter readings from most sites, and the lack of any metering at many smaller sites.

Appendix 3 – Analysis of cost of losses

Introduction

3.1 The smearing across all suppliers of the cost of electricity lost on the distribution networks creates an externality specific to the issue of electricity distribution losses. Furthermore, the wholesale price of electricity does not internalise the value of environmental damage from generation. These two externalities are likely to produce a sub-optimal level of losses because the full cost of the lost units is not faced by those parties whose actions primarily determine the rate of losses.

3.2 A reduction in non-technical losses will represent a reallocation of, rather than a reduction in, electricity consumption. Instead of a direct improvement in social welfare, a redistribution of benefit will occur from those agents whose consumption has been identified to suppliers and general consumers. However, if consumed units of electricity are correctly allocated, cost signals should encourage a more efficient level of demand for electricity.

3.3 One DNO has provided Ofgem with half-hourly data for their network. The information includes the number of units purchased at the GSP and the number of units distributed at HV and LV levels. This has been analysed in combination with wholesale price data to produce preliminary estimates of the cost of losses. Because data has been provided by only one DNO, it should be noted that these estimates might not be robust across all distribution networks in Great Britain.

Impact of losses

3.4 Although suppliers and their customers bear the generation and transportation costs of the lost units of electricity, they have little scope or incentive to reduce the rate of losses. It would be efficient for the costs of losses to be allocated to those parties that can exert significant control over the main factors that affect the magnitude of losses.

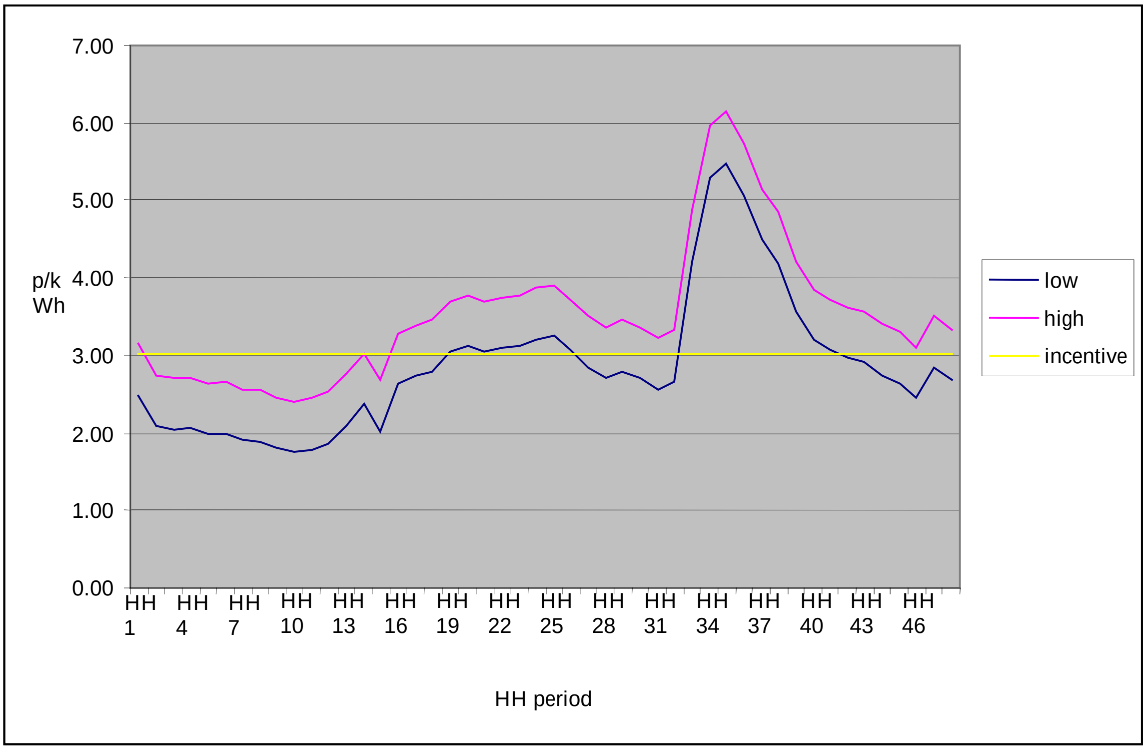
3.5 Most of the environmental damage from electricity losses is caused by the production of emissions, particularly CO_2, during the generation process. The value of this environmental damage is not internalised in the wholesale price of electricity.

3.6 The generation of the units lost on the distribution networks is responsible for approximately 3 percent of all UK CO_2 emissions. A fall in aggregate transmission and distribution losses from 9 to 8 per cent would represent 4 per cent of the reduction in CO_2 emissions that the UK is committed to under the Kyoto protocol.

Profile of cost of losses

3.7 The current incentive sets a fixed value for losses of 3.03p/kWh (2001/02 prices). However, the generation, transportation and environmental costs of losses are all significantly larger at peak load when the rate of losses is at its highest. Hence, it may be inappropriate to impose an incentive mechanism that provides a fixed benefit per kWh in all time periods.

Figure 1 – HH profile of average unit cost of losses



3.8 Figure 1 displays an estimated profile of the unit cost of losses. The methodology employed is outlined below. The low estimate uses the lowest value in the environmental cost range and the high estimate uses the top figure in the range.

Wholesale cost of lost electricity

3.9 There are 17520 different half-hourly wholesale prices throughout the year. A simple time-weighted average price[8] will typically underestimate the value of losses because the price of electricity and the rate of loss both increase with load. A preliminary estimate of the loss-weighted[9] average wholesale price is 1.79p/kWh.

Transmission and distribution costs

3.10 NGC transmission charges for demand customers consist of an energy consumption tariff and a demand tariff, which are levied on non half-hourly metered units and half-hourly metered units respectively. The energy consumption tariff is designed to recover the same amount of revenue as if the demand tariff was also applied to non half-hourly metered customers. Consequently, an estimation of the overall transportation cost of losses can be produced using only the demand tariff.

3.11 It is unclear what is the best approach to allocate the overall transportation costs in order to create a half-hourly profile. Smearing the transportation costs across all units lost in the period covered by the energy consumption tariff (1600-1900) reflects the fact that network capacity is designed to be sufficient to carry peak loads. The rate of losses at peak load is significantly greater than the average loss percentage. This produces an initial estimate of 1.08p/kWh, which is built into Fig.1. If the costs are divided across all lost units, a preliminary estimate of transportation unit cost is 0.15p/kWh.

3.12 It is difficult to produce a robust quantitative estimate of the distribution costs of losses because DUoS charges are differentiated by customer size, voltage level, time of day and time of year. Even if it is assumed that distribution charges provide a suitable proxy for the distribution cost of a lost unit, the accuracy of estimation is limited by the fact that some losses occur independently of load and therefore cannot be linked to demand. An analysis of half-hourly data

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[8] A time-weighted average unit cost is the mean of the unit cost in each half-hour.
[9] A loss-weighted average unit cost is calculated by multiplying losses by unit cost for each half-hour. The aggregate cost is then divided by the total number of lost units to produce a loss-weighted average unit cost.

produced an initial estimate of overall distribution unit cost of 0.56p/kWh. This can be broken down into figures of 0.66p/kWh for losses on LV networks and 0.26p/kWh for losses on HV networks.

Environmental costs

3.13 The most important environmental impact is the emissions of carbon dioxide (CO_2) associated with the generation of lost energy. There are other environmental impacts but they are less significant and are not evaluated here. The loss-weighted average emission rate for generation will be greater than the demand-weighted average emission rate because peak load plants, typically coal or oil-fired, have a higher rate of CO_2 emission than baseline plants.

3.14 Preliminary estimates suggest that the emissions associated with the generation of lost electricity is between 57 and 138 grams per kWh with the value of damage per kWh increasing with load. If a cost of carbon of £81/tC is used (the expected allowance price in the EU emissions trading scheme,[10] which generators will participate in from 2008 at the latest) this suggests an environmental cost of between 0.46p/kWh and 1.12p/kWh.

Overall cost of losses

3.15 The real value of the current losses incentive was fixed at 2.9p/kWh (1999/2000 prices). This figure produces a valuation of aggregate losses of nearly £600m.

3.16 This figure compares to the preliminary Ofgem estimates of an overall average unit cost of losses of 2.96-3.62p/kWh, which values overall losses at between £600m and £725m.

Incentive Structure

3.17 Because the rate, cost and environmental impact of electricity distribution losses all increase with load, there may be a case for an incentive mechanism that tracks wholesale prices, which are readily available. Alternatively, there could

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[10] Capros, P. and L. Mantzos, Institute of Communication and Computer Systems of National Technical University of Athens, 'The Economic Effects of EU-Wide Industry-Level Emissions Trading to Reduce Greenhouse Gases, Results from the PRIMES Energy Systems Model'. May 2000.

be a cruder method of setting an incentive that differs across time bands. For example, these bands could be designed to match the periods covered by line loss factors.