Incentives to improve energy efficiency in EU Grids
Incentives to improve energy efficiency in EU Grids

Subtitle

By: Dr. Georgios Papaefthymiou, Christina Beestermöller and Ann Gardiner
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1 Introduction

The Energy Efficiency Directive (2012/27/EU) includes provisions related to network tariffs and regulation. It is timely therefore to revisit the potential options for energy efficiency in grids, the treatment of energy efficiency in network tariffs and alternative policies for improving energy efficiency. This project builds on work done previously for the European Copper Institute in this area [KEMA09a].

In this paper, we concentrate on energy efficiency in electricity network design and operation. Other articles in the Directive relate to the role of the network tariffs and regulations in enabling or incentivising the provision of energy efficiency to end users.

The most important Articles for energy efficiencies in networks are:

- **Article 15(1)** For electricity, Member States shall ensure that network regulation and network tariffs fulfil the criteria in Annex XI, taking into account guidelines and codes developed pursuant to Regulation (EC) No 714/2009.

- **Annex XI 1.** Network tariffs shall be cost-reflective of cost-savings in networks achieved from demand-side and demand-response measures and distributed generation, including savings from lowering the cost of delivery or of network investments and a more optimal operation of the network.

- **Art 15.2b** Member States shall ensure, by 30 June 2015, that concrete measures and investments are identified for the introduction of cost-effective energy efficiency improvements in the network infrastructure, with a timetable for their introduction.

- **Article 15.4** Member States shall ensure the removal of those incentives in transmission and distribution tariffs that are detrimental to the overall efficiency (including energy efficiency) of the generation, transmission, distribution and supply of electricity or those that might hamper participation of demand response, in balancing markets and ancillary services procurement. Member States shall ensure the network operators are incentivised to improve efficiency in infrastructure design and operation, and, within the framework of Directive 2009/72/EC, that tariffs allow suppliers to improve consumer participation in system efficiency, including demand response, depending on national circumstances.

In the next section, we describe technical efficiency measures to reduce losses (improve energy efficiency) in the grid. Section 3 reviews grid tariffs in three countries to identify whether they provide incentives or disincentives for energy efficiency in the grid. Section 4 discusses and evaluates alternative regulations for energy efficiency in grids. Section 5 concludes and discusses the main components of the optimal policy framework.
2 Technical energy efficiency measures in grids

2.1 Network losses: General

Network losses are defined as the amount of electrical energy that is consumed by a power system for the transmission of electricity from generation to consumption. Network losses can be divided into 
technical losses, which refer to energy transformed to heat and noise during the transmission and therefore physically lost, and non-technical losses, which refer to energy delivered and consumed, but for some reason not recorded as sales.

In general technical losses can be split into [KEMA09a]:

- Variable losses (also referred to as load or copper losses), which occur mainly in lines and cables and also in the copper in transformers. They vary in proportion to the square of the current and to the conductor resistance. In general, variable losses contribute roughly to two thirds to three quarters of the total power system technical losses.

- Fixed losses (also referred to as non-load or iron losses), which occur mainly in transformer cores for as long as the transformer is energised. They are invariant with current, and in general contribute to roughly one quarter to one third of the total network losses.

- Corona losses, which occur in high voltage lines. They vary with the voltage level and the physical wire diameter and with weather conditions such as rain and fog.

Technical network losses depend on factors such as network design, operation, and maintenance and may vary significantly between systems. Below we present some key information on network losses:

- Losses in distribution networks are generally higher than in transmission grids. For example in EU Member States, the average losses in transmission networks are between 1% and 2.6% while in distribution networks they are between 2.3% and 11.8% [ERGEG08]. As discussed above, the range of these values is due to the specifics of the power system of each country.

- Losses in Transformers: Transformers are the system components presenting both fixed and variable losses. Typically, a third of the total system technical losses occur in transformers [LEO2005] while fixed losses account for about two thirds of total transformer losses. Although transformers reach high levels of maximum efficiency (97.5-99.4% at 40-50% loading), their operational efficiency is smaller since they do not operate at maximum efficiency all of the time. On average, the efficiency of distribution transformers operating in Europe is 98.38% [SEEDT08]. Such losses over the lifetime of the asset (approx. 40 years) represent a significant sum.

- Variable losses: marginal vs average values. Since variable losses vary with the square of the current, marginal losses contribute more to variable losses than average values. Therefore, losses increase disproportionally when the system loading is higher, which is actually when
they are least affordable. When system loading is high there is usually a correlation with higher power prices. In addition, there is the risk that available generation resources that could meet high load levels alone would not be sufficient to meet both load and the disproportionately high marginal losses. In this respect, efficiency measures that help reduce the marginal loading of the system would have a higher contribution to the reduction of system losses [RAP11]. On the other hand, increasing line capacities leads to a reduction of the currents and subsequently a reduction of network losses. This however means lower utilisation rates of the assets. Thus, the strategy of increasing the utilisation of the network’s capacity (lower investment in new assets) has an adverse impact on losses, since it translates into higher loading levels of the assets. Consequently, there is a trade-off between the cost of financing surplus capacity and the cost of losses [OFGEM03].

- **Role of losses on lifetime operational costs**: As mentioned, the higher the loading of system components, the higher their variable losses, thus a trade-off between load and losses should be made for investment decisions. Losses constitute a major component of the lifetime operational costs of the asset and can steer decision making when included in investment analysis (Lifecycle costing – LCC). In the case of transformers, including the cost of losses in investment analysis shows that the purchase of energy efficient equipment could be optimal decision regardless of the higher initial capital costs [OFGEM03]. In distribution network design, the inclusion of the cost of losses leads to much lower utilisation rates of the assets (thus higher installed capacities) in contrast to the practice of using the assets as much as possible to increase capital efficiency [CUR2001].

- **Role of DG and RES on system losses**: the potential of distributed generation (DG) and renewable energy sources (RES) in reducing network losses has been repeatedly discussed in related literature [OCHOA11]. The general idea is that locating generation closer to demand could reduce distribution losses as the distance over which electricity is transported is shortened and the number of voltage transformation levels is reduced. However, this is only true when the energy generated by DG and RES units is consumed locally. In reality, in liberalised environments, their dispatching (fixed or stochastic infeeds) can lead to increased network flows (and thus losses), often translated into reverse flows from distribution networks to transmission systems. In addition, there is an issue with reactive losses discussed below.

- **Reactive losses**: the transmission of reactive power to support system voltages induces reactive currents which increase network losses. Local reactive power compensation is the most widely accepted means for supporting voltages and reducing reactive losses in distribution networks. In passive distribution networks (comprising of loads), the placement of capacitors for local injection of reactive power is the state of the art solution for voltage support [BAR1989], which leads to reduced reactive currents in the system. In active distribution networks (comprising of loads and DG), DG units are often also responsible for voltage control. Where there is high penetration of variable distributed generation, this
voltage support action can translate into additional reactive power and thus increase reactive power losses in the network.

2.2 Technical measures for the reduction of network losses

Taking into account these main issues regarding network losses, different technical measures could be employed. Strategies for minimisation of network losses can be classified into two main categories: 1) equipment replacement solutions and 2) Network architecture or management.

2.2.1 Equipment replacement solutions

1. **Installation of energy efficient transformers**
   The lifetime of transformers is typically around 40 years. In many cases however, assets are still operational beyond this point, but with significantly lower efficiency levels. The efficiency potential analysis for European transformers presented in the SEEDT project [SEEDT08] showed that 10% of the oldest transformers are responsible for 21.5% of the total transformer fixed losses and 15.2% of the variable losses. In replacing these assets, the choice of more expensive energy efficient transformers could be the optimal investment decision taking into account the cost of losses in a full LCC analysis. As replacing transformers is easier than changing cables or lines, this option presents a good loss reduction potential. For this to be realised, it is important to have regulation that takes into account reduced power losses over the equipment lifetime instead of just capital costs.

2. **Expanding the capacity of network lines**
   Variable losses are decreased by increasing the cross sectional area of lines and cables. As discussed above, if the cost of losses is taken into account, the optimal average utilisation rates for lines and cables in a network could be significantly lower than if the cost of losses is not considered. Large-scale replacement of network lines is however difficult to implement.

3. **Increase the system voltage levels**
   At higher voltages a lower current is required to distribute the same amount of electricity; moving to higher voltages will therefore reduce utilisation and losses on the networks. To implement this solution though the network would have to be totally re-designed and most components replaced.

2.2.2 Network architecture and management solutions

1. **Reduction of fixed losses**
   Fixed losses can be reduced without replacing equipment by reducing the number of energised transformers in the system. This can be achieved by eliminating transformation steps or by switching off transformers. Elimination of transformation steps could be achieved by direct coupling of higher voltage levels to lower ones without the use of intermediate transformers. Switching off transformers could be possible in periods of low demand for configurations where multiple transformers are required in a substation for peak load.
2 Network reconfiguration (more direct connections)
Often the configuration of the network has an effect on losses in terms of the distance the electricity is transported. 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 shorter, more direct lines to where demand is situated currently.

3 Demand Side Management
As discussed, variable losses are higher during peak network loading. In passive networks (only loads), peak demand reduction based on time-tariff structures leads to a reduction of the power flows in the system and thus to an over-proportional reduction in system losses. However, in active networks (loads and DG/RES) system losses follow the system net load (load minus generation). Therefore, for loss reduction the system demand should be able to adapt to dynamic price operational signals. For this, enabling communication and control infrastructure should be in place (SmartGrids).

4 DG and RES
As discussed, in liberalised environments the location of DG and RES units (possibly far from load centres) and their dispatching (fixed or stochastic infeeds) can lead to increased network flows (and thus losses). To enable reduction of network losses, DG and RES units could be operated based on an overall network loss minimisation objective. The controllability of RES units could be enhanced by including energy storage in the network. Therefore, for loss reduction the DG/RES units should be able to adapt to dynamic price operational signals. For this, enabling communication and control infrastructure should be in place (SmartGrids).

The approach to increase the flexible dispatch and control of DG and RES units should be balanced with considerations of the overall system benefits of network expansion (see point 2, section 2.2.1) and network reconfiguration (see point 2, this section). Network expansion/reconfiguration has a high capital cost and challenges of implementation in an energised electrical system. However, the additional costs for enhanced communication and control of DG and RES units is significant as well. From a practical point of view, implementing the enhancements to DG and RES units involves many more asset owners and varied technologies than carrying out network expansion/reconfiguration. A whole systems benefit analysis is needed over a defined geographic area to reach the optimal result.

5 Operating transformers at efficiency maximising utilisation rates
Transformers are often not optimally loaded, e.g. in EU-27 the average loading of distribution transformers in electricity distribution companies is 18.9% [SEEDT08]. In many cases this is due to excessive number of transformers either for system redundancy or because users avoid high loading of transformers that are in poor technical condition. By actively managing the loading of the transformers (e.g. switching off redundant ones) the operational efficiency can be significantly increased.
6  Reactive power management
Reactive power management aims to reduce the reactive current in the network. As discussed, in traditional networks this is achieved by injecting reactive power by capacitor placement. Another way to reduce reactive power requirements is to provide incentives to customers to improve their power factors. However, as mentioned, local generation (DG and RES) can lead to increased reactive losses.

7  Network reconfiguration (operational)
Distribution networks can be designed so as to allow changing network configurations by employing specific switches in the system. In this case, circuit state optimisation can be used to minimise network losses for each operational snapshot [NIP2007].

8  Power flow controllers
Controlling the system network flows can lead to a reduction of the system losses. For this, power flow control devices could be used with a control objective to minimise network losses.

9  Balancing three-phase loads
Balancing three-phase loads periodically throughout a network can reduce losses significantly.

2.3  Conclusion

As presented, the technical measures for the minimisation of network losses can be classified into two main categories,

-  *equipment replacement solutions* proposing focusing on the use of more efficient equipment or on dimensioning the network with target on increasing its efficiency and
-  *network architecture or management solutions*, focusing on establishing operational modes and network structures that promote the network efficiency.

For the transition to more efficient grids, both categories of solutions should be promoted. The first category of solutions forms a first step for network efficiency, especially taking into account networks where a large number of aged and inefficient assets are still operable. In parallel, to optimise the use of the current assets, efficiency should be a target for the system operation and design. However, to fully uncap the potential of operational measures, the controllability of networks should be increased (transition to Smartgrids). For this, a transformation of the system is needed by the installation of enabling communication and control infrastructure.
3  Disincentives and incentives in grid tariffs

3.1  Introduction

In this section, we review the grid tariff regulations in three countries (Germany, UK, and Spain) against the objectives of the EED. There are two main relevant elements in the tariff regulations:
- the way the tariff is calculated, which determines the amount that can be charged to the consumer; and
- whether there is an incentive regulation for minimising costs.
Either of these elements may act as an incentive or disincentive.

The regulations are reviewed in the context of providing incentives for increases in energy efficiency (reduction in losses) in the distribution and transmission networks. Other requirements relevant to network regulation in the EED are outside the scope of the analysis.

In essence, the main considerations for energy efficiency are:
- Can capital costs of investments in energy efficient solutions be recovered by the DSO/TSO?
- Is there an incentive to invest specifically in reducing network losses? Businesses such as DSOs and TSOs have limited capital. If there is such an incentive either explicitly or in the way operating costs are treated and capital costs are recovered then it is more likely that capital will be invested in grid energy efficiency than if no incentive exists.

3.2  Germany

Regulatory Setting
The regulatory scheme in Germany includes the two components where energy efficiency is taken into account, the tariff structure and the Incentive Regulation. Grid tariffs for both distribution and transmission grid operators are calculated by the grid operators and need to be approved centrally by the Regulatory Agency. The Grid Tariff Regulation (StromNEV) specifies the calculation method for the tariffs. Since 2009, the German Incentive Regulation has set a revenue-cap for grid operators taking into account an increasing cost-efficiency factor.

Calculation Method of Grid Tariffs
According to § 17 StromNEV the tariffs are calculated on the basis of all relevant operation costs of transmission and distribution. Costs for purchasing energy to make up losses can be regarded as relevant grid operation costs and are, thus, taken into account when calculating the tariffs (§ 10 StromNEV). As a consequence, grid operators can transfer these costs directly to the consumers and do not face any incentive to minimize the losses.
### Treatment of Losses in the Incentive Regulation

The Incentive Regulation was established in 2009 and sets revenue-caps to the grid operators on a yearly basis. The costs that are relevant for setting the revenue and cost-efficiency targets are calculated every five years. For this, grid operators have to report to the regulator about all kinds of costs for transmission and distribution operation. These costs are classified into ones that the system operators can influence and ones which they cannot and are included in the calculation in different manners. According to a decision of the Regulatory Agency, costs for purchasing energy to make up losses are regarded as volatile cost components and belong to the category of costs they cannot influence ([BNETZA09]), Eckpunktepapier BNetzA, 27.6.2012). Further, they are not treated with an increasing cost-efficiency factor within the regulation. The relevant formula for the revenue cap is the following:

\[
EO_t = KA_{dnb,t} + (KA_{vnb,0} + (1 - V_t) * KA_{b,0}) * \left(\frac{VPI_t}{VPI_0} - PF_t\right) * EF_t + Q_t + (VK_t - VK_0) + S_t
\]

where EO is the revenue cap and VK denotes the volatile costs. As it can be seen in the formula, higher losses (i.e. higher volatile costs VK) translate into a higher revenue cap.

For distribution grid operators, costs for losses can be calculated and benchmarked every year [BNETZA10]. However, the benchmark is only intended to increase cost-efficiency and to provide incentives for grid operators to purchase energy to make up for losses in a cost-efficient way. Thus, technical efficiency in grids is not incentivised. The amount of losses is a fixed component for distribution grid operators without a yearly adjustment and there is no incentive to reduce the total amount. Therefore, this does not give the distribution grid operators any incentive to increase technical transmission or distribution efficiency. As a consequence there are no incentives to invest in a more efficient grid infrastructure.

To further develop the treatment of losses the German regulator has indicated recently that costs for energy losses will be fixed by the regulator from the next regulatory period on [BNETZA12]. Further details on this approach are not yet available, however there is an indication that energy losses will gain importance and attention among the market participants, initiating changes to the German regulatory mechanism.

### Treatment of operational and capital costs

With the revenue-cap and the implemented cost-efficiency factors, grid operators are incentivised to minimise their general operational costs. One way to do this could be investing in efficient (but more expensive) grid infrastructure. However, since the allowed amount of losses is a fixed number (for distribution grid operators) that is not adjusted on a yearly basis, there is no specific incentive for the grid operator to invest in efforts to increase technical efficiency. Transmission grid operators do not have incentives to minimise losses either, since they could reach a higher revenue cap with higher cost for grid losses.

Capital costs are reported to the regulator once every regulatory period and grid operators are not compensated for any costs exceeding those reported. Remuneration for any supplementary or special investments can be solicited from regulator as a further procedure. Therefore it is not certain whether
such capital costs are remunerated. This structure may provide a disincentive in investing in more efficient but also more expensive equipment.

**Conclusion**
The treatment of energy losses within the regulatory setting in Germany does not create any incentives to improve infrastructure design and operation to increase energy efficiency. The current design could be argued to be detrimental to energy efficiency. However, it has been signalled that there will be a change which could increase the importance of energy efficiency in the regulatory treatment. The actual outcome of this remains to be seen.

### 3.3 UK

**Regulatory Setting**
The UK has regulated the field of electricity (and gas) distribution and transmission with a price cap regulation. From 2013 (for distribution from 2015), the RIIO-mechanism (Revenue = Incentives + Innovation + Outputs) will be implemented, which developed from the current scheme. It prolongs the regulatory periods from five to eight years, after which a new price development is calculated. The mechanism should incentivise companies to develop and submit reasonable business plans and focuses on different aspects of transmission and distribution operation like innovations or environmental issues. Related to grid tariffs the Balancing Service Incentive Scheme (BSIS) is established which sets the methodology for calculating grid tariffs.

**Calculation Method of Grid Tariffs**
The charge grid users have to pay to the grid operator is part of the balancing use of system (BUoS) charge [NATIONALGRID10]. BSIS is a proportion of the BUoS charge and comprises internal and external costs. Internal costs are administration and staff expenditures whereas external costs are incurred when operating the system and are referred to as the Incentivised Balancing Costs (IBC). Grid operators have a target concerning the amount of internal and external costs (BSIS) as well as the amount of IBC. The IBC include a component that adjusts the BSIS incentive target if transmission losses are below or above the agreed target. Namely, the target costs are reduced when losses are below the target and increased when losses are above the target. The loss volume is converted into cost by applying a reference price. The current target that National Grid developed together with Ofgem for the period 2011-2013 is 8,9 TWh +/- 0,6 TWh [OFGEM11a]. With this, a clear incentive for a loss reduction is not set. Distribution Use of System Charges are calculated by applying the Common Distribution Charging Methodology (CDCM) which is approved by OFGEM. This methodology also implies a cost component for losses but does not incentivise grid operators for a loss reduction [ENA10].

**Treatment of Losses in the price-control scheme**
For transmission system operators, new incentives within the RIIO-mechanism have been developed: the output-component of the RIIO-mechanism is classified in seven different categories [OFGEM12b]. The category “environmental” comprises the aspect of transmission losses and sets incentives by
publishing the overall strategy for transmission losses and annual progress in implementation and impact of transmission losses. This includes a reputational incentive for transmission loss reduction. However, it does not imply any financial incentives for a loss reduction.

Distribution losses are calculated by OFGEM as an allowed loss percentage on an annual basis for each distribution company. Distribution system operators are receiving a reward or penalty based on the performance against the target [OFGEM12a]. In 2009 the financial incentive for the reduction of transmission losses has been 5p/kWh [SOHNASSOCIATES09].

**Treatment of operational and capital costs**

The regulation of both transmission and distribution system operators is designed with a certain amount of allowed capital and operational costs for each company [OFGEM12a+b]. For transmission grid operators the allowed cost of capital within RIIO will vary over the period (2013-2021), which is a new design aspect compared to the previous mechanism. Furthermore, the new design provides project specific funding for electricity transmission infrastructure [OFGEM12b]. With this, it might also be possible to implement a specific funding on loss reduction but no further information on it is available at the moment.

Operational costs of distribution grid operators are defined by the performance of their business operations and maintaining their network. Capital costs are expenditure on investment in distribution assets with a long lifetime, such as underground cables, overhead electricity lines and substations. As a consequence, DSOs are remunerated for investments in efficient grid infrastructure as long as they are part of their forecasts in the business plans and at the same time they are incentivised to minimise operational costs. This design is an effective and efficient combination of output- and input-based components to achieve loss reductions as it also takes into account the lifetime operational costs.

**Conclusion**

The overall regulatory design of the UK does have incentives for loss reductions. The incentive for transmission grid operators is a reputational and not a financial incentive, which could also create pressure and promote action. For distribution grid operators, incentives are clearly stronger as the regulatory authority calculates allowed loss percentages annually. DSOs are penalised or rewarded based on their performance in losses. Thus, they have strong financial incentives to improve in distribution efficiency. At the same time, they are rewarded for their announced capital costs and incentivised to minimise operational costs. This represents a combination of input- and output- based regulatory scheme.

### 3.4 Spain

**Regulatory Setting**

Spanish grid operators are regulated through a revenue-cap in four-year regulatory intervals. The allowed revenue for grid operators depends on operational and maintenance costs and further cost components are differentiated between distribution and transmission grid operators [EDP12]. The
network tariffs but also the end-consumers’ last resort tariffs are regulated and centrally calculated on an annual basis.

**Calculation of grid tariffs**
The current tariff structure and the methodology for calculating the reference or average tariffs are established in the Royal Decree 1432/2002 [EDP12]. The tariffs include cost components of the whole production chain like generation, transmission and distribution costs but also permanent system costs and tariff deficit and extra-peninsular costs. However, the tariffs are set based on the revenues needed to satisfy business activities of the market participants, considering the forecasted electricity consumption. Transmission and distribution losses are not considered in the tariffs as the grid operators are not allowed to purchase energy to compensate losses. They are separately recovered in the energy market and charged proportionally to the demand.

**Treatment of Losses in the Revenue Caps**
Remuneration of transmission grid operators is updated annually based on RPI-X (Retail-Price Index, including an efficiency factor X that represents the required development in cost-efficiency) and includes remuneration for operating and new instalments [EDP12]. In 2008, a new remuneration framework was established to support the implementation of the Infrastructure Plan. As pointed out above, the costs for transmission losses are recovered by the energy market which implies that the TSO has no incentives to minimise losses. The distribution grid operators’ remuneration explicitly takes a component on losses into account and sets incentives for loss reduction. The loss incentive scheme applies a formula that includes a loss target for each company. Depending on the actual performance of the company a price can be calculated which goes into the revenue calculation and is capped at -/+1 % of the allowed revenue [KEMA09b]. As a consequence, when calculating this price according to their loss-performance they must not deviate from the allowed revenue by more than 1 %.

**Treatment of operational and capital costs**
The regulatory scheme in Spain accounts for an operational cost component and incentivises grid operators to minimise operational cost. The remuneration of transmission grid operators also takes into account new instalments. In addition to an income corresponding to asset depreciation, new transmission assets are remunerated with an interest rate that is aligned with 10-year State Bonds plus 3.75 % . The second component of their remuneration is operational and maintenance costs. Their treatment is based on unitary standard costs including operation and maintenance costs and is fixed by the regulator. As a consequence, they are not incentivised to minimise their capital costs, but their operational costs. In the regulatory design for distribution grid operators capital cost is not explicitly accounted for although their remuneration also depends on investment costs. Presumably, they have to be approved by the regulator and, thus, during the regulatory period they are not incentivised to minimise costs.

**Conclusion**
The Spanish design of dealing with energy losses is partly incentivised. Transmission grid operators are not encouraged to reduce transmission losses since they are not allowed to purchase energy. At
the same time distribution grid operators are faced with real financial incentives for a loss reduction. Thus, the Spanish system could be extended to stronger and more precise incentives on the transmission level. Although losses decrease with a higher voltage level they increase with higher distances (that are usually covered by transmission lines). It can be concluded, that there is already a good design implemented, but it can also be extended to further increase efficiency aspects. Overall it is very similar to the British design with a slight difference regarding the individual target losses. Where in the UK companies are either rewarded or penalised when they exceed or do not meet their targets, in Spain operational performance can be reflected in calculating a price which is capped at a deviation of 1% of the allowed revenue.

3.5 Conclusions

Both the UK and Spanish tariff schemes do include an incentive for loss reduction and the regulator in Germany has signalled that they will implement such an incentive in the future. There is a reputational driver for loss reduction in the transmission system in the UK but no incentive in Spain. In both Spain and UK, distribution system operators are faced with clear financial incentives to reduce distribution losses. The UK regulation includes a combination of input and output measures. A full assessment of the effectiveness of the incentives in these policies for energy efficiency improvements is beyond the scope of this project but there are clearly incentives included as well as lessons for other countries.
4 Alternative regulations for an energy efficient grid

4.1 Methodology and overview

As discussed above, there are examples of regulations in several countries that provide incentives for energy efficiency in grids. These incentives are provided mainly through the existing grid tariff structure and incentive regulations. The analysis of technical measures showed however that there are trade-offs between incentives to reduce losses and to increase the capital efficiency of the assets, be it the installation of more expensive energy efficient transformers or extra lines to optimise utilisation rates. In other industries, different policy options are used to bring about energy efficiency improvements. Such options are reviewed in this section against a set of criteria used to point out advantages and disadvantages. As discussed in Chapter 2, there are many technical measures available to reduce losses in the grid including both equipment replacement and operational measures. Some of the policy options discussed below can apply to both types of measures while others to only one. Here we present a high-level review of the basic options; further details of the specific policy design are very important in determining the real effectiveness and cost-efficiency. The proposed criteria are:

- **Applicable to both equipment and operation**: Does this measure set incentives to both investing in the most efficient equipment and minimising operational costs in a long-term perspective?
- **Fits in with current regulation**: Does this measure fit with the regulatory mechanism currently in place or would it require fundamental regulatory changes?
- **European approach**: Is this measure set on a European level compared to a Member States approach?
- **Effective regarding improved energy efficiency in power transmission and distribution**: How effective is this measure in achieving the aim of increased energy efficiency in grids?
- **Transaction costs** regarding administrative and political barriers to set up a political measure
- **Stakeholder acceptance**: will the market participants like grid operators as well as suppliers of equipment support the measure?
- **Economic/Distributional Effects**: what is the overall economic performance of the measure? Is a general cost-efficiency possible and will certain groups of the economy (taxpayers, grid operators etc.) benefit more than others?

Table 2 gives an overview of the chosen policy options including an evaluation according to the mentioned criteria. The choice of policy options is based on a literature review ([SEEDT08],
[KEMA09a], etc.) and on the expertise of Ecofys. The evaluation is according to the following rating scheme (Table 1):

Table 1: Explanation of the rating scheme

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
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<tbody>
<tr>
<td>+</td>
<td>Category is fulfilled (depending on the category meaning yes/high/positive)</td>
</tr>
<tr>
<td>++</td>
<td>Category is highly fulfilled, stronger than (+), (depending on the category meaning clear yes/very high/very positive)</td>
</tr>
<tr>
<td>-</td>
<td>Category is not fulfilled (depending on the category meaning no/low/negative)</td>
</tr>
<tr>
<td>--</td>
<td>Category is not fulfilled at all (depending on the category meaning clear no/very low/very negative)</td>
</tr>
<tr>
<td>+-</td>
<td>Category is rated neutrally</td>
</tr>
<tr>
<td>o</td>
<td>Rating of this category is not relevant in that context</td>
</tr>
</tbody>
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Table 2: Overview of the evaluation of the analysed policy options

<table>
<thead>
<tr>
<th></th>
<th>Applicable to both equipment and operation</th>
<th>Fits in with current regulation</th>
<th>European approach</th>
<th>Effectiveness</th>
<th>Transaction costs</th>
<th>Stakeholder acceptance</th>
<th>Economic/Distributional Effects</th>
</tr>
</thead>
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<td><strong>Technical Standards</strong></td>
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<td>Conductors</td>
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<td>(+)</td>
<td>(+)</td>
<td>(-)</td>
<td>(-)</td>
<td>(+)</td>
</tr>
<tr>
<td>Transformers</td>
<td>(++)</td>
<td>(+)</td>
<td>(-)</td>
<td>(+)</td>
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4.2 Technical Standards for Conductors and Transformers

Losses related to equipment in the grid are largely in conductors and transformers. To analyse policy instruments for increased grid efficiency through equipment improvement, the following paragraph focuses on conductors and transformers and examines technical standards for such assets. The evaluation of both, conductors and transformers, is similar and thus not explicitly separated from each other.

Definition
This option involves setting technical standards, such as mandatory minimum energy efficiency standards for equipment design and sizing. It has been applied widely to a range of equipment. However, dynamic standards can signal to market participants in what direction the market will develop.

In the particular case of conductors the standards would apply to the sizing criteria of conductors, optimizing the trade-off between upfront investment and net present value of losses along the lifespan of the asset.

Currently (effective: February 2013), minimum energy performance standards (MEPS) for transformers are being developed in the Ecodesign-Directive. This will result in a binding regulation of transformer-standards.

Evaluation:

Application to equipment and operation: Technical standards both for conductors and transformers cannot be applied to both equipment and operation. Grid operators will be obliged to fulfil given MEPS with their equipment. Once the equipment is purchased there is no more incentive to reduce operational costs. Rating is (-).

Fit with current regulation: Setting technical standards both, for conductors and transformers will mean that grid companies will invest in more efficient assets (if the standards are set at that level). It may be possible to adapt specific regulatory design so that investments in equipment that meet the standard are included in the remuneration in an easier way, while a case has to be made if the standards are not met. In any case, such technical standards can be included within an incentive regulation without making significant changes. It has been rated with a (+).

European Approach: Technical standards are currently being developed on a European level. This means, they only have to be developed and implemented once which can also lead to reduced transaction costs. Also, in case of an inefficient functioning of the national regulatory mechanism those European standards can still guarantee a minimum level of efficiencies. Rating is (+).

Effectiveness: Mandatory technical standards of both, conductors and transformers, will lead to an overall improvement in efficiency, as they are the main source of losses
in equipment in the networks. Increasing the grid efficiency with these assets is thus a very effective way. It has been rated with a (++).

**Transaction costs:** Setting specific standards in general is a political decision and needs agreements on sensible and appropriate standard levels. There are transaction costs in setting the standards which however are lower once a standard is defined. There are interdependencies to be considered with the question of European or Member States approach of the instrument. Since setting technical standards is a European approach, developing and implementing is only needed once for all the Member States. This reduces transaction costs beforehand, whereas afterwards costs for compliance and monitoring remain on national levels.

- **Conductors:** Upfront transaction costs for the definition of standards for conductors might be a burden to political and regulatory authorities since many technical details come into play that influence transmission losses. Compliance and monitoring after the implementation will also be more complex. It is rated (-).
- **Transformers:** Setting standards for transformers from a technical perspective is not as complicated as for conductors. Compliance and monitoring efforts remain, but will also be less complex. It is rated with (+-).

**Stakeholder acceptance:** Grid companies that are forced to meet specific technical standards are limited in their degrees of freedom regarding their business activities. This limited scope might, in general, lead to them opposing this option. Optimizing the design of conductors and transformers normally leads to higher investment costs. However, such upfront investments will create a reduction of operational costs. These savings in OPEX could be translated by the regulator into a higher CAPEX allowance. Thus, depending on the regulatory design the implementation of conductor standards might be well accepted. It is rated (+-).

**Economic/Distributional Effects:** As already shown for the stakeholder acceptance, technical standards for conductors and transformers set as a fixed requirement reduce the companies’ degrees of freedom. Homogenous standards applied to heterogeneous market participants can impede the overall effectiveness of the measure. On the other hand, as stakeholders are involved in the process and introduction of standards shouldn’t be disruptive with the other potential investments. This category is classified (+ -).
4.3 Financial incentives

**Definition**
In general, financial incentives to increase efficiency can be of various forms, e.g. grants, loans or tax breaks. They can also be set via higher interest rates for energy-efficient investments. To further motivate and simplify investments, specific energy-efficiency budgets can be set up. Given that the transmission and distribution networks are regulated industries, the most appropriate way to deliver financial incentives would seem to be via the existing regulations. Another option is setting individual targets for network losses for grid operators which can be a mechanism that financially penalises or rewards deviations from the target. This can be supported by political measures like reasonable payback periods or upfront payments within the incentive regulation.

**Evaluation**

**Application to equipment and operation:** As described in the definition, setting financial incentives contains various design aspects. Thus, it is possible to make investments in energy efficiency more attractive by guaranteeing a full compensation, providing specific budgets for efficiency improvements or cheap interest rates. With this, clear incentives can be set for energy efficient equipment. At the same time, individual targets on energy losses can be set and companies are either rewarded or penalised for meeting or not meeting the targets. This can be a strong incentive for companies to improve in operational performance while leaving them free space to decide on the most effective measure. To conclude, it can be clearly applied to both aspects, and thus the rating results in a (++).

**Fit with current regulation:** Adding design aspects like efficiency budgets or individual loss targets to an incentive regulation does not require significant changes of the regulatory surrounding and can be applied quite easily. It is also supported in the language of the Energy Savings Directive, with the references to network tariffs. It is rated with (+).

**European Approach:** Setting financial incentives within the regulatory design is a national measure. That is, development and implementation is needed in every single Member States which has interdependencies with the extent of occurring transaction costs. Rating is (-).

**Effectiveness:** Strong financial incentives will have an impact on company performance and should lead to energy efficiency improvements. It is rated with (+).

**Transaction costs:** Adapting financial incentive schemes needs various political decisions. Since it is a measure on a national level it needs to be developed and implemented in each Member State which leads to a higher amount of transaction costs as European measure would cause.
It can affect the companies' business performances to a significant extent. The design of the incentive will involve some agreement on how to measure efficiency improvements and at what level to set the incentive. However, as seen in Chapter 3 there are already such incentives in place. It is rated neutrally with (+-).

**Stakeholder acceptance:** An attractive remuneration of capital expenditure is likely to be supported by affected companies. A system of penalty and reward is likely to cause pressure, but especially when the reward is attractive (not only financially but also in the form of reputation), their overall acceptance will most likely be given. It is rated with (+).

**Economic/Distributional Effects:** If companies are given the freedom to choose how to achieve their targets, cost-efficiency is possible. They can adapt their business activities to the required loss targets. On the other hand, remuneration of capital expenditure can also cause inefficiencies due to asymmetrical information between the actor that is applying for approval and reporting the amount of costs and the actor that is in charge of approving. The society cost of efficiency will depend on getting the level of financial incentive at the optimum level. For measures like grants and tax breaks the detailed incentive design is important, since incentives at inadequate levels could burden tax payers - rating of (+-).

### 4.4 Obligation or certificate schemes

**Definition**
With obligations or certificates for energy efficiency and energy savings, grid operators are given specific shares of losses (and savings) that they have to meet, just like the option of financial incentives. In many schemes, there is also the option to trade certificates to meet the obligation. In case of not conforming to the obligation penalties can be set to promote actions to meet the obligation which is a key difference to financial incentives.

**Evaluation**

- **Application to equipment and operation:** Theoretically it is possible to take both aspects into account. Companies could sell excess-certificates when they have very efficient equipment as well as when they prove a very efficient operation. Rating is (+).

- **Fit with current regulation:** An incentive regulation with an obligation on energy efficiency in the grid combined to trading of certificates for over and under achievement is theoretically possible. It would provide another source of revenues for grid operators which would have to be taken into account properly within the regulatory design. This type of policy is already applied in several countries to energy companies, with trading of so called white certificates. However, these obligation and
Certificate schemes are aimed at end user efficiency measures. It would be very difficult to establish a robust methodology to achieve equivalence between those white certificates and ones for grid efficiency. Trading would therefore have to be limited to TSOs and DSOs. It is rated with (+-).

**European Approach:** Setting obligations or certificate schemes is a national measure. That is, development and implementation is needed in every single Member State which has interdependencies with the extent of occurring transaction costs. Rating is (-).

**Effectiveness:** Obligation or certificates can theoretically lead to higher efficiency since they allow an overall cap of losses. The final performance of such a scheme depends to a large extent on the scheme details and cannot be foreseen generally. As discussed above, trading would likely have to be limited to TSOs and DSOs. In many Member States, the limited number of grid operators would make any market for certificates small. To make trading effective, cross country trading would be needed which brings in higher transaction costs. To reflect the uncertainty it is rated with (+-).

**Transaction costs:** Setting up a rather complex obligation and certificate trading scheme would cause high transaction costs. The rules for measuring and verifying energy efficiency savings would have to be developed and also the infrastructure for trading. As discussed a competitive trading and a liquid market for such certificates is questionable. The monitoring activities of such a trading scheme would also cause additional administrative expenditure. This category is thus rated with (-).

**Stakeholder acceptance:** As a complement to a financial incentive scheme, but one in which there is an alternative way of complying, grid companies might look on this favourably. Whether there was acceptance would depend on the balance between perceived benefits and the relative costs associated with a trading scheme. This uncertainty about how stakeholders would adopt this option is indicated with a rating of (+-).

**Economic/Distributional Effects:** The way companies achieve and prove the set shares can be chosen by themselves. As a consequence they will choose the optimal way for them which leads to an overall cost-efficiency. It is rated with (+).
4.5 Voluntary Agreements

Definition
Setting voluntary agreements would comprise non-binding guidelines e.g. for a maximum share of grid losses in power transmission and distribution. It can acquire the market participants’ attention on the issue and provide alignments on grid operation.

Evaluation

Application to equipment and operation: Voluntary Agreements can be done on equipment standards as well as on operation performance e.g. with agreed shares of losses. It is rated with (+).

Fit with current regulation: Such agreements can be set up in a revenue cap regulation without counteracting. As a consequence it does not have an impact on the performance of regulatory mechanisms and can go in line with a revenue-cap regulation. However, the regulation would need to be adapted to make provision for extra investments to achieve higher efficiency. It is rated with (+).

European Approach: Like technical standards, voluntary agreements can be developed on a European level. This means, they only have to be developed and implemented once which can also lead to reduced transaction costs. Also, in case of an inefficient functioning of the national regulatory mechanism those European standards can still guarantee a minimum level of efficiencies. Rating is (+).

Effectiveness: Since the agreements are voluntary without any financial consequences, the effect on energy efficiency is generally relatively weak. However, in some cases voluntary agreements have paved the way to further action in an industry, rated with (-).

Transaction costs: Setting up voluntary agreements is generally less intensive than other policy options and does not cause significant administrative expenditure. This category results in a (+).

Stakeholder acceptance: Voluntary agreements are only effective if stakeholders are engaged. Due to this rather soft option stakeholder should not oppose such a decision The rating is (+).

Economic/Distributional Effects: Companies are free to decide whether they want to realise the agreements. They could also decide about the way they want to meet them. These degrees of freedom lead to an overall economic cost-efficiency. Rating (+).
4.6 Labelling schemes

**Definition**
Within a labelling scheme, equipment available on the market are classified according to their efficiency. It can also direct the market participants’ attention to more efficient equipment as well as to the life-cycle costs and can support producers to sell efficient products. Such option could apply to transformers.

**Evaluation**

**Application to equipment and operation:** Labelling schemes can only be applied to equipment (namely transformers) in a similar way to the technical standards and cannot evaluate a company’s performance in energy efficiency. It is rated with (-).

**Fit with current regulation:** Since there are no new revenue sources or costs for grid operators within a labelling scheme, this option does not contradict a revenue-cap regulation and can be combined easily. In a similar way to technical standards, labelling could be linked to remuneration. It is rated with (+).

**European Approach:** Implementing labelling schemes is a national measure. That is, development and implementation is needed in every single Member State which has interdependencies with the extent of occurring transaction costs. Rating is (-).

**Effectiveness:** If labelling is only used in a voluntary way, the effectiveness is relatively limited. It has been more effective when linked to a financial incentive such as grants for higher label equipment. Additionally, there might be measures in grid operation that improve efficiency but cannot be labelled (e.g. over-sizing conductors). The effectiveness is thus limited, respectively only to a small extent. It is rated with (-).

**Transaction costs:** There are transaction costs in setting label classifications and labelling products themselves. It is rated with (+-).

**Stakeholder acceptance:** Product manufacturers will be in favour of this option as they can then better sell the more efficient equipment. Grid operators are likely to be relatively neutral, at least they are not expected to reject this option – rating is (+).

**Economic/Distributional Effects:** There is relative freedom of participation so it is likely that the economic effect is neutral or slightly positive. Further economic effects may arise from the suppliers’ benefits as they might improve the sales of their more efficient products (+).
4.7 Information campaigns to overcome lack of information and motivation

**Definition**
There are two potential areas where lack of information might influence: with the regulators not understanding completely the case for energy efficiency and not setting the regulatory framework and with grid operators not having all the information for a business decision. An information campaign about best practices set up by the regulator can overcome such barriers.

**Evaluation**

**Application to equipment and operation:** The information can cover both the advantages of efficient equipment and benefits of minimising grid losses (which is then applied to the operational performance). It is rated with (+).

**Fit with current regulation:** Launching information campaigns do not have any further impact on costs or revenues of the companies, nor on the overall regulatory surrounding. As a consequence it fits with the current regulation. The rating is (+).

**European Approach:** Setting up information campaigns is decided on national levels. Each Member State adopts such campaigns on its own. This has also interdependencies with the extent of occurring transaction costs. Rating is (-).

**Effectiveness:** This option will have only a weak effectiveness as it will draw attention but not promote any actions immediately. An overall improvement of energy efficiency cannot be guaranteed. It is rated with (-).

**Transaction costs:** This option does not cause very high transaction costs, neither will further administrative changes or monitoring activities be needed. This category is rated with (+).

**Stakeholder acceptance:** This is intended as a support measure so stakeholder acceptance is not an issue. It is rated with (o).

**Economic/Distributional Effects:** No direct actions are promoted within an information campaign. Similar to the effects of labelling schemes, suppliers will benefit from information if increased awareness about energy efficiency results in higher sales of their products. Thus, there is likely to be a small net financial benefit. It is rated with (+-).
4.8 Support of R&D

**Definition**
A state-based supporting scheme for R&D activities fosters the development of technical measures for grid efficiency.

**Evaluation**

**Application to equipment and operation:** Further technical improvements can be achieved which may be useful in both minimising losses in the operation and the quality of the applied equipment. It is rated with (+).

**Fit with current regulation:** Adapting a subsidy for R&D would be a political decision and be separated from the regulation. Thus, costs and revenues of the companies would not be affected and it can fit well with the current regulation. It is rated with (+).

**European Approach:** Implementing support of R&D is decided on national levels. Each Member State adopts such a support on its own. This has also interdependencies with the extent of occurring transaction costs. Rating is (-).

**Effectiveness:** With an R&D-support no direct actions are promoted. Rather there can be long-term and indirect benefits. Still, it cannot be guaranteed that this option leads to increased energy efficiency in grids. It is rated with (--).

**Transaction costs:** Providing a budget for R&D does not cause high transaction costs. Monitoring the right deployment of the financial support might need some administrative expenditure, but its extent can be neglected within this analysis. This category is rated with (+).

**Stakeholder acceptance:** Grid companies as well as sellers will be in favour as they either get money or they can develop new products. Stakeholders’ acceptance will be given, it is rated with (+).

**Economic/Distributional Effects:** Companies receive a budget for R&D and do not face significant costs. Thus, the question of cost-efficiency is not relevant and is rated with (o).
4.9 Conclusion and combination of options

4.9.1 Conclusion from the policy evaluation

The analysis above is a high-level evaluation of different policy options for increasing energy efficiency in electricity grids. Given the overall performance in the criteria, the option of setting financial incentives via tariff regulations appears to have the most advantages. This also fits with the requirements of the directive. The design of such an option is very important for efficiency and effectiveness and possible distributional effects.

Some of the other options, such as Technical Standards, Information Campaigns and Support R&D, might be useful as supporting policies as discussed below. Although a certificate schemes has certain advantages to be combined with the regulatory scheme, in practice it would be hard to implement, since it would be difficult to develop a sufficiently liquid market.

Since the option of financial incentives is a national approach, a European measure can easily be combined with it. That is, Technical Standards as well as Voluntary Agreements can potentially be combined with financial incentives without any conflicts on the national level. Due to the low performance of Voluntary Agreements in the evaluation mainly rooted in the low effectiveness, this combination is not regarded. All further potential combinations are listed below.

4.9.2 Potential combinations of policy options

The option of financial incentives can be combined with the following supportive measures:

- **Minimum Energy Performance Standards (MEPS) for transformers**
  Mandatory technical standards for equipment such as transformers, if set at the right level, would increase grid efficiency. Compared to standards for conductors, the occurring amounts of transaction costs would be limited, also since it is a measure on an European level. It would apply to new installations or replacements and the related capital expenditure should be recognised in the incentive regulation. In theory, any incentive in the tariff regulation should apply to efficiencies over and above those that would occur by replacement of transformers if a MEPS is in place. To put this into practice would depend on how the efficiency targets are agreed.
  However, in any case that national financial incentives are ineffective, transformer standards set at the European level can still guarantee a minimum of grid efficiencies.
  Thus, it can be a good first step (before setting financial incentives) to provide a solid efficiency basis.

- **Labelling Scheme**
  A labelling scheme for transmission assets might be useful in helping grid operators chose energy efficient equipment. Alternatively, an approach where the regulator approves
automatically the costs associated with equipment related to a particular label category could be implemented.

- **Information Campaigns**
  If an incentive is in place through the tariff regulation, an Information campaign such as sharing best practice could help grid operators meet targets more efficiently.

- **Support of R&D**
  As discussed in Chapter 2, many options for improving energy efficiency in grids exist already. However, R&D still has a place in developing new technologies and operational improvements.
5 Central findings of the analysis

This paper investigates the energy efficiency aspects in the network design and operation based on the Energy Efficiency Directive (2012/27/EU) and its provisions related to network tariffs and regulation.

The analysis on the possible technical efficiency measures to reduce losses (chapter 2), shows that a variety of both equipment replacement and operational improvements can lead to greater efficiency. The regulatory mechanisms for network tariffs in Germany, UK and Spain have been reviewed in chapter 3 to assess whether they provide an incentive for energy efficiency in the grid. The current design in Germany does not provide such an incentive, although there are signals that it will do so in the near future. In UK and Spain, especially for distribution system operators there are clear financial incentives to reduce distribution losses.

In chapter 4, several policy options for improving technical efficiency in grids were evaluated in the basis of a set of high-level criteria. The analysis concluded that setting financial incentives through the grid tariff regulation appears to be the most effective policy option to achieve efficiency improvements and is supported by the language in the Energy Efficiency Directive. The design and implementation of such a measure in a national approach is very country specific as details of the market and of grid regulations is different in each country.

Figure 1: Aspects to consider for implementation in practice

Figure 1 gives considerations for implementation in practice, showing four main steps. These steps should be followed as standard in any case in good policy making. Below, the main aspects of these steps are presented.

- Review regime to identify what changes will be necessary and what amount of switching costs will arise
- Look at best practice in countries with similar regulatory regimes
- Review for unintended consequences e.g. will the changes adversely affect customers or reduce other system efficiencies
Different regulatory regimes also have different treatments of OPEX and CAPEX.

- Describe allowable costs in the context of regulation
  - Define costs for losses as non-allowable costs to incentivise their minimisation
- Examine trade-off between CAPEX and OPEX from a number of different viewpoints (societal, customer, operator)
  - Classify investments costs for an increased grid efficiency as CAPEX that are remunerated
- Look at the long-term and short-term cost and energy efficiency considerations (e.g. lifecycle-assessments of assets)
- Look at the interaction with other regulations/policies for example MEPS and determine if there are links that can be made
- Determine balance in regulation to be implemented and check that this has no unwanted consequences such as excessive transaction costs

This is linked to the CAPEX/OPEX consideration and the target setting.

- The regulatory period needs to be sufficiently long to give certainty on investments for grid operators
- The regulatory period needs to be sufficient for grid operators to benefit from achieved loss reductions and thus cost reductions
- The regulatory period needs to be tight for customers to benefit from the reduced costs through the next regulatory cost-calculation that takes into account reduced losses

- Again there are already different approaches to setting targets or caps in incentive regulations. The appropriate target will be determined by the regulatory regime and the operational circumstances of the grid operator
- The financial incentives and loss targets need to be set at a level that will bring efficiencies that would not be realised under business as usual
- Define consequences for not-meeting/exceeding the targets
- Experience from other countries could be helpful in guiding the process, but targets will need to be set taking into account local circumstances
An example from the UK

- Loss targets for each operator are calculated by the average of losses in the previous regulatory period, and adjusted by the electricity usage within substations that were reported as losses
- Rewards/ penalties reflect wholesale value of electricity per MWh

Box 1: Example: Setting individual loss targets in the UK (Source: [OFGEM09], [OFGEM11b])
6 Literature


[BNETZA09]: Bundesnetzagentur, Eckpunktepapier zur Festlegung von volatilen Kostenanteilen für die Kosten aus der Beschaffung von Verlustenergie für die zweite Regulierungsperiode, 27.6.2012.


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[OFGEM11b]: Consultation on regulatory measures to address the effects of gross volume correction and other settlements data adjustments on the distribution losses incentive mechanism, Ref.: 137/11, October 2011


