Empowering Mediterranean regulators for a common energy future.

Consumer Working Group

Regulatory practices on handling technical and non-technical losses for electricity

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MEDREG – Association of Mediterranean Energy Regulators
Corso di Porta Vittoria 27, 20122 Milan, Italy - Tel + 39 02 655 65 529 - Fax +39 02 655 65 562
info@medreg-regulators.org – www.medreg-regulators.org

Abstract

This document (Med19-28GA-3.3.1) presents a report on power losses among MEDREG members.

First, it provides an overview of the situation of MEDREG members with regard to power losses. The state of play is presented through an analysis of the factors affecting power losses, which include the features of power systems, an understanding and definition of losses, transmission, distribution and non-technical losses, the calculation of losses, the coverage of losses, applied measures in mitigating power losses as well as the applied regulatory incentives and the role of regulators.

An analysis of such a situation is based on the contribution by MEDREG members through case studies, which in some cases also provide data on the amount of losses, whether technical or non-technical, along with the methods of calculation, the procurement of losses and the applied incentives.

Furthermore, this report provides recommendations on reducing power losses from the perspective of not only energy efficiency but also consumer protection, aiming to guide MEDREG members in taking doable measures, according to the economic and social situations of their respective countries. Some of them already have a plan of activities aimed at power loss minimisation, which are even marked by targets.

Keywords: Power[1] losses, energy efficiency, technical losses, transmission losses, distribution losses, non-technical losses, fixed technical losses, variable technical losses, MEDREG members

[1] "Power", whenever used in the text of this document, has the same meaning as "electrical" and vice versa.

About MEDREG

MEDREG is the Association of Mediterranean Energy Regulators, which brings together 27 regulators from 22 countries spanning the European Union, the Balkans and North Africa.

Mediterranean regulators work together to promote a greater harmonisation of the regional energy markets and legislations, seeking progressive market integration in the Euro-Mediterranean basin.

Through constant cooperation and information exchange among members, MEDREG aims to foster consumer rights, energy efficiency, infrastructure investment and development based on secure, safe, cost-effective and environmentally sustainable energy systems.

MEDREG provides information exchange and assistance to its members as well as capacity development activities through webinars, training sessions and workshops.

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For more information, please visit www.medreg-regulators.org

If you have any queries relating to this paper, please contact the following:

MEDREG Secretariat

Telephone: +39 02 65565 524

E-mail: vlenzi@medreg-regulators.org

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EXECUTIVE SUMMARY

The reduction of power losses contributes to stable, reliable and cost-effective energy supply, strengthening energy efficiency measures and consumer protection. It also betters the financial and environmental situation of a state. In this respect, MEDREG attempts to identify the common and specific difficulties across its members, in order to guide them to work towards reducing power losses via prioritised interventions in response to their power system characteristics and the situations of their home countries.

The reduction/minimisation of power losses is one of the pillars of an energy-efficient approach to harnessing electrical power. Although it is commonly accepted that power losses cannot be eliminated, MEDREG members and other countries are making continuous efforts to identify the areas of concern and address them properly. In this regard, this report attempts to diagnose the problems concerning the power losses across MEDREG members and provides recommendations as possible solutions.

While different countries encounter different challenging issues with regard to power losses, this report intends to guide and support MEDREG members in prioritising their intervention activities. In certain countries, transmission and distribution losses represent the majority of losses, while in others the accounts of non-technical losses are also high.

The concept of energy efficiency improvement, as also defined in the EU Directive[2] on energy efficiency, calls for an increase in energy efficiency owing to technological, behavioural and/or economic changes. The same also applies for power losses.

A unified definition of losses is not feasible due to the diverse understanding of losses in different countries, particularly of non-technical losses. Such differences affect the analyses of loss situations at a comparative level. A harmonised definition of technical and non-technical losses could help MEDREG member countries replicate the mitigation measures than are proven to be successful in other countries, in addition to encouraging them to adopt common regulatory approaches. Regardless of the lack of the definition of power losses, all countries have resorted to measures and efforts meant to reduce the same.

The procurement of losses is an aspect of high significance from the perspective of consumer protection. Such particular importance is related to the fact that in the majority of cases, the costs of losses are charged to consumers. Therefore, the accountability and transparency principle should be observed along with the process of drafting, consulting and introducing measures that would instead incentivise system operators to minimise the losses incurred.

Across the MEDREG countries, there are rules in place to ensure that the costs of transmission losses are recovered from all transmission network users, as part of their transmission network charges.

The roll-out of the new generation of smart meters should be promoted, since the remote actual meter readings enables more frequent bills to be issued on actual readings rather

[2]Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing 2004/8/EC and 2006/32/EC

than estimates, reduces inaccuracy in billing due to human error (for example, incorrect manual readings) and provides consumers with easier means to access information on consumption. Possibly, automatic meter readings are extended to metering at strategic points along the electricity systems, such that a network operator would have easier access to information, which may be analysed to detect parts of a network that are frequently overloaded and possibly identify areas prone to potential theft incidents.

Demand-side management, in the form of differentiated tariffs applied to different time periods during the day/night, is recommended for countries with relatively high technical losses so that they can possibly shift the demand. The penetration of an embedded generation should be encouraged, particularly for self-consumption, since this reduces the load on a given network, particularly in which the centralised production sources are distant from the demand centres.

System operators, particularly DSO's, should be encouraged to take actions that facilitate load balancing of a network and the introduction of power factor correction equipment. DSOs should be incentivised enough to reinforce a network based on sound network planning and on its actual consumption and loading.

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List of abbreviations

Term	Definition
MEDREG	Mediterranean Energy Regulators
TSO	Transmission System Operator
DSO	Distribution System Operator
DSP	Distribution System Provider
HVAC	High Voltage Alternating Current
EHV	Extra High Voltage
HV	High Voltage
MV	Medium Voltage
LV	Low Voltage
KV	Kilovolt
PV	Pole Vault
N-TL	Non-technical Losses
Km	Kilometre
KWh	Kilowatt hour
MW	Megawatt
USD	American dollars
LBP	Lebanese pound

1 Introduction

Power losses refer to losses of energy incurred upon the transfer of power from the source to the load. It is well known that not all of the produced energy reaches the end consumers due to losses in the transmission system, at either high- or low-voltage levels or at the distribution level. These losses are categorised as technical or non-technical in nature.

Technical losses are caused by the physical properties of very components of a power system, mainly identified by power dissipation in electrical system components, such as transmission lines, power transformers, measurement systems and other components of transmission and distribution systems. Such losses occur during transmission and distribution and involve substation-, transformer-, and line-related losses. In turn, losses include the resistive losses of primary feeders, the distribution transformer losses (also considered as resistive loses), resistive losses in a secondary network, resistive losses in service drops and losses in kWh meters. Losses are intrinsic to the distribution of electricity and cannot be eliminated. Technical losses occur due to current flowing in the electrical network; the following types of losses can be generated:

- Copper losses, which occur due to I2R losses that are inherent in all inductors because of the finite resistance offered by conductors;
- Dielectric losses, or losses that result from the heating effect on the dielectric material present between conductors;
- Induction and radiation losses that are produced by the electromagnetic fields that surround conductors.

On the other hand, non-technical losses are caused by external actions that are unrelated to a power system or by loads and conditions that a technical loss computation process fails to consider. Such losses are more difficult to measure and occur because of theft, metering inaccuracies and unmetered energy. Theft may occur when the energy delivered to customers is not accurately measured by an energy meter, as a result of meter tampering, or due to the bypassing of a meter that registers the amount of energy delivered (which is to be paid for by the consumers).

Losses due to metering inaccuracies are defined as the difference between the amount of energy actually delivered through the meters and the amount that is registered by the meters.

The most common causes of non-technical losses are the following:

- Tampering of meters to diverge their normal functioning, resulting in the recording of a lower consumption reading;
- Tapping (hooking) on low-voltage lines;
- Arranging false readings by bribing meter readers;
- Stealing, e.g. by means of bypassing a meter or constructing illegal connections;
- Ignoring unpaid bills;
- Faulty energy meters or un-metered supply;
- Errors and delay in meter reading and billing;

- Non-payment by customers;
- Errors in the calculation of non-technical losses due to errors in the computation of technical losses.

Non-technical losses cannot be computed and measured easily but can still be estimated as the result of the difference between total losses and technical losses. Technical losses are computed using appropriate load-flow studies. Although some electrical power losses are inevitable, correctional measures can contribute to their minimisation. Several measures have been applied across MEDREG members, including those related to technology improvement and others targeting human manipulation and proper sanctioning.

2 State of play regarding power losses across MEDREG members

2.1 Background

The information provided and analysed in this part is based on the contribution of MEDREG members through case studies. The analysis builds on the assumption that power losses are inevitable regardless of the design of a system. However, the intention here is to identify the features of networks and the modes of operation from the perspective of power losses and also to provide recommendations on loss minimisation.

Power losses might be either technical or non-technical, the latter being a result of the illegal consumption of electricity by users. Technical losses can be further categorised as fixed and variable technical losses.

For the purpose of this analysis, the reflection of the MEDREG members' situations is provided in the succeeding sections, each of which addresses different aspects such as the features of an electric system, transmission losses, distribution losses, non-technical losses, added to the role of and the incentives applied by regulatory authorities or other responsible authorities.

Furthermore, this report includes the analysis of the national case studies of 14 MEDREG members, namely Albania, Cyprus, Egypt, France, Greece, Italy, Jordan, Lebanon, Malta, Palestine, Portugal, Slovenia, Spain and Turkey (reflected in the Annex attached to this report). It paints a nuanced picture of the pertinent state-of-play in the Mediterranean region and of the regulatory practices to mitigate technical and non-technical losses.

2.2 Features of the power systems and amounts of losses

Power losses are intricately connected to the characteristics of the power system of a country as well as its economic and social situations. Transmission over long distances adds up to the normal rates of power losses. Based on the wide range of types/sources of electrical system losses and the sizes of individual countries, the situations regarding power losses vary significantly from country to country. In some countries, the situation differs even from one geographical part to another, if the power losses are higher in only a part of their total landmass.

The power generated in power stations passes through large and complex networks composed of transformers, overhead lines, cables and other equipment, until it reaches the consumers. Therefore, the analysis of the features of power systems across the MEDREG members (who have submitted information in this regard) will contribute to a better understanding of the state-of-play and, simultaneously, to the recommendations of reasonable and feasible measures.

Power losses are always present in electricity systems and are not related to how a country designs its transmission and distribution systems, in light of the inevitable losses along the transmission and distribution networks and the values of power losses at different steps. Electric power losses are caused by the energy dispatched in a system, along with internal and external factors. However, the longer the transmission lines, the higher the losses.

Sometimes, the power source is situated far away from the demand, as in the case of Albania, half of whose installed capacity is derived from three public hydropower plants located in the country's north, while the highest electricity demand is in its centre, near its capital, wherein lives one-third of the population and where the important industrial undertakings occur. Albania has reported a total levels of transmission losses being 2.46% and the distribution systems being 23.96%. This indicates that the highest level of technical losses is reached in the 0.4 kV low-voltage networks, reaching up to 50% of the total of technical losses, as about 80% of Albania's total consumption is supplied via 0.4 kV output lines.

The amounts of power losses are different and also differently reported. However, all countries display efforts and results related to reducing power losses. Italy has reported an average loss level of 6.2% in the 2013–2017 period and 5.8% in 2017, both of which represent the lowest levels of losses in these periods. France reports a low level of losses in its distribution networks (a 6% level), while the losses in the interconnected islands vary from 4.94% to 13.1%. Here, in the transmission and interconnection networks, which carry large quantities of energy over long distances at 400 kV or 225 kV, the level of losses is low. In another example, Greece has reported an average level of losses in the transmission network, 2% in the 2014–2018 period, added to a decrease of distribution losses from 9.3% in 2014 to 8.1% in 2017.

Turkey has 21 DSOs and reports power losses in its distribution networks at a level of 11.8% and in the HV system at a level of 1.9%. It's HV system consists of 380 kV and 154 kV systems, whereas its MV consists of 36 kV (and below) systems. Further, Slovenia reports a level of 2.68% in transmission losses and of 4.18% in distribution losses for the year 2018, while Cyprus reports distribution network losses at the level of 2.1% and transmission network losses of 1,35%.

Palestine reports technical losses at the level of 8%–10%. Notably, Lebanon's losses are considered the most problematic issue related to its power sector, at the highest level of 38%, out of which 4% are witnessed in the transmission network, along with 13% technical losses in its distribution network and 21% non-technical losses. Meanwhile, Spain reports total losses of 8.7% for the year 2018, as Egypt reports power losses in its distribution network at the level of 15.9% and in the transmission system at the level of 4.5%. In Egypt, the length of the Distribution System Lines is 197.741 km for MV and 288.867 km for LV. The length of the Transmission System Lines varies from 22 kV to 400–500 kV.

In Portugal, starting from 1999, ERSE has set the reference values for distribution network losses in each year. IEA has indicated that in 2017, the power losses in Portugal were around 7.8%.[3]

[3] https://www.iea.org/statistics/

Jordan reports a significant distance between each of its MV/LV substations and, consequently, long feeders which contribute to power losses; in 2014, Jordan's losses were around 11%[4]. The features of the distribution network in Jordan are given below:

- Considerably long feeders, with respect to the high-density load to be served, which characterises the 11-kV network of Amman's electricity distribution.
- The average distance between each MV/LV substation is quite high, leading to a very high average length of the LV feeders.
- The average power factor of the LV system is too low (0.75), which also involves a low power factor in the 11-kV networks (0.85).
- The efficiency of some electrical components (distribution transformers) is not aligned using the best technologies available.

Malta represents a non-typical case because it does not have a transmission system. Its electricity system is connected to Italy's transmission system through a 200 MW HVAC 220 kV (mainly) submarine cable. Such electricity interconnection is considered as an extension of the distribution system in Malta, which comprises a network of 5,179.1 kilometres, composed of 2,889.792 km of underground cables, 2,176.1 km of overhead cables and 113,235 km of submarine cables. The local distribution voltage ranges are 132 kV, 33 kV, 11 kV and 400–230 V. The low-voltage network at 400–230V is mostly overhead, whereas the network consisting of higher voltages is mostly located underground. Malta reports losses at the level of about 3% in the year 2018, the majority of which are found to be technical losses at the level of 3.5%.

2.3 Definition of losses

The definitions of losses reflect the way in which they are understood by different countries. They are addressed in a special section of this document so that one can identify and analyse the differences. Such differences affect the analysis of the situations across the respondent MEDREG countries and make them less likely to be comparable.

Losses are commonly represented as an occurrence of technical reasons and human behaviours, marking a clear difference between the meanings of technical and non-technical losses. In the feedback received from MEDREG members, it seems that a unified understanding or a standard definition of losses remains lacking. However, most respondent countries define losses as the difference between injected and withdrawn power. It is noted that the concepts of technical losses are almost identical, while arguments on non-technical losses and their components vary. The segment of non-technical losses, in some countries, ends in billed electricity and, in other case, in electricity paid for by the end-users or consumers.

[4] https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS?locations=JO

As a rule, in comparing the losses across network operators, the first step would entail the adoption of a common technical standard for the measurement and reporting of losses. Generally, the TSO and DSO network losses can be defined as the difference between the electricity entering the transmission and distribution network, from fixed electricity generators, and the electricity exiting the network, for consumption purposes, properly accounted for (as percentile) in a given period.

Distribution network losses are conventionally broken down into two categories: technical losses and non-technical/commercial losses. The former are caused by the physical infrastructure and its components within a power system, such as the power dissipated in distribution lines, measurement systems and transformers due to internal electrical resistance. Deriving from the case studies of Albania, Malta and Spain, technical losses are further sub-categorised: variable losses, which are related to the level of a load, and fixed losses, which are not related to level of the load in a network.

Some countries have provided an official definition of losses in a legal or regulatory document, as in the case of Turkey, Cyprus and Italy. Others do not refer to a particular document that provides a legal definition of losses. However, in their feedback, MEDREG countries have presented their understanding of losses, as in the case of Malta, Albania, Egypt, France, Jordan and Palestine. Other countries have not provided any information on the understanding and/or definition of losses; they merely refer to such losses, as in case of Portugal, Spain and Lebanon.

The energy law in Turkey provides defines losses as the differences between the energy entering the distribution system and the amount of energy accrued by consumers in this distribution system, which eventually affect the costs. Technical losses are considered as arising because of technical reasons, while non-technical losses occur due to illegal use power and other non-technical reasons.

In Cyprus, trading and settlement rules define the transmission system losses, as the losses induced in the transmission system by the energy flow on the high-voltage transmission lines, transformers and other equipment. Transmission system losses do not include non-technical losses. In Cyprus, the same document defines distribution system losses as those induced in a distribution system, of low and medium voltage, to cover the loads of the offtake meters. Distribution system losses include both technical and non-technical losses.

In the case of Italy, ARERA regulation categorises technical losses as those marked by the inevitable dissipation of electric energy into the equipment necessary for energy transmission and distribution. Non-technical losses primarily occur due to human action and failure along the distribution network, because of the illegal use of energy and errors in metering.

In the case of Malta, distribution losses are understood as the differences between the volumes of electricity sent to a distribution system from all sources (local generation and the net of any internal consumption and the interconnector) and the volume of electricity exiting the system, either metered or estimated at the point of exit.

In Albania, distribution losses include technical and non-technical losses. The total amount of technical losses is derived from a fixed amount and a variable amount. Non-technical losses are related to meter reading, defective meters and errors in meter reading, the billing of customers' energy consumption, the lack of good administration, financial constraints, added to difficulties in estimating the unmetered supply of energy as well as energy that is stolen.

In the case of Egypt, losses in electrical energy are defined as the differences between the electrical energy transmitted to the outputs of lifting transformers in power plants and the electric energy actually consumed by consumers. Also, losses are defined as the energy consumed in the elements of the electrical network, including transmission lines, transformers, controllers, along with protection and measurement during the transmission and distribution of electrical energy. Non-technical losses (commercial losses) equal the difference between total network losses and technical losses. Causes of commercial losses relate to deviations in the work of energy meters, errors in meter readings, difficulty in accessing the meter readings in some houses, the disruption of meters and the stoppage of recording of the amount of consumed energy. Illegal consumption is defined as the energy that is actually consumed and is left unmonitored by energy meters.

In France, technical losses are considered as those caused due to the heating of conductors and transformers during electricity transmission. Non-technical losses are related to cases when the energy consumed cannot be billed to an end-user. The reasons behind these categories of losses include imprecise or incorrect readings, fraudulence and human error.

In Greece, transmission system losses are calculated as the differences between the total energy exported to the transmission system (by the generating resources connected to the transmission system) minus the total offtake from the same system. The distribution network power loss factors express the average power loss in the distribution network and are applied to calculate the quantities of energy charged to suppliers in the wholesale market (for electricity supplied to customers in the network). These factors are, therefore, considered by suppliers to determine the cost charged through the invoices they offer to customers in the given distribution network. In addition, because the energy corresponding to the dominant supplier is calculated by subtracting the energy corresponding to the other suppliers from the total energy injection into a network, it is important for equal-treatment reasons that the loss factors are as close to reality as possible, e.g. the actual average power losses in the distribution network.

In the case of Palestine, technical losses are considered as those caused by the physical properties of the components of a power system, such as the power dissipated in distribution lines, measurement systems and transformers due to internal electrical resistance. The non-technical losses include electrical thefts, faulty energy meters, in addition to errors and delays in meter reading and billing and non-payment by customers.

In *Jordan*, the distribution system losses (MV and LV distributions) are determined by the differences between the total energy purchased from a transmission system and the total energy sold to the customers by a distributor, including non-technical losses.

In Slovenia, there is no special methodology for exact splitting between technical and non-technical losses. However, technical losses are defined as physical losses that depend on the design of a power grid, the voltage and transformation levels and the length of the power lines, being calculated on these bases. On the other hand, non-technical (commercial) losses include any non-metered consumption, theft or other types of losses such as metering errors, or differences in metering, billing and data processing.

The case studies included in the reports of countries like Palestine and Jordan show that non-technical losses include also the non-payment of bills by customers, which is not considered as a source of non-technical losses for other MEDREG countries. In a wider understanding, non-payment in the power sector is addressed under the term ‘debt' or ‘bad debt'.

While analysing the causes of non-technical losses causes, the respondent countries report electricity theft as one of the main reasons behind non-technical losses, as in the cases of Albania, Portugal, Turkey, Spain, Palestine, Malta, Lebanon, Jordan, Italy, France and Egypt, even though in all such countries theft is considered as an illegal activity by consumers and is legally punishable. In addition to sanctions provided in cases of theft and fraud detection, countries have taken other complementary measures to mitigate their incidences: e.g. in Malta, the DSO has moved from surveillance-based on-site visits to ones based on analytics, back-office analyses of consumption and considers a percentage tolerance.

Metering-related problems are considered as the second-most important cause of non-technical losses that lead to errors, expressed in the form of under- or over-recordings of real consumption. Replacing old meters with smart or master meters is considered as a proper measure that addresses non-technical power losses.

2.4 Transmission and distribution losses

In addition to the general division of losses into technical and non-technical losses, another division is commonly used for the losses occurring in transmission and distribution networks. Such losses are referred to as transmission and distribution losses, respectively.

All respondent MEDREG countries have reported a distinction based on the differences between transmission losses and distribution losses. Furthermore, in all cases, non-technical losses are reported as constituting a part of distribution losses.

The transmission power lines allow for a decreased level of losses, due to higher voltages but lower current. Other factors, like network imbalances and the quality of electricity, also have an impact on such losses. Therefore, electricity generators must produce more energy to ensure that all the demand users receive the required amounts of energy in order to cover their network losses. Unlike transmission networks, distribution networks operate at medium and lower voltages. Hence, these networks are subject to higher levels of losses.

In case of Albania, with regard to distribution losses, the highest level occurs in the 0.4 kV low-voltage networks, reaching up to 50% of the country's total technical losses. The main reasons behind this high percentage of technical losses in the 0.4 kV networks are related to the fact that about 80% of OSHEE's total consumption is supplied via 0.4 kV output lines, a higher average resistance of overhead line conductors (above 1.5 Ω/km) and higher average lengths of feeders in some regions (more than 1.5 km), with a possible occurrence of the latter two reasons simultaneously. Distribution losses are caused by old technology, low efficiency, lack of renovation and modernisation, overloads, the lack of capital investments, poor repairs and maintenance services.

In Turkey, the higher number of losses is found to occur in its distribution system, while the loss ratio in its transmission system remains low. Another element relevant to distribution losses is related to the high number of DSOs in the country.

In Cyprus, transmission losses are considered as those induced in a transmission system due to the energy flow on high-voltage transmission lines, transformers and other equipment. In this regard, factors that affect transmission losses have been identified as follows: peak load, load factor, reactive power load – installation of reactors, wind park capacity, backbone system transmission lines capacity factor, the strengthening of backbone system transmission lines and energy injection from the distribution system due to dispersed generation. On the other hand, distribution losses are considered as those induced in the distribution system, of low and medium voltages, to cover the loads of the offtake meters.

Greece has reported that its transmission system losses are calculated as the differences between the total energy exported to a transmission system by the generating resources connected to the same minus its total offtake.

In case of Jordan, a cause behind transmission and distribution losses has been identified: the number of distribution transformers is low with respect to the extension of the lines and the density of the load. Other causes of high technical losses may be the low number of distribution transformers (considering the extension of lines and the density of a load), long feeders and a high average length of LV feeders, a low power factor and a low efficiency of distribution transformers.

In Lebanon, technical losses calculated in the transmission network (of 4%) are connected to deficiencies in maintenance, insufficient capital investments, high loading levels and the need of modernisation. Reducing losses in the transmission network is extremely important, since it directly targets the 220 KV system's backbone, which ensures a stable power flow throughout a whole network. However, the most significant amounts of losses, including technical and non-technical losses, are observed at the level of the distribution systems. Power losses are caused by deficiencies in maintenance, insufficient capital investments, high loading levels, the need of modernisation, infrastructure bottlenecks in transmission systems, illegal connections on distribution systems and uncollected revenues. In 2012, a project was launched in Lebanon to reduce technical and non-technical losses as well as to fix and upgrade the distribution network via infrastructural upgrades, but the project has unfortunately failed.

In case of Egypt, the reasons behind transmission and distribution losses are identifies as follows: inequitable distribution of production and consumption centres, significant expansion of the medium and low distribution networks without the corresponding construction of more adequate substations, the lack of adequate electrical networks for monitoring and protection systems, the absence of a good programme for the periodic maintenance of electrical networks, the lack of investment necessary to implement the necessary electrical projects, the growing population explosion and the failure of laws and regulations, in terms of enforcement, regarding the investment and consumption of electric power.

In addition, measures to address transmission and distribution losses include improving the phenomenon of electrical unbalance, conducting a change cycle for loaded and unloaded transformers (turnover of transformers), control cable loading and processing load, monitoring and rectifying low voltage situations, focusing attention on links in different network points, on inventory and renewal of old and obsolete networks, on examinations of the existing operational conditions and the preparation of optimal operating conditions, follow-up and measurement of the power factor for different segments of consumers, added to giving attention to the planning and development of electrical networks and the elimination of bottlenecks in medium- and low-voltage networks.

In case of Malta, there are no transmission losses as there is no transmission network. With respect to distribution losses, distributed generation has the additional benefit of being located in proximity to demand and is believed to contribute to the reduction of technical losses, due to the shorter distance of transportation and the reduced utilisation of the network at certain hours. Distributed generation consists mainly of PVs and a reduced number of voltage transformation levels.

In Slovenia, the amounts of losses on the transmission system are determined based on the differences between the amounts of electricity from the production site connected to the transmission system, as well as the quantity of electricity at the connecting points between the transmission and distribution systems and the consumption of electricity from a transmission system on an annual basis. In such calculations, the amount of electricity measured on the cross-border interconnectors is also considered.

Relevant data regarding distribution and the transmission systems in Portugal, Spain, Palestine, Italy and France are addressed in other sections of this report.

2.5 Non-technical losses

Non-technical losses consist of units that are delivered and consumed but are not recorded as part of sales. Every respondent presents different causes regarding N-TL and their calculations, but the most common reasons are related to error in meter reading, wrong billing of energy consumption and theft, as in the cases of Albania, Egypt, Jordan, Malta, Palestine, Portugal, Slovenia, Italy, and Spain.

Particularly in Lebanon and Italy, the non-technical losses derived from theft are more prominent. In Italy's case, N-TL are considered as human actions and have significant impact, especially in *the* south of the country. In the case of Turkey, N-TL is considered as losses accrued by illegal connections. Egypt defines illegal consumption as the energy actually consumed (and left unmonitored) by energy meters. Cyprus is an exception, because it hasn't specified N-TL but has instead given an overall picture of power losses in the two main systems at distribution and transmission levels, wherein N-TL are included in the overall distribution system losses. In this vein, Greece reported that in the year 2018, 7,790 cases of confirmed theft were recorded, which resulted in a sum of almost 80 GWh considered as lost. In economic terms, the competent authority regarding the operation of distribution systems has claimed more than € 21.5 million in 2018 itself. Out of this amount, 17% belongs to the Greek DSO as the necessary network maintenance fee, with the remaining 83% being identified as the electricity production cost.

Some countries have paid particular attention to N-TL and have presented strategies and measures to reduce them as much as possible. In Italy, a new approach was taken into consideration for dealing with power losses during 2016–2018, which required DSOs to make improvements in order to detect N-TLs. Another important step was improving the cooperation between external contractors and the justice machinery, so that the necessary measures would be taken in cases of fraud. In Lebanon, due to the increasing levels of N-TLs, an action plan has been approved that aims to take coercive measures against those who create illegal connections to steal electricity. Egypt is focused more on improving its meter system by installing electronic meters and calibrating existing meters periodically, as all N-TLs occur due to defects and errors. This strategy also relies also on the following factors:

- Activating and rectifying the status of inactive consumer accounts.
- Replacing meters whose presence in the network exceeds their shelf lives.
- Applying a prepayment system in places with a large percentage of commercial losses.
- Ensuring coordination between contracted capacity and counter-rotation capacity.
- Meeting the demands of electrical supply immediately.
- Raising the citizens' awareness regarding the ways in which to rationalise electricity consumption.

Malta is the only country that doesn't have a transmission system but only a distribution system. However, it has made constant efforts to reduce power losses, which have yielded positive results. The most frequent reasons behind N-TLs in Malta through the years have been errors in meter reading and unmetered electricity, but the installation of smart meters has proved to be beneficial in reducing them overall. Spain, Palestine and France share the same opinion about installing smart meters that can significantly reduce N-TLs, although in France's case this is not the only solution and other measures need to be taken simultaneously. France considers the misuse of energy as theft, which is punishable by the penalties provided in articles 311-3 and 311-4[5] and can lead to a fine of up to € 45,000 and several years of prison, even if its courts rarely implement these sanctions. Similar

[5] French criminal code.

sanctions are applied in Portugal, where fraud, once detected, is subject to criminal prosecution, without the prejudices of operators who have to be compensated based on an estimated value.

2.6 Calculation of losses

The classical ways of measuring and calculating losses is by metering the difference between the energy injected and withdrawn or an estimation based on calculation. The metering of losses is usually used as a method for transmission networks, while estimation is suitable for distribution networks. This applies for technical losses, while non-technical losses are mostly calculated as the difference between total losses and technical losses.

The respondent MEDREG countries report different ways of calculating losses in terms of the methods used, the measurement used, the type of information produced (whether aggregated or disaggregated) and the level of losses, the data on which are also affected by the differences in the meanings of losses. Due to the characteristics of the countries and their power systems, when such information is disaggregated, the calculations of losses indicate the weight of technical losses versus that of non-technical losses; such findings also help in facilitating the reduction of losses. In some other countries, no disaggregated information is available to assess which part of the system is more responsible for losses, like in the case of Jordan. The calculation of the losses is extensively linked to the meanings of losses in a given country.

Losses are usually calculated for a given period, like a month, a quarterly, a semester, a year, or 3–5 years. In case of using metering as a method, imprecisions in the calculation of losses may happen due to the differences between the data collection time of input meters and the data collection time of consumption meters. The determination of losses through the estimation method also carries a margin of error. Even the reporting is sometimes presented in terms of an absolute amount, or as a percentage of the energy produced or injected.

The total losses equal the sum of the technical and non-technical losses. From the technical point of view, power losses are consequences of the transport of electricity generated in power plants across a power grid. As the field of praxis shows that the electrical energy generated by power plants is not equal to the amount of electricity distributed to the end consumers (billed to them or paid by them), a percentage of the units indicates losses in the network and beyond. The losses in such a network refer to losses in the transmission system and in the distribution network. Their calculations can be based on the metering method, like the cases of Jordan and Malta, or an estimation method, like in the case of Slovenia.

In Jordan, as mentioned above, losses are calculated by network type (transmission and distribution) and voltage level (HV, MV, LV) for each network type. The gross amount of system losses (MV and LV distribution) is calculated as the difference between the total energy purchased from a transmission system and the total energy sold to the customers of a distributor, which also includes non-technical losses.

Also, in other respondent countries like Portugal, Italy, Albania and Cyprus, the losses are calculated as per the network type and the voltage levels (HV, MV, LV and EHV) based on the difference between network injections and withdrawals. In the case of Portugal, losses are quantified by the means of hourly loss profiles, approved by ERSE upon the proposal by network operators.

In Italy, standard loss factors for withdrawals are estimated at different voltages. The estimation of standard loss factors includes technical and non-technical losses. Actual losses are determined annually, as the difference in a particular period between the energy injected and the energy withdrawn by consumers in the grid.

In Albania, transmission losses are calculated as hourly energy balance, as the difference between injections and offtakes. Distribution losses are calculated at the voltage level; the highest level of losses occurs in the 0.4 kV low-voltage networks, reaching up to 50% of the total technical losses. The medium-voltage network consists of 6 kV, 10 kV and 20 kV feeders and the level of technical losses occurs mostly in the 6 kV and 10 kV networks, where the level of losses reaches 8–9%, while the technical losses in the 20 kV medium voltage feeders are about 2.0–2.5%.

In Cyprus, transmission system losses are calculated as the differences between the total energy exported to a transmission system (by generating resources connected at the transmission system) minus the total offtake from the transmission system, including the transmission–distribution boundary offtake. The TSO is responsible for the emergent transmission loss factors on an annual basis. Furthermore, transmission system losses do not include non-technical losses.

Distribution losses at a medium-voltage level are calculated on the basis of total injections to the medium voltage distribution system, including the transmission-distribution boundary offtake, minus the total offtakes from the medium voltage distribution system and the energy transferred from a medium voltage to a low voltage system. Distribution losses at a low voltage are calculated on the basis of total injections to a low-voltage distribution system, including the energy transfer from a medium voltage to low voltage, minus the total offtakes from the same system plus the losses at a medium voltage (attributed to the net energy transfers from the transmission–distribution boundary to the medium-voltage–low-voltage boundary). The DSO is responsible for calculating the distribution loss factors on an annual basis, separately for each voltage level (LV, MV). Distribution losses include both technical and non-technical losses.

Countries like France have provided detailed information on the process and formula of the abovementioned calculation. Losses are calculated in a two-step process. The first step occurs closely after the real time, within one week, and estimates the electric losses using the following equation: losses = a * (injections from the transmission network + decentralised production – backflows from the distribution network to the transmission network) ² + b * (injections from the transmission network + decentralised production – backflows from the distribution network to the transmission network) + c. Two sets of coefficients (a, b, c) are used. One applies to weekdays and the other to bank holidays and weekends. This first step enables one to quickly allocate electricity flows to the entities responsible for different balances. The second step occurs 14 months after the end of an electric losses measurement period (a full year) and uses real measurement data obtained from all network users. The real volume of electric losses is then derived by calculating the difference between all the injection and consumption load graphs and readings gathered from all customers.

In Greece, transmission losses are calculated on an annual basis and constitute the responsibilities of the transmission system operator. In case of distribution losses, the distribution system operator is responsible to calculate them on annual basis, separately for each voltage level (low voltage and medium voltage).

In the case of Malta, technical losses are estimated based on the results of studies on a network that are carried out from time to time, along with the non-technical losses that are determined as the differences between the total losses and the technical losses. The studies of technical losses involve the use of electrical models applied to estimate flows in a network. Based on the latest “Distribution Losses Study” prepared by the DSO, the percentage used to calculate technical losses with reference to the units sent out to a distribution system is 3.35%. This percentage amount, however, does not include the losses in the Malta-Sicily interconnector.

In Slovenia, the methodology for determining losses is based on the withdrawal quantities of electricity. Therefore, only the percentages of losses, calculated on withdrawal quantities, are taken into account. Losses are calculated in an aggregated way, separately for the transmission levels (110 kV to 400 kV) and for the distribution levels (0.4 kV to 110 kV), but they are not determined as per the voltage levels. The calculation of losses is based on the estimation of electricity values, as they are not directly measured. The amounts of losses on the transmission system are determined based on the differences between the amounts of electricity from the production site connected to the transmission system as well as the quantity of electricity on the connecting points between the transmission and distribution systems, and the consumption of electricity from a transmission system in each year. The amount of electricity measured on the cross-border interconnectors is also relevant. Distribution losses are established on the basis of the differences between the amounts of electricity on the border between a transmission and distribution system and the quantity of electricity measured at the consumption points of the final consumers in each year. Moreover, these losses include the amount of electricity provided by the producers connected to a given distribution system.

In Egypt, losses in electrical energy are defined as the differences between the electrical energy transmitted to the outputs of lifting transformers in power plants and the electric energy actually consumed by consumers. Technical losses are defined as energy consumed by the elements of an electrical network, including transmission lines, transformers, controllers, along with protection and measurement during the transmission and distribution of electrical energy. Non-technical losses are equal to the differences between total network losses and technical losses.

In the cases of Turkey, Spain, Palestine and Lebanon, no information has been provided regarding the calculation of losses. Instead, Lebanon has reported some estimations on the impact of the reduction of losses on the financial status of its utility: a 1% reduction in either technical or non-technical grid losses can potentially increase a utility's revenues by 20 billion LBP (or an equivalent of 13.4 million USD).

2.7 Procurement of losses

Each country, as a rule, defines its procedure to deal with the coverage of power losses, regardless of the causes of losses and their natures. In most countries, power losses are borne by transmission and distribution network operators, while in some particular cases they are charged to suppliers and consumers.

Different approaches toward the procurement of losses have been reported by respondent MEDREG countries. No information has been provided in this regard by Spain, Cyprus, Egypt, Jordan, Lebanon, Malta and Palestine.

In Albania, transmission losses are handled by TSOs, which ensure that the necessary power is acquired to compensate the losses. The costs of purchasing losses in a transmission system comprise a part of the Approved Revenue Requirement for a regulatory period. Two different ways of purchasing losses in the transmission network were applied in Albania: up to the year 2017, the TSO purchased losses from the Public Generation Entity with a regulated price, and from 2018 and onwards, the purchase of losses has occurred from the market.

In the case of France, network operators are responsible for loss compensation. They carry out public consultations (to which suppliers respond) and also intervene directly on the markets until the day before delivery.

In Slovenia, both transmission and distribution system operators are responsible for the procurement of losses. On the other hand, the NRA is responsible for forecasting network losses. For each regulatory period, the NRA sets a methodology to evaluate the quantities (percentages) of losses as well as the prices to purchase the electricity that would cover those losses based on market-related future prices. The costs of covering losses are remunerated via network charges, paid by the final customers.

In Italy, the standard losses (that is, the majority of losses) are covered by network users throughout its wholesale market. They are priced in accordance with the wholesale market price with respect to supply consumption. The possible differences between the actual and standard losses transmission are procured by the TSO and the costs are subdivided among all the network users. Depending on whether these costs are positive/negative, they are finally paid/received by network users via uplift (dispatching cost-plus component). The possible differences between distribution actual and standard losses are procured by a single buyer, the subject that procures energy in a regulated market.

In the case of Portugal, the costs of power losses are borne by suppliers, as per the logic that power losses are physically injected by themselves. Indeed, suppliers are supposed to fulfil their consumption needs in the most efficient way. Thus, by having losses already included in the purchases, one can assert that the power loss procurement is optimised.

In the case of Turkey, the projected costs for losses are determined for each company by EMRA and are included in the distribution tariff. If a distribution company achieves a lower/higher loss rate than the target, it deals solely with these extra gains/losses.

2.8 Measures taken

The reduction of losses is and has been a challenge. The figures below show lower rates of losses compared to the previous years. The improvement of this situation is attributed to the measures taken by individual countries.

Depending on the identified causes of losses, MEDREG countries report that they have already taken up measures and plans to mitigate the effects of losses and reduce them altogether. Some countries have gone further by calculating the financial effects of losses, as in case of France, and the same effects of the loss reduction plan, like in the case of Lebanon. The plans developed by these respondent countries and the measures taken by them are based on the identified causes of losses and response to the specific situations in individual countries.

In the case of Jordan, because non-technical losses represent a significant part of the losses incurred, legal proceedings and debt remedy measures have been foreseen as mitigative strategies. Meanwhile, in Palestine, for the same type of losses smart meters are being installed, even though this project is still in its early stages. In Portugal, fraud cases are subject to criminal procedures divested of the prejudices of operators, who are compensated based on an estimated value.

In the case of Albania, in the last three years, several high-priority investments have been made in the distribution system, which have already had an impact on the improvement of network performance indicators in terms of the technical loss of energy, the continuity of supply of electricity to consumers and the achievement of the objectives of these indicators. Investments have been mainly focused on areas covered by high technical losses, on informal and underdeveloped areas deprived of any technological intervention and on areas marked by high energy consumption and non-technical losses. The plans for the future, in this light, include investments that are cost effective and can reduce losses, the need to be cautious about adding capital investment solely to reduce losses, loss minimisation at peak being a primary focus and Smart Grids, which is capable of dynamically optimising system operations, including losses and the elimination of the illegal connections.

In the case of Malta, the distribution system operator Enemalta, in 2013, drafted a plan to reduce the distribution losses implemented in conjunction with the IUBS-AMM project. The main aim of IUBS-AMM was to implement a nationwide rollout of smart meters that would replace the existing conventional or electronic meters at the consumption points at the final customer ends. This project also involved the development of a billing system that would be integrated with the Automated Meter Management system. The project IUBS-AMM further involved the installation of master meters at the substation level, to enable the reconciliation between the smart meters at the consumer end and the units sent out from the substation. The results of such intervention can be noticed in terms of the revenues resulting in a net revenue recovery of € 4 million per year but also in terms of the better protection of customers who were provided costly bills due to the errors in consumption recordings by the metering systems. The policy of the DSO, as of 2018, is to eliminate completely unmetered supplies.

In the case of Lebanon, the recent completion of the 220 KV loop in the “Mansourieh” area brought down these losses by around 1% and reduced the current technical losses on the transmission network to around 3%. Additional grid reinforcements are already included and approved in the national utility’s master plan, to accommodate the planned increase in the generation capacity and to further reduce the technical losses. In addition, the national utility and the Distribution System Provider (DSP) have both developed a plan for the period till 2021, targeting a reduction of total losses in the distribution system by 22%. This reduction plan shows the level of technical losses in the transmission system at the level of 4% in 2018, further targeting the reduction of transmission losses to 3.5% by 2021 and to 3% by 2025. The level of technical losses at the distribution system level is targeted to be 6% by 2021 and 5% by 2025, as compared to 13% in the year 2018. As for the non-technical losses in Lebanon’s distribution system, the actual level is 21%, while the target for the 2021–2025 period is 3%. Already, there has been a significant decrease of the technical losses in Lebanon’s distribution system, from 13% in 2018 to 9.4% in 2019, as well as the reduction of non-technical losses, from 21% in 2018 to 14% in 2019.

In the case of Greece, the distribution network operator bears the responsibility of detecting and dealing with cases of power theft. More specifically, the DSO should proceed with the following: documenting the amount of power loss, undertaking cost calculation of power loss, added to collecting and monitoring relevant debts and rendering debts to competent authorities. In order to tackle such phenomena, several legal texts concerning power theft have been adopted along with an administration-set price for the ascription of non-recorded power cost and the allocation of electricity theft debts.

In the case of Palestine, the Council of Ministers has developed and approved an instruction for customers with a huge amount of old unpaid invoices. Other instructions for disconnecting consumers due to non-payment have been adopted by the Palestinian Energy and Natural Resources Authority. In addition, pre-paid smart meters have been installed.

In Turkey, target loss and theft rates are determined for all distribution companies via an incentive regulation perspective. Meanwhile, in the case of Italy, DSOs were required to develop actions that could better detect N-TLs via improvements in the processes of recording electricity consumption, the training and management of external contractors and cooperation with justice departments to ensure effective action for cases of fraud.

The implementation of smart meters, pre-paid meters and master meters are mentioned in the cases of Spain, Portugal and Lebanon, respectively.

2.9 Applied incentives and the role of regulatory authorities

The amount of power losses constitutes a considerable part of the costs of electricity supplied in the abovementioned countries. In turn, application of incentives to transmission and distribution operators motivates them to improve their systems and components and reduces the burden on the consumer to pay for such losses.

Power losses have an important impact on the supply and demand side as well as on the efficiency of a power system. It is common knowledge that unpaid consumption implies overconsumption, with subsequent effects on electricity supply capacity and increased costs of the services provided by network operators.

The role of national regulatory authorities is evident in MEDREG countries, despite the impacts or the levels of both technical and non-technical losses. Such losses are handled under the tariff setting processes. Thus, the NRAs play a crucial role in sectoral reform by managing electricity losses in a better way. Indeed, national regulatory authorities have developed and applied regulatory mechanisms that target network operators.

The data collected by the respondent MEDREG countries indicate that there exist different and combined regulatory mechanisms across MEDREG countries that target the losses in their transmission and distribution systems.

Countries such as Albania have set up loss-target systems that reward over-performance and penalise the non-proper performances of network operators. Enforcing these schemes, national regulatory authorities have agreed to set a limit on the allowed percentage of losses that can be covered through consumers' electricity tariffs. Such mechanisms have been imposed on network operators so that they can manage all the uncovered losses above their pre-set targets.

In the cases of Portugal, Albania, Spain and France, incentives have been applied to encourage projects and investments that contribute to the reduction of extended losses.

The reference values of DSO losses for a given period is another type of incentive that serves as a reward/penalty mechanism mainly referred as pre-set target losses, target losses, or projected costs, as in the cases of Portugal, Turkey, Albania, Jordan, Italy and France. Both the reference values of DSO losses and the reward/penalty incentive mechanism allow the DSO to be rewarded if the level of losses is found to be lower than the pre-set target.

The implementation of smart meters, pre-paid meters and master meters, as in the cases of Spain, Palestine, Portugal, Malta and Lebanon, is also mentioned.

Demand side management is another measure considered by the regulators. In this regard, peak demand mechanisms (through differential tariffs) to reduce demand and to increase the efficiency of electricity systems were introduced in Spain and Malta.

Specific mechanisms that fit the characteristics and geographical conditions or, as in the case of *France*, an incentive of control expenses in relation to loss compensation, have been introduced in the non-interconnected islands in Italy and France, as well as in specific regions throughout the countries that display higher rates of illegal consumption.

In the case of Slovenia, the regulatory authority NRA is responsible for forecasting network losses. For each regulatory period, the NRA sets the methodology using which to evaluate quantities (percentage) of losses and the price of purchasing the electricity that can cover such losses, based on market-related future prices. An incentive for the TSO and the DSOs has been introduced in the new methodology for the regulatory period 2019–2021, which consists of the reduction of the prices of losses (for which the TSO and DSOs are placed in charge) and are applied to cases when the achieved price for the purchase of electricity (to cover losses) is lower than the reference price set by the given regulator.

Another key incentive mechanism used by countries relies on the implementation of intelligent metering systems, especially to handle the non-technical losses caused by human behaviours. The analyses of case studies provided by some MEDREG members shows the introduction of incentive schemes based on proper characterisation of the respective countries. The fact that data on how the pre-set targets and other related inputs of losses set by regulators are unavailable makes it difficult to prepare an assessment of the proper incentives to be used. However, in the first place it still allows the assessment of the different incentive mechanisms used to reduce losses at the transmission and distribution levels.

3 Conclusion and Recommendations

As discussed previously, the concept of electricity losses and their impacts may vary significantly among countries. In all case studies concerning the respondent MEDREG members, electricity losses are defined as technical and non-technical in nature.

Technical losses are caused mainly by the following:

- Inadequate equipment capacity;
- Old infrastructure such as old lines, meter readings etc.

The causes of the commercial losses have been identified as follows:

- Illegal connections;
- Metering problems;
- Billing challenges;
- Collection challenges.

MEDREG members have implemented different forms of incentives to reduce electricity loss, of which the most common is the application of a reward/penalty mechanism and modernisation, such as the implementation of intelligent meters (as described above).

Both technical and non-technical losses are regulatory issues, and financial incentives for the initial loss targets might be set via benchmarking with the required annual improvements and together with a balance between consumer–utility benefits.

Developing roadmaps and strategies is a key component with respect to addressing the losses in the power sector. Infrastructure upgrades, including new metering and smart grids, seem to be one of the first steps of loss reduction, but those alone cannot be the only solutions. Loss reduction strategies should first identify the strengths and weaknesses in terms of the internal organisation of a utility, network development and consumer profile/category programs. By classifying consumers based on the volumes of electricity they consume, a utility could better identify its revenues and how they are affected by consumer behaviours. For example, industrial consumers may comprise the minority with regard to the total number of consumers of a utility. However, on the other hand the electricity supplied to them may constitute an important part of the utility's revenues.

In relation to non-technical losses, the concern from a regulatory prospective is with the extent to which non-technical losses can be included in the allowed revenues. Non-technical losses, as reported by France, are indirectly borne by all consumers who pay their bills and also amount to a legislative issue. This is because they affect the legal means of keeping people responsible for actions like electricity theft and impose economical penalties not only as part of the damages recovered but also as a question of law enforcement.

The reduction in N-TLs is linked to the reallocation of revenue and benefits between consumers and utilities that provide electricity services, as not only does it affect the financial sustainability of utilities, but the increased billing (in parallel with cost reductions) would translate to a possible benefit for consumers.

In cases of electricity losses, it is imperative to consider the low-income consumer programmes. Considering the levels of losses in different MEDREG countries, an in-depth analysis of the impact of high prices on the levels of losses may be fruitful. Under the pressure of higher prices, consumers tend to avoid electricity payments through late payment or even via illegal connections. For the purpose of N-TLs, some other reduction steps might include the following:

- Monitoring service connections and the energy consumption of customers;
- Automating commercial management systems;
- Installing meter database management systems;
- Using smart metering technologies/applications.

Proper consumer programmes for the reduction of non-technical losses are important, considering that illegal consumption has both direct and indirect effects. As explained above, large consumers serve as an important source of revenues for utilities, but on the other hand, the phenomenon of consumers paying for the costs of the illegal consumption of electricity incurred by others has a negative effect on law-abiding consumers who would ideally want to be billed according to their consumption instead of the additional costs related to this consumption.

MEDREG members have identified a wide range of circumstances as sources of non-technical losses. Typical cases include theft of electricity through illegal connection to a grid, inaccurately metered data consumption etc. In this view, investing in the organisational management of a utility requires the regulator to properly address the issue of technical losses in a rate setting process.

The reduction of technical losses in electricity transmission and distribution grids is a matter of technology that involves power network development, regardless of the organisation of the power sector and the ownership of operating electricity utilities. Both vertically integrated and unbundled operators face electricity losses. In any case, instances of loss reduction are products of common actions in regulation, by technical and organisational management and qualified staff, via consumer engagement and technology implementation.

Regulatory authorities have a direct effect on overall utility performance, considering that regulatory authorities typically are responsible for the following:

- Tariff methodologies and the price setting of monopoly activities in the electricity sector. A proper tariff methodology that reflects reasonable costs allows a continuous and efficient network operation under service quality standards;
- Approval of network plans for transmission and distribution network operators. Indeed, regulators must assure, through network investment plans, the role of technologies as investments in information technology (SCADA, DMS, OMS etc.) and provide efficient measures to avoid attacks on such networks due to technological interventions in their daily operations.

Furthermore, electricity loss reduction requires a periodic monitoring of the actions taken and their efficiencies in terms of utility and consumer profits. In such a case, the use of technology through real-time data transfer and by creating reports of performance monitoring is recommended.

In any case, the selection of loss reduction actions requires the need to address the characteristics of each country's electric system, to identify the following:

- Types of losses as technical or non-technical. In some countries, illegal consumption is not reported as a challenge, but for other countries within MEDREG, thefts and cases of illegal consumption are reported as having a direct impact on the levels of non-technical losses.
- Types of consumers and specificities that characterise the geographical/urban areas, in which each DSO operates, in relation to the possible different geographical distribution of network losses.
- Cost and benefits parameters, referring to the present statuses and future targets of losses (in terms of costs) to realise the desired targets/goals in the power sector.
- Stakeholders' regulator/utility and consumer engagement is crucial. Without the three factors collaborating, the possibility of a successful program taking place is limited.

4 Annex –Power losses data from the case studies

MEDREG Country members report on electrical losses

Countries		Received report	Responsible institution	Main features of electrical losses in the system
1	Albania	✓	ERE	***Data on power system;*** ***Transmission losses;*** ***Distribution losses;*** ***Identified reasons for electrical loss:*** ○ Overload. ○ Old technology. ○ Low efficiency. ○ Lack of capital investments. ○ Illegal connections in the network. ○ Lack of renovation and modernisation. ○ Poor repair services and maintenance. ***Regulatory incentives;***
2	Cyprus	✓	CERA	***Transmission losses;*** ***Identified factors causing transmission loss:*** ○ Peak load. ○ Wind park capacity factor. ○ Reactive power load installation of reactors. ○ Energy injection from distribution system due to dispersed generation. ○ Backbone system transmission lines capacity factor. ***Distribution losses;***

Countries		Received report	Responsible institution	Main features of electrical losses in the system
3	Egypt	✓	Egypt Era	***Definitions of losses;*** ***Data on power system;*** ***Cause of technical losses:*** ○ Inequitable distribution of production and consumption centres. ○ Significant expansion of the medium- and low-distribution networks without the corresponding construction of more adequate substations. ○ Provision of transport and distribution networks. ○ Lack of some electrical networks that serve as monitoring and protection systems. ○ The absence of a good program for the periodic maintenance of electrical networks. ○ Lack of investment necessary to implement the necessary electrical projects. ○ The growing population explosion. ○ Failure of laws and regulations enforced regarding the investment and consumption of electrical power. ***Causes of non-technical losses:*** ○ Illegal consumption. ○ Errors in meter readings. ○ Deviations in the work of energy meters. ○ Disruption of meters and inability to record the amount of energy consumed. ○ Difficulty raising the meter reading in some houses. ***Procedures in place to deal with TL and NTL;***
4	France	✓	CRE	***Definitions of losses;***

Countries		Received report	Responsible institution	Main features of electrical losses in the system
				Data on power system; ***Legal aspects;*** ***Calculation of losses;*** ***Total losses*** represent nearly ***6%*** of the energy transmitted through a network, and network operators are responsible for loss compensation. ○ Low levels of losses in a transmission and interconnection network. ○ Average loss rate being 10.9% in the 2013–2016 period. ○ Installing advanced metering systems can prevent non-technical losses. ***Incentives;***
5	Greece	✓	RAE	**Definitions of losses;** **Transmission losses;** **Distribution losses;** **Calculation of losses:** Transmission losses and distribution losses on an annual basis, separately for each voltage level (low voltage and medium voltage). ***Non-technical losses*** are caused by thefts and remain the major problem for the DSOs.
6	Italy	✓	ARERA	***Definitions of losses;*** ***Data on total losses*** represents an average of ***6.2%***. The majority of losses (***Standard losses***) are covered by network users throughout the wholesale market. Factors that affect loss reduction are geographical distribution and different operating conditions of a network. ***Non-technical losses*** and ***mitigation of NTL;*** ***Regulatory and incentives mechanism;***
7	Jordan	✓	MEMR	***Data on power system;*** ***Calculation of losses:*** Losses are calculated by network type (transmission and distribution) and voltage level (HV, MV, LV)

Countries		Received report	Responsible institution	Main features of electrical losses in the system
				Non-technical losses are caused by thefts and metering errors ***Technical Losses*** arise due to long feeders, a high level of distance between each MV/LV substation, the low power factor of the LV system and the functionality of distribution transformers. ***Procurement;*** ***Regulatory incentives;***
8	Lebanon	✓	LCEC	***Data on losses in transmission and distribution;*** A total of 38% losses in the power sector. The most significant amount of losses, including technical and non-technical losses, is observed at the level of the distribution system. ***Causes of losses in the transmission network:*** ○ deficiency in maintenance. ○ insufficient capital investments. ○ high loading levels. ○ need for modernisation. ***Causes of losses in the distribution system;*** ***Loss reduction plan;***
9	Malta	✓	REWS	***Data on power system;*** ***Definitions of losses;***

Countries		Received report	Responsible institution	Main features of electrical losses in the system
				Malta does not have any transmission system. Its electricity system is connected to Italy's transmission system. There is no legal definition of "distribution losses" in Malta. It is noted that with the passage of time, efforts to reduce technical and non-technical losses have brought positive results. ***Causes of technical losses:*** ○ Energy losses in transformers or conductors, even if no electricity is delivered to customers. ○ The main source of fixed losses is "core" or iron loss in transformers. ○ Variable technical losses occur due to the internal resistance of conductors. ***Causes of non-technical losses:*** ○ Measurement errors, ○ Delayed activation of accounts and/or un-activated accounts ○ Data collection errors ○ Unmetered supplies ○ Theft and fraud ○ Delayed invoicing ○ Unmetered street lighting ***Loss reduction activities;***
10	Palestine	✓	PERC	***Data on losses;*** ***Definitions of losses;*** ***Technical losses*** are caused by the physical properties of the components of a power system, such as the power dissipated in distribution lines, measurement systems and transformers due to internal electrical resistance. ***Non-technical losses*** are caused by electrical thefts, faulty energy meters, errors and delays in meter readings, billings and non-payment by customers. ***Loss reduction procedures;***
11	Portugal	✓	ERSE	***Categories of losses*** are calculated in relation to network type and voltage level. Losses include physical losses, unavoidable thefts and metering errors. Power losses are physically injected by suppliers. ***Evaluation;***

Countries		Received report	Responsible institution	Main features of electrical losses in the system
				Tariffs and regulation; ***Incentive regulatory mechanism in place***;
12	Slovenia	✓	AGEN-RS	***Definitions of losses;*** ***Transmission losses;*** ***Distribution losses;*** ***Regulatory framework;*** ***Procurement***: Both transmission (TSO) and distribution (DSO) system operators are responsible for the procurement of losses. The costs of covering losses are remunerated by a network charge that is paid by the final customers. ***Technical losses*** are defined as physical losses. ***Non-technical losses*** include the following: o Non-metered consumption. o Theft. o Metering errors. o Differences in metering. Billing and data processing.
13	Spain	✓	CNMC	***Types of losses;*** ***Technical losses*** arise due to the demand reduction, that increases the weight of fixed losses; e.g. in transformers (MT/LT). ***Causes of non-technical losses:*** o Fraud. o Insufficient regulatory incentives. o Smart metering deployment and demand increase seem to mark an improvement in network electricity losses. ***Measures for reduction of losses;***
14	Turkey	✓	EMRA	***Data on power system;*** Turkey established a new Electricity Market Law in the 30th of March, 2013. ***Data on losses***: Turkey's system is operated by TEİAŞ, which is successful regarding energy losses, with loss ratio of 1.9% in 2018.

Countries		Received report	Responsible institution	Main features of electrical losses in the system
				Incentive regulation perspective: Energy losses are decreasing significantly after the privatisation of DSO's. Target loss and theft rates are determined for all distribution companies via an incentive regulation perspective. The projected costs for loss and theft are determined by the EMRA for each company and are included in the distribution tariff. ***Causes of energy loss*** emerge from a distribution network.