Cost-benefit analysis of advanced metering in Slovenia

Final Report

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The English version of this document is a translation from the original Slovene text. In case of discrepancies between the two versions, the Slovene version shall prevail.

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LIST OF ABBREVIATIONS

AGEN-RS	Public Agency of the Republic of Slovenia for Energy
AMM	Automated Meter Management
BPS	Billing Pricing System
CB1	Cost benefit item
CBA	Cost benefit analysis
CHP	Combined Heat and Power
CRMS	Customer Relationship Management System
DSM/DR	Demand Side Management / Demand Response
DSO	Distribution System Operator
DU	Distribution Utility
EC	European Commission
EDI	Electronic Data Interchange
EDM	Energy data management
EDMS	Energy Data Management System
EL	Energy Law
ESCO	Energy Service Company or Energy Savings Company
EU	European Union
GIAI	Global Individual Asset Identifier
GPRS	General Packet Radio Services
GSM	Global System for Mobile Communications
HAN	Home Area Network
HES	Head End System
IDIS	Interoperable Device Interface Specifications
IHD	In Home Display

IRR	Internal Rate of Return
MC	Metering Centre
MDMS	Meter Data Management Systems
MMS	Metering Management System
NPV	Net Present Value
PLC	Power Line Communication
PTP	Point-to-point
RF	Radio Frequency
SCADA	Supervisory Control and Data Acquisition
SCSN	Service Centre for Smart Networks
SG	Smart Grid
SM	Smart Meter
WAN	Wide Area Network
WiMAX	Worldwide Interoperability for Microwave Access
WMS	Workforce Management System

EXECUTIVE SUMMARY

Directives 2009/72/EC and 2009/73/EC suggest to EU Member States to evaluate the costs and benefits of a roll-out of smart metering in the areas of electricity and natural gas within the framework of an economic cost-benefit analysis (hereinafter "CBA"). To conduct such an economic CBA the Energy Agency of the Republic of Slovenia (hereinafter "AGEN-RS") has contracted a Consortium of DNV KEMA and Korona.

A CBA is a common tool used for investment decision making by systematically comparing the long-term costs and benefits arising over the life span of an investment project for all relevant groups of stakeholders. Objective of this study is accordingly to evaluate the possible impact of a roll-out of smart metering for electricity and/or gas in Slovenia for all stakeholders directly or indirectly affected under different scenarios. In addition, also qualitative evaluations on the preferred scope and the framework of a smart metering roll-out have been conducted. The results of these assessments are presented within this report.

Smart metering service model

Based on the four smart metering service models proposed by AGEN-RS, the establishment of a new independent entity, the Service Centre for Smart Networks (SCSN), carrying out the role of metering data aggregator, has been recommended in case of a joint roll-out of smart metering for electricity and gas. The establishment of the SCSN has the advantage to provide easy and non-discriminatory access to all necessary data, which may particularly facilitate the development of multi-utility smart metering services. A single point of contact for suppliers and other market participants may also be more transparent and understandable and may be associated with less cost for market participants.

The integration of the SCSN and the electricity distribution system operator (DSO) within a single entity may support a more efficient (less costly) exchange of metering data for suppliers and other stakeholders. In addition, such model may also have the advantage that it is easier and quicker to implement, since it may require smaller adjustments to the existing legal framework and since some of the existing infrastructure and resources of the electricity DSO may partly be used for the set-up of the SCSN.

Depending on whether a roll-out of smart metering is considered for both electricity and gas or only for electricity, the establishment of a joint communication infrastructure (in the first case) has been recommended, enabling synergies and avoiding duplications of investment and operational costs.

Smart meter functionalities and services

AGEN-RS has defined a set of (basic) mandatory functionalities for electricity and gas smart meters, to be considered for a roll-out, as well as a set of optional functionalities and associated smart metering services, which can provide significant additional benefits. Standard types of smart meters currently offered on the market however now more or less provide most of these optional functionalities, following standardisation efforts on European level as well as developments by smart meter manufacturers. Main differences in the costs of smart meters are therefore generally not to be found in the listed functionalities, but in the communication interfaces (e.g. GSM/GPRS or PLC) and in the number of measured phases (one phase or three phase meters). Smart meters with very distinctive / selective sets of functionalities would also come at an extra cost, since smart meters currently on the market tend to be very much standardised across manufacturers and any adjustments to these sets would need to be specifically calibrated by the manufacturers.

CBA results

To account for Slovenian country characteristics, specific Slovenian data has been applied wherever possible. For this purpose we have sent questionnaires with detailed data requests to the electricity distribution utilities and the electricity and gas DSOs and suppliers of Slovenia. Wherever sufficient and credible data has been provided to us by the distribution companies, we have included these in our assessment. Furthermore information provided by AGEN-RS as well as information from publicly available sources for Slovenia have been considered for the specification of the various input parameters of the CBA. Wherever such country specific information has not been available, international data from other CBAs, studies and pilots as well as data gathered from manufacturers conducted in comparable countries have been considered.

Within the framework of the CBA it could be shown that a mandatory roll-out of smart electricity metering can generate significant net benefits for Slovenia. Such net benefits would be largest when a fast roll-out (such as an 80% deployment target up to 2020) is conducted and when a high percentage of PLC/GPRS or PLC/WiMAX can be applied (e.g. 95%). Costs discounted to their present value will be particularly high at the beginning of a smart metering roll-out, whereas significant discounted benefits will arise over a much longer period. It will therefore take at least one investment cycle for smart meters until discounted costs are outweighed by discounted benefits. These results are quite robust to changes in the assumptions for key input parameters as could be shown within the sensitivity analysis and a stochastic Monte Carlo Simulation. When further additional benefits – which could not be assessed within the CBA – are considered in the evaluation, higher net benefits for an electricity smart metering roll-out are to be expected; this includes for example likely cost reductions of asset management and call centre costs of the DNOs/DSOs, reduced generation capacity investments and positive impacts on competition following a roll-out of smart metering.

A joint mandatory roll-out for electricity and gas would provide net benefits only for some roll-out scenarios. A break even between discounted costs and benefits will however only be achieved in the most beneficial scenario after 25 years, which may be considered too long-term when uncertainty on future developments is considered. Even more so as the results are quite sensitive to the values of key input parameters. Furthermore, given the much smaller number of gas meters, positive NPVs estimated for some joint roll-out scenarios may partly if not largely been driven by the positive electricity results, as could be shown, when compared to a gas only scenario (which is associated with large and significant net costs).

A natural roll-out can neither be recommended for electricity nor for gas unless it is conducted on a voluntary basis and costs are not cross-subsidised by other stakeholders not benefitting from smart metering.

Following the decision for a (mandatory) roll-out, a precise implementation plan should be specified covering the required roll-out, both in terms of time (start and end date and possible intermediate targets) and volume of meters to be replaced (i.e. the deployment target). The plan must include clearly defined milestones and responsibilities and should serve as the common point of reference for all involved market parties alike.

Data privacy and data exchange

Before a roll-out takes place, provisions should be implemented to ensure that personal data is not accessed by unauthorized parties and that there are clear regulatory provisions on how data is gathered, processed, stored and evaluated, and who has access to which data for legitimate purposes. This should include technical and procedural measures for a secure data communication (e.g. data encryption), explicit rules on data access, handling and disclosure to third parties, as well as the monitoring and enforcement of this framework. Further recommended measures include provisions to limit the type and amount of data that can be collected to clearly and properly defined purposes, to limit the time for which data can be kept, and to anonymise personal data.

Cost allocation

Since the metering task will remain part of the regulated DNOs/DSOs, allocation of efficient smart metering investment and operational costs will mostly take place within the regulatory network price control. It will be a key task for AGEN-RS to make sure that only efficient and only net costs (i.e. costs of smart metering minus the benefits / costs savings arising to the DNOs/DSOs) are passed on by the DNOs/DSOs to other stakeholders (e.g. to the consumers via network charges).

As a first step we recommend to adjust the cost reporting mechanism to ensure that costs for smart metering are reported separately to AGEN-RS in a transparent and accurate way. It would allow AGEN-RS to assess the real costs of the roll-out and to control for the efficiency of these costs. Provisions for cost reporting should be accompanied by cost allocation guidelines, which define how specific cost items have to be allocated to different segments. Transparency on the smart metering costs can furthermore be increased, when the net costs are recovered by a separate metering charge or a smart metering system charge.

1 INTRODUCTION

Directives 2009/72/EC and 2009/73/EC suggest to EU Member States to conduct an economic cost-benefit analysis (hereinafter "CBA") for the roll-out of smart metering in the areas of electricity and natural gas by 3rd of September 2012 (unless a roll-out has already been carried out). If such analysis provides a positive assessment for a roll-out, a timetable for the implementation of 'intelligent metering systems' needs to be prepared. Following a positive assessment smart metering systems have to be installed for at least 80% of electricity customers by 2020 and a timetable for the implementation within 10 years has to be prepared. For gas no firm time horizon for implementation is provided in the EU Directive.

To conduct such an economic CBA for the roll-out of smart metering in the domains of electricity and natural gas the Public Agency of the Republic of Slovenia for Energy (hereinafter "AGEN-RS") has contracted a Consortium of DNV KEMA and Korona. Objective of this project is accordingly to evaluate the long-term costs and benefits for different stakeholders in the Slovenian market and the society as a whole that would result from a roll-out of smart metering under different scenarios. Taking into account the requirements specified in EU and Slovenian legislation, the specifics of the Slovenian energy market, the smart metering service models proposed by AGEN-RS as well as other documents published by AGEN-RS,[1] the study should support AGEN-RS in determining the optimal scope, manner and pace of a roll-out of smart metering in Slovenia. Furthermore the study shall assess and provide recommendations for the funding of a smart metering roll-out.

In doing so, this final report describes the legal framework for smart metering and explains the applied CBA methodology. It discusses the results of the CBA for different roll-out scenarios and provides recommendations related to data privacy and the cost recovery of the smart meter investments, both of which can be crucial barriers for a successful deployment of smart metering. The final report is structured as follows.

The following chapter 2 describes the legal framework and requirements set by the EU as well as the relevant legislative framework of Slovenia. The general tasks of the various stakeholders in relation to smart metering and their expected major costs and benefits are discussed in chapter 0. The four smart metering service models proposed by AGEN-RS are assessed in chapter 4; within the same chapter also a detailed description of the properties of the preferred model is given. In chapter 5 we provide a qualitative assessment of smart meter functionalities and services and specify the smart meter functionalities applied in the CBA. Chapter 0 compares the approaches of recent CBAs for smart metering conducted in other European countries. The proposed methodology for the CBA and the scope of the CBA analysis are explained in chapter 7, including a specification of the modelling assumptions and the scenarios assessed within the CBA. Chapter 8 discusses and analyses the results of the CBA and

[1] In 2010/2011 AGEN-RS has already prepared a number of studies, most notably the "Guidelines for the introduction of smart metering in Slovenia", outlining possible roles and responsibilities for the implementation of smart metering and functionalities that advanced metering services should provide. In addition, also the terms of reference for this project define specific requirements to be taken into account when analysing costs and benefits of a smart metering roll-out in Slovenia.

evaluates the impact of variations in the model input parameters on the results of the CBA (sensitivity analysis). Data exchange and data privacy are addressed in chapter 9, whereas the issue of cost recovery is analysed in chapter 10. The report concludes with a short summary and recommendations for a roll-out of smart metering in Slovenia (chapter 0). In addition, we have attached an appendix to this report presenting further details on the specific input data we considered for each cost and benefit item for electricity and gas within our CBA framework.

2 LEGAL FRAMEWORK FOR SMART METERING

Specific requirements for the methodology and the elements of an economic CBA for smart metering are provided in the legal framework of the EU, while on national level the relevant provisions of the EU directives have not been implemented in Slovenia yet. On EU level, *Directives 2009/72/EC* and *2009/73/EC* among others set the legal requirement to conduct an economic CBA, while *Commission Recommendation 2012/148/EU* provides further recommendations as regards the methodology and the elements of an economic CBA including a non-exhaustive list of variables and data to be set or collected as inputs for the economic CBA modelling.

Within the legislation in force and the present regulatory framework of Slovenia, provisions for smart metering are subject to on-going discussions. The relevant provisions on smart metering of the EU Directives have not been implemented in Slovenia yet. AGEN-RS has however published *Guidelines for the introduction of smart metering in Slovenia* outlining possible roles and responsibilities for the implementation of smart metering and functionalities that advanced metering services should provide.

The following sections briefly describe the EU legal framework and requirements as well as some requirements relevant for envisaged legislation of Slovenia in this domain.

2.1 EU legal framework and requirements

The current EU legal framework for smart metering is particularly set by the Directives on the internal markets for electricity and gas (*2009/72/EC and 2009/73/EC*)[2]. Requirements to promote and implement smart metering – or as the Directives specify it 'intelligent metering systems' – are defined in Annexes I of both Directives. The implementation of smart metering shall – according to the Directives – *"assist the active participation of consumers in the electricity/gas supply market. The implementation of those metering systems may be subject to an economic assessment of all the long-term costs and benefits to the market and the individual customer or which form of intelligent metering is economically reasonable and cost-effective and which timeframe is feasible for their distribution. Such assessment shall take place by 3 September 2012.*" For gas, only the preparation of a timetable for smart metering implementation is required, subject to economic assessment. For electricity, a time horizon of ten years is set for the implementation timetable. Furthermore, if a roll-out is assessed positively, Member States are required to ensure that 80% of consumers are equipped with intelligent metering systems by 2020.

Implicit requirements for the implementation of smart metering can also be drawn from *Directive 2012/27/EC*[3] on energy efficiency.[4] Article 9 of the Directive requires that "*final customers are pro-*

[2] *Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC*, and *Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC.*

[3] *Directive 2012/27/EC 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 Directives 2004/8/EC and 2006/32/EC.*

vided with competitively priced individual meters that accurately reflect the final customer's actual energy consumption and that provide information on actual time of use".[5] However, the requirement is subject to technical feasibility, financial viability and the ability to potential energy savings. Where smart meters are rolled-out, existing meters are replaced, a new connection is made in a new building or a building undergoes major renovations, information on actual time of use shall always be provided to final customers.[6]

Within the legal framework of the EU directives no further details are provided as regards the methodology of the economic assessment of the costs and benefits of a roll-out of smart metering – in fact not even the framework of an economic cost-benefit analysis (CBA) is explicitly mentioned as such in the Directives. However, for electricity further recommendations concerning the framework of an economic CBA and possible variables to be assessed are given in *Commission Recommendation 2012/148/EU*[7], which itself is a summary of the "*Guidelines for cost-benefit analysis of smart metering deployment*" from the European Commission Joint Research Centre Institute for Energy and Transport.[8] When assessing the roll-out of smart metering within the framework of an economic CBA a wide range of costs and benefits (including environment externalities) should be taken into account. The Annex of the Recommendation provides non-exhaustive lists of model input variables and possible cost and benefit categories to be considered for the assessment of a roll-out of smart metering for electricity consumers. Furthermore, also recommendations for the quantification and monetization of possible benefit categories are provided. A consistent, credible and transparent assessment should further include a sensitivity analysis of critical input variables and different forecast scenarios, including at least the comparison of a "*business as usual (do nothing and nothing happens)*" scenario with a 80% roll-out scenario of smart metering for 2020 (i.e. assessing the incremental impact of a roll-out of smart metering). In addition, the Recommendation also outlines recommended measures in the area of data protection and data security and common minimum functional requirements of smart metering systems.

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[4] The adoption of real-time advanced metering systems by EU Member States is also encouraged in Article 5 of *Directive 2005/89/EC of the European Parliament and of the Council of 18 January 2006 concerning measures to safeguard security of electricity supply and infrastructure investment.*

[5] *Directive 2006/32/EC of 5 April 2006* (preceding *Directive 2012/27/EC*) was transferred into the Member States' national legislation quite differently and only in a few Member States has it led to a requirement to install smart meters.

[6] This provision is also mentioned in *Directive 2010/31/EC of the European parliament and of the council of 19 May 2010 on the energy performance of buildings* specifically in Article 8: "*Member States shall encourage the introduction of intelligent metering systems whenever a building is constructed or undergoes major renovation, […]*".

[7] *Commission Recommendation (2012/148/EU) of 9 March 2012 on preparations for the roll-out of smart metering systems*.

[8] Further details on the methodology of a CBA (although in a slightly different context) are also provided in a guide by DG Regio (European Commission, Directorate General Regional Policy (2008): *Guide to Cost Benefit Analysis of Investment Projects*) and in *EU Regulation No 347/2013 of the European Parliament and of the Council of 17 April 2013 on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC and amending Regulations (EC) No 713/2009, (EC) No 714/2009 and (EC) No 715/2009/EC* .

Whereas the directives described above set the requirements for smart metering installation, *Directive 2004/22/EC*[9] on measuring instruments sets the general technical requirements for metering appliances including smart metering appliances. It contains technical provisions for metering devices for electricity, gas, water and for other liquids, heat meters, scales, etc. Based on the subsidiary principle, *Directive 2004/22/EC* only includes regulations covering the process until the metering device is offered on the market or brought into operation. Further requirements during the lifetime of the meter, regarding calibration, tolerances, etc. are subject to national legislation.

2.2 Slovenian Legal Framework

The *acquis communautaire* requires EU Member States to transpose the above provisions into national laws and regulations in accordance with the characteristics and rules of national laws governing the respective fields. Implementation of the EU Directives also requires the modification of existing and/or the adoption of new primary and secondary legislation (i.e. rules, regulations, ordinances and by-laws).

In the current Slovenian law, the basic legal regulation governing the relevant field of energy is the *Energy Law - EL* (Official Gazette of the RS (hereinafter "OG RS"), nos. 27/2007 - UPB2, 70/2008, 22/2010, 37/2011, 10/2012, and 94/2012). Further details are specified in a number of by-laws as well as in other regulations and rules. The relevant provisions of the EU Directives in the area of smart metering (most notably *Directives 2009/72/EC* and *2009/73/EC*) have not been fully implemented into Slovenian national legislation yet. Only some elements of the EU Directives also relevant for smart metering are to some degree already implemented in the existing Slovenian legislation. This includes in particular requirements of non-disclosure of commercially sensitive information to third parties,[10] interoperability of metering systems and their standardization,[11] information suppliers are required to publish on the invoices for their end-customers[12] and measures to promote energy efficiency.[13]

Also an amendment of the *Energy Law* (i.e. *EL-1*) is already under preparation and expected to implement –among others– the missing provisions of the respective EU Directives in Slovenian legislation rather soon. A draft proposal of the new *EL-1* had already been published in June 2013, and has been recently submitted in the parliamentary procedure.[14] As specified in the text from June 11 2013,

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[9] Directive 2004/22/EC of the European Parliament and of the Council of 31 March 2004 on measuring instruments

[10] This subject matter is regulated in existing Slovenian legislation in Article 39 of the *EL*.

[11] See for example Article 40 of the current *EL*.

[12] The current *EL* in Article 19/5 provides only some of the elements that suppliers must publish on the invoices for their end-customers.

[13] See on the promotion of energy efficiency for example, Articles 65 and 66 of the *EL*

[14] A recent version of the *Proposal* (as of 1.10.2013) can be found on: www.vlada.si/delo_vlade/gradiva_v_obravnavi/gradivo_v_obravnavi/?tx_govpapers_pi1%5Bsingle%5D=%2FMAN-DAT13%2FVLADNAGRADIVA.NSF%2F18a6b9887c33a0bdc12570e50034eb54%2Faf2b0467a6fbb2b7c1257bf6005a35b6%3FOpenDocument&cHash=0dc61267160ce36b755c221ccaa29a38

Articles 42 and 158 of the *EL-1* will implement the provisions of Article 3 (11) of *Directive 2009/72/EC* and Article 8 of *Directive 2009/73/EC* into Slovenian law. [15] Further decisions, subsequent by-laws, and general acts of AGEN-RS are expected to define relevant actions, deadlines, procedures and standards on smart metering in more detail,[16] depending on the results of the CBA and on the final political decision whether and to what extent to implement smart metering in Slovenia. This includes for example the adoption of appropriate technical regulations as well as objective and non-discriminatory harmonized (where necessary) functional requirements and technical rules in this domain.

Since the amendment of the Slovenian *Energy Law* will likely implement smart metering provisions closely to the text of the EU Directives and since more detailed provisions on smart metering (beyond the European provisions) are not yet provided within the Slovenian legislation, smart metering is throughout this report primarily assessed on the basis of the relevant European provisions.

Further details on the functional requirements for smart metering and the provision of smart metering services in Slovenia are summarized and elaborated in the *Guidelines for the introduction of advanced metering in Slovenia*[17] and the *Specification models of advanced metering in Slovenia*[18] both published by AGEN-RS. We will further evaluate the smart metering service models proposed by AGEN-RS in chapter 4 and possible smart meter functionalities and services in chapter 5.

[15] E.g., the current *EL* in Article 19/5 now provides only some of the elements that suppliers must publish on the invoices for their end-customers.

[16] See for example Articles 39-40, 42 and 47-48 for electricity and Articles 157-158 and 167-168 for gas of the *Proposal of the EL-1* as of June 11, 2013.

[17] AGEN-RS (2010/2011): Guidelines for the introduction of advanced metering in Slovenia. AGEN-RS's Guidelines reflect the recommendations provided by ERGEG in their Guidelines of Good practice (ERGEG (2011): Final Guideline of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas, Ref: E10-RMF-29-05)

[18] These have been published by AGEN-RS together with the tender documentation for this project in December 2012.

3 SMART METER STAKEHOLDERS AND THEIR COSTS AND BENEFITS

The term *smart metering* is used in a broad context and is often defined in a variety of ways. In order to provide clarity about the design of a smart metering system and the subsequent (possible) roll-out decision it is necessary to provide an unambiguous definition of smart metering. In line with EU Directives 2009/72/EC and 2009/73/EC (and the European Commission's Interpretative Note on the Directive)[19] as well as the European Regulators' Group for Electricity and Gas (ERGEG) Guidelines of Good Practice (GGP)[20] we define smart metering within this report and CBA generally as follows:

Smart metering is the application of smart meters on a large scale that enables automatic (remote) reading, processing and transmission of metering data and the possibility of bidirectional data communication in real-time (or with only a small time lag). Furthermore, smart metering supports additional services and applications on the consumer's side, such as home-automation or remote (dis-)connection of supply. Thus, smart metering is much more than the individual smart meter installed at an energy consumer's house or facility metering the consumer's energy consumption. Smart metering includes a complete smart metering infrastructure, which basically consists of the following main elements:[21]

- Metering device and associated devices on the consumer's premises (optionally connected to a smart home unit controlling household appliances, for instance based on tariff information, in case demand side management is applied)
- Optionally, a graphical display within the consumer's living space providing actual real-time meter data and eventually information on tariffs or other relevant data (in-home display, IHD)
- Communication and data processing infrastructure between the devices on the consumer premises and the back-end systems
- Information systems at the metering operators back-end that provide necessary energy and metering data to billing and invoicing systems of the supplier and optionally to the consumer, e.g. on a web page, and to other relevant stakeholders as well as information systems required for the management of the smart meters (see also section 4.7.4)

Based on the above definition of smart metering several stakeholders can be identified, which are either directly or indirectly affected from a roll-out of smart metering.

[19] European Commission (2010): Interpretative Note on Directive 2009/72/EC Concerning Common Rules for the Internal Market in Electricity and Directive 2009/73/EC Concerning Common Rules for the Internal Market in Natural Gas – Retail Markets, Commission Staff Working Paper

[20] ERGEG (2011): Final Guideline of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas, Ref: E10-RMF-29-05.

[21] Further details of different smart metering functionalities and services and their evaluation are provided in a separate chapter (5).

Distribution network owner and distribution system operator

In its role as metering operator the DU/DSO[22] is responsible for the installation and the operation of the smart meters and the smart metering infrastructure. As such the DSO has to carry out and finance (at least in the first place) the investment in smart meters and the communication and data processing infrastructure necessary to establish a smart metering system. Depending on the regulatory framework (see chapter 10) much of these costs may be further passed on to other stakeholders (most notably the consumers) through network or specific metering charges.

With smart metering, digital meter data are automatically submitted to the meter data centre. Manual meter readings and the manual entering of meter data into data management systems are therefore no longer required. Data can be easily processed and evaluated and meter-to-bill operations can be significantly improved. Integrating smart meters into the IT infrastructure of the network operator can also help to optimize processes and reduce operational costs (process optimization). For electricity, not only the meter reading, but also the disconnection and reconnection of customers can be handled remotely and (partly) automatically, reducing the need to send out technicians to customer sites to suspend and resume electricity supply.[23]

A wide deployment of smart metering provides the DSO with precise information on the actual consumption and feed-in at specific sites of its low voltage/pressure distribution network. Electricity network operators will be able to improve security of supply by faster fault detection and location, faster power restoration, improved monitoring of voltage quality, the ability for quick remote disconnection or reconnection of customers and the ability for remote reduction or restoration of power. Reducing the time period between the time a fault occurs and the time the grid operator's control centre receives this information (automatically) via the smart metering communication infrastructure allows the network operator to immediately and more accurately dispatch the technicians required to restore the fault.

Real-time, accurate and comprehensive information on the distribution network (e.g. pressure levels, voltage quality, losses) also allow more accurate predictions of electricity/gas flows, which can be used to improve network and maintenance planning. Detailed information on the current status of the network also provides a basis for sound investment planning.

[22] Throughout this report we will use the abbreviations "DSO" (distribution system operator) and "DU" (distribution utility) interchangeably for electricity – unless we explicitly refer to either entity. When we use the term "DSO", we generally refer to the distribution (and metering) tasks carried out by distribution network owners and distribution system operators. It can therefore not be concluded from the use of "DSO" whether these tasks shall be carried out by the DSO (or SODO) or by the DUs). In the area of gas no separation of distribution network ownership and operation does exist in Slovenia; regardless of the usage of DSO and DU within the report, we refer to the DSO when we talk about distribution (and metering) activities in the area of gas. For further details on the roles and responsibilities of the various stakeholders within the recommended smart metering service model for Slovenia see chapter 4.

[23] Remote dis-/reconnection of gas supply is theoretically also possible, however due to tight safety provisions for the (re-)connection of gas supply not feasible in Slovenia.

Smart metering together with the application of time-of-use tariffs sets incentives for consumers to shift parts of their electricity consumption from peak to off-peak periods and thereby reduce the maximum network capacities required to distribute electricity at peak load, which in turn reduces the need for network investments. Less consumption by customers may – depending on the regulatory framework – also increase network tariffs, since eligible network costs will be allocated on a smaller amount of distributed energy.

Furthermore, smart metering can also have a significant impact on the reduction of commercial losses (detection of fraud and energy theft), since it allows for an easier detection of previously unmeasured consumption and provides more accurate information about the location of losses and theft. Smart meters can also be fitted with anti-tampering devices alerting the DSO automatically when manipulation of the meter is attempted.

Whether the above cost savings represent a benefit to the DSO or to the consumer, depend on whether these savings are completely passed-through directly to the customers or whether they can (temporarily) be kept by the DSO (see also chapter 10).

Consumer

Smart meters together with effective feedback mechanisms (e.g. via in-home displays, web portals or more detailed bills) provide consumers with detailed information on their consumption levels and patterns during different periods of the day. Increased transparency may enable customers to better understand the impact of individual electricity and gas appliances or a certain consumption behaviour on their energy bill (and possibly also raise awareness of the impact of their consumption on the environment). As a consequence, customers may reduce their consumption and/or (with time-of-use pricing) shift part of their consumption from peak to off-peak periods, which will allow them to reduce their energy bill. The ability and willingness of customers to realize energy savings depend on the electricity and gas price levels and on the expenses for electricity and gas in relation to the monthly income. Also, the range of electricity and gas applications used by a consumer and the consumer's ability to replace old devices with more energy efficient equipment, influence the extent to which consumer are able to reduce their electricity and gas consumption.

The possibility to offer real-time pricing and innovative tariffs, as well as interfaces between smart metering and household appliances, could result in various new types of energy services being available to customers – to help manage consumption (and costs) and to promote energy efficiency (such as demand side management, i.e. the direct control of household appliances). Smart metering can also facilitate pre-payment options, which allow customers to pay in advance and hence to better manage their budgets.

Smart metering can also have a strong impact in simplifying customer switching procedures, as smart meters can be easily read at any time on request. Automation and simplification of data exchange through smart metering should speed up the process for changing suppliers and simplify the action required from the customer to make the change. The transparency of individual electricity consumption patterns and costs provided to the customer by smart metering also allow the customers to make more informed decisions on the selection of the most convenient supplier, further facilitating customer switching.

Depending on the location of the conventional meters (whether located outside a building or inside), smart metering may also have the additional benefit that it does not require someone from the household to be present when the meter reading takes place.

Supplier

Automated meter reading can reduce the likelihood of incorrectly read or entered meter data leading to faulty invoices, which in turn reduces the number and costs of customer complaints (including reduced customer service centre staff). The possibility of remote and instant disconnection of customers by the meter operator can also help to reduce the risk of payment default for the supplier (debt management).

Smart metering enables suppliers to offer new tariffs and services arising from detailed information on individual end-user's consumption patterns. Such new services could, for example, help the customer to become more energy efficient. Suppliers also have the opportunity to offer customized contracts reflecting individual consumption patterns. These contracts may include time-of-use or more sophisticated tariff elements and might also provide for automatic demand side management. By providing such additional services, suppliers operating in competitive retail markets may be able to improve customer satisfaction resulting in a higher willingness to pay and higher customer retention. Smart metering can also facilitate the customer switching procedures due to real-time metering, allowing customers to change their supplier (at least theoretically) in real-time or at very short notice and on any chosen date. This could particularly be beneficial for new suppliers entering the market.

Furthermore, smart metering might allow the supplier to use actual load profiles of individual customers rather than standard customer load profiles. Through improved load profiling and forecasting, suppliers are able to more precisely predict their customers' demand at specific points of time, which allows them to reduce their wholesale purchasing costs. To enable all of the above services and to efficiently use and integrate the automated meter reading data into their existing systems, suppliers may have to invest in IT infrastructure and to adjust some of their operating procedures.

Other stakeholders and society as a whole

Consumption reductions and shifts of demand do also have an impact on the transmission network owner / system operator and for the electricity producers. Both will transmit or sell less electricity or gas respectively, which in turn will also require less transmission and generation capacities. Reduced demand at peak (and off-peak) times may also result in lower wholesale prices. Increased energy efficiency will also have an impact for the government through lower tax revenues since revenues from value added tax and any other energy taxes based on consumption levels/or end-user payments will be accordingly lower. Society as a whole can also benefit from reduced carbon emissions, resulting from reduced consumption levels encouraged by smart metering.

Roles and responsibilities of the various stakeholders within the recommended smart metering service model for Slovenia are provided in chapter 4, further details on the measurement of the various costs and benefits are explained in chapter 7.

4 EVALUATION OF PROPOSED SLOVENIAN SMART METERING SERVICE MODELS

4.1 Introduction

Smart metering of electricity and gas may, based on the functionalities of the smart meters, potentially involve various service providers (or stakeholders) and various services throughout the smart metering process.

Services in the process of smart metering may generally involve the following:

- Installation of smart meters and other devices that are necessary for the data transfer from the smart meters to the metering centres (MC)
- Maintenance of smart meters and associated devices and equipment
- Data reading (metering data and other data available) from smart meters
- Validation of the metering data
- Processing and integration of data and their further use

Relationships between the various stakeholders in the process of smart metering are defined in different service models. For the provision of or metering services for electricity and gas (and in relation to the ownership of the (smart) meters) three main models can be identified throughout Europe:

1. The (distribution) system operator model, where the system operator carries out the metering and is usually also the owner of the metering devices (i.e. smart meters). The metering device can also be owned by the consumers.
2. The independent metering system operator model where the metering device could be owned by the consumers, the system operator or the metering system operator. The independent metering system operator carries out the metering and provides the validated measurements (and other processed and aggregated) data to other entitled stakeholders on the market.
3. In the supplier model the owner of metering devices is the supplier who is also responsible for carrying out the metering.

With the aim of fostering competition on the electricity retail market the distribution system operator (DSO) has been established in the year 2007. The DSO merged the operation of the five electricity distribution companies – operating the electricity distribution system in Slovenia before the year 2007 – in a separate entity and unbundled it from supply. Ownership of the electricity distribution networks in Slovenia however remains with the utilities. DSO, therefore, has to rent the network and services related to the infrastructure from the five distribution utilities (DUs), owners of the distribution networks. The DSO is responsible for construction and maintenance of the distribution network as well as for the measuring (or metering) of electricity consumption in Slovenia. The DUs however perform contracted (construction and maintenance) tasks for (in the name of) the DSO on their own infrastructure (and in some very rare cases, on the DSOs infrastructure). The DUs are usually the owners of the metering devices, while in some cases the metering devices are owned by the consumers.

In the area of natural gas ownership and operation of the distribution networks are generally not separated;[24] i.e. both are handled by the gas DSOs (which themselves are only legally unbundled from supply as provided by legislation). The gas DSOs furthermore handle all tasks related to the metering of gas consumption in Slovenia and are usually also the owners of the metering devices.

When we distinguish between tasks to be conducted by the DSO and DUs throughout this report, we thereby only refer to electricity. Whereas for electricity, installation and operation of the meters (including the conduction of the metering itself) lies within the domain of the electricity DUs (but DSO is responsible for), all metering activities in the area of gas are conducted by the gas DSOs.

To facilitate the provision of multi-utility smart metering services and the development of smart metering services, AGEN-RS suggests establishing a new entity carrying out the role of a metering data aggregator, which among others would be responsible for the development and provision of the following tasks:

- Receiving and aggregating validated data (processed at DSO level) in non-real time
- Acting as »multi-utility« information hub for all market participants (regulated and commercial) by providing multi-utility electronic data interchange (EDI) services (aggregated data on electricity, gas, water, heat consumption etc.)
- Provision of interdependent EDI services
- Supporting energy-efficiency analytics and aggregation services on national level
- Providing forecasting services for smart grid functions

This new role could be either attached to one existing DSO or to an entirely new legal and independent entity. AGEN-RS named this new role a Service Centre for Smart Networks (hereinafter SCSN). The SCSN will act as a data aggregator irrespective of whether it functioned as an independent entity or it will be attached to an existing DSO. The establishment of the SCSN may cause (additional) investments into the information system and electronic data interchange standardization, which would have to be taken into account of this CBA.

If the SCSN is not fully independent from the DSOs/DUs (legally or in terms of ownership) it will be crucial that access to data and information is provided to all interested parties in a non-discriminatory manner. It will furthermore be important that services like demand response and real-time data access, who require local access of these services at the meter, are also provided non-discriminatorily to all market participants by the DSOs/DUs (and where relevant by the SCSN), respecting issues of data privacy and security (see also chapter 9). We recommend that local access to the smart meter for third parties is precisely and effectively regulated and that the exact details are specified in the legislative and regulatory framework.

[24] Some gas distribution networks in Slovenia are however owned by the respective municipalities and not by the gas DSOs.

AGEN-RS proposes basically two main smart metering service models:, whose properties we describe and evaluate in the following.

1) Basic model A:

In model A raw metering data from electricity, gas, heat and water meters would be exchanged through the smart meter gateway attached to the smart electricity meter (multi utility option). From the smart meter gateway data would be transferred to (and from) the data concentrator in the distribution substation via power line communication (PLC).

Metering data from (and to) all meters connected to the data concentrator would then be exchanged with the head end metering system of the DU via different communication technologies (with use of optical network or with use of WiMAX or GSM/GPRS technology). At some more remote (rural) sites it may not be efficient to establish a PLC infrastructure to a data concentrator; in this case communication may take place directly between the smart meter gateway and the head end metering system of the DU via GPRS. For connection between the distribution substation and the metering centre at the DU a wide area network (WAN) is used. The communication system may be owned and operated by the DU or contracted to and operated by a telecommunication company.

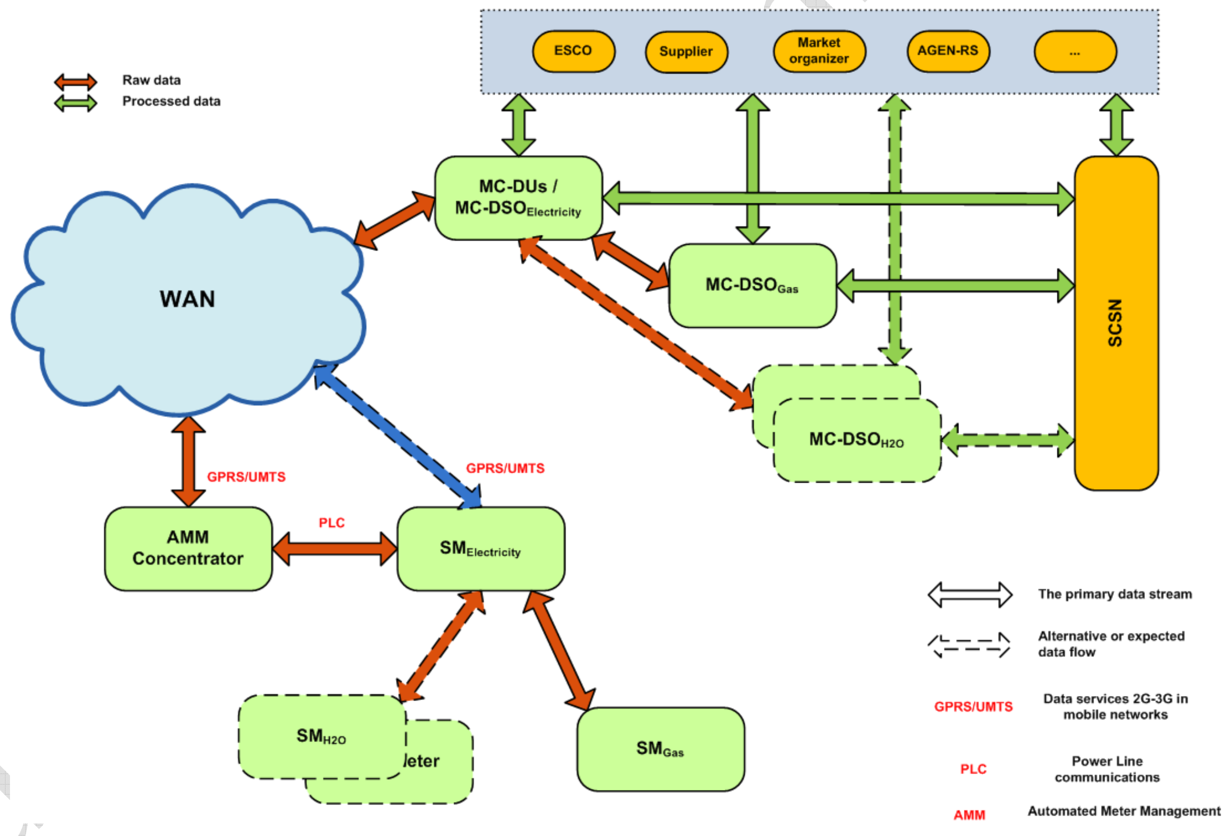

Figure 1: Physical layer of model A[25]

From the metering centre of the DU the metering raw data for gas (water, district heating) are further distributed to the metering centres of the respective gas (water, district heating) DSOs. The DUs/DSOs then forward the processed data to the meter data aggregator, i.e. the SCSN. The SCSN can be organ-

[25] AGEN-RS, November 2013

ized as a completely separate entity or as a part of the electricity DSO. The following figure shows the physical layer of model A.

2) Basic model B:

In model B, each DSO and DU is responsible for the data transfer from/to their meters to/from their head end metering centres. Metering data for electricity, gas, heat and water are transferred via separate communication infrastructures. For electricity, PLC technology would be used to exchange data to and from the data concentrator in the distribution substation. For all other meter data (gas, water, district heating) exchange would take place directly between the smart meter and head end metering centres of the DSOs.

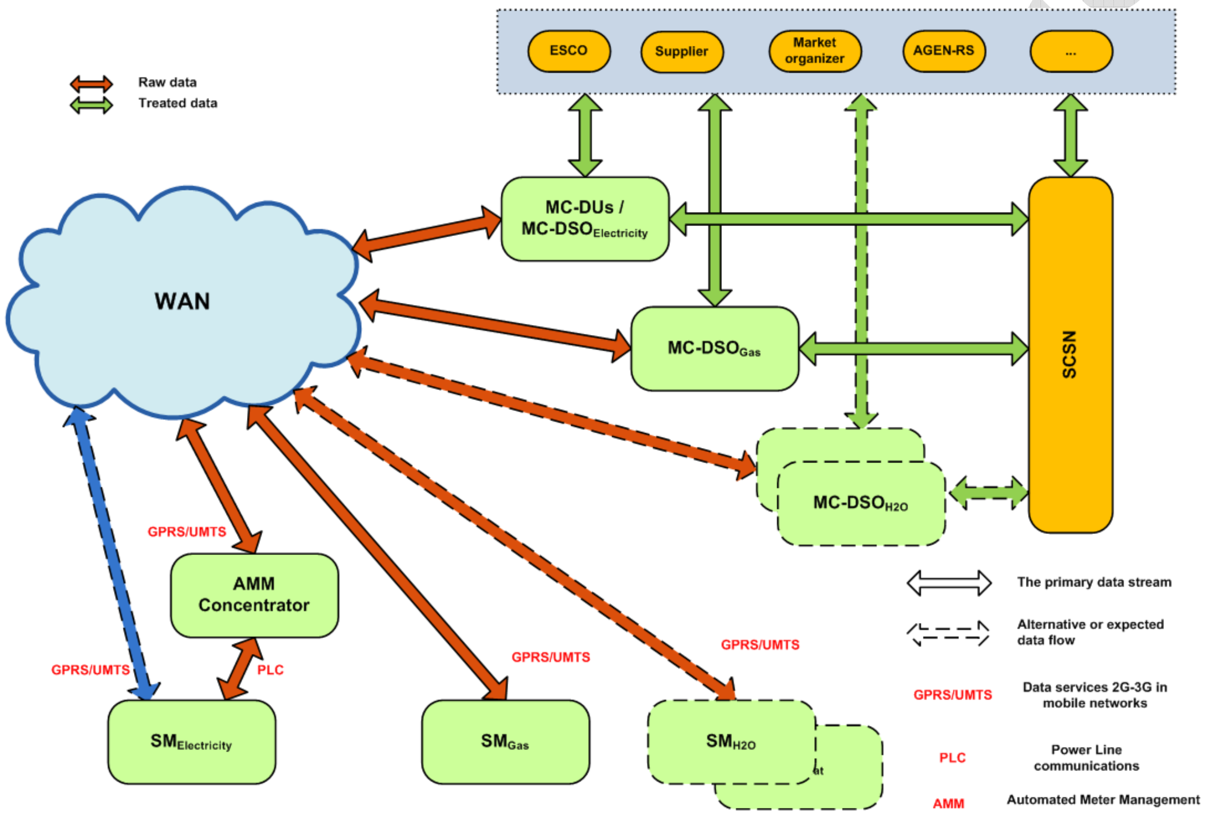

Figure 2: Physical layer of model B[26]

Model B is associated with higher investment and operational costs since each smart meter would require an individual communication module and since non-electricity smart meters would need to use more expensive GPS/GPRS modules to communicate with the head-end system instead of PLC ones (which would only be used for electricity).[27] In addition, every DSO would need to contract individu-

[26] AGEN-RS, November 2013

[27] Consequently the PLC infrastructure, connecting the smart meter with the data concentrator in the distribution transformer substation, would only be used for electricity smart metering data and its costs only be recovered within the electricity system.

ally with telecommunication service operators, which would increase contracting costs and reduce economies of scale.[28]

In case smart meters would only be rolled out in one area (e.g. only for electricity), model B would allow to keep the existing (conventional) metering in all other areas (gas, water, district heating); a smart metering communication infrastructure would then only be installed for electricity. The following figure shows the physical layer of model B.

In both basic models ownership of meters would remain with the DU or DSO (gas) or the consumer as in the current system. Installation and maintenance of meters would remain a task of DUs and gas (water, heat) DSOs. With respect to the roles and responsibilities of the different market participants in the proposed two basic models different options have been specified by AGEN-RS for each model, which are described hereinafter.

4.2 Roles and responsibilities in model A

4.2.1 Exchange of data in model A

The DU is responsible for collecting and forwarding the raw metering data from (and other data information to) the smart meters in its area. The exchange of data between market players depends on the type of data:

- Raw metering data (non-validated) are interchanged between the smart meters and MCs at the DUs.
- Billing data and data for imbalance settlement are exchanged between the DSO / (DU), suppliers and the market operator. The billing processes involve the DSO and suppliers.
- Validated data form smart meters will be sent from the DUs/DSOs to the SCSN, who will further process and aggregate the data and then interchange the data with other stakeholders providing energy-efficiency (e.g. demand side management) and other smart data services in competition.[29]

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[28] It can also be expected that telecommunication service providers would offer more costly services for the transfer of smaller amount of data in comparison to one contract with high data volumes.

[29] The DSO would remain responsible for the provision of smart services that are crucial for network operation, whereas smart services addressing end-users would be offered by suppliers and other third parties. A related split of roles and responsibilities has also been proposed by the German regulatory authority (Bundesnetzagentur) in the context of smart grids, who suggests to distinguish between smart grids and smart markets (Bundesnetzagentur (2011): Eckpunktepapier - "Smart Grid" und "Smart Market"). According to the definition of the Bundesnetzagentur the conventional electricity grid will become a smart grid by being upgraded with communication, metering, control and automation technology as well as IT components. This would enable a better use of the grid infrastructure reducing the need for network expansions or improve the stability of grids at constant load levels. Smart meters and grids enable smart markets, where (according to their definition) energy volumes or services

4.2.2 Responsibility for smart meters and communication infrastructure in model A

Each metering device is owned by the DUs (electricity) or DSOs (gas) or the consumer. Also the electricity DSO could (in principle) become the owner of the smart metering device if it would perform the procurement process for required quantity of smart meters needed on the national level itself. The DSO is responsible for installation and operation (including maintenance) of the metering device by the law. DUs install and maintain the smart meters according to their contracts with the DSO. Non-electricity DSOs are responsible to assure interoperability between their meters and the electricity smart meters.

The DUs must ensure the availability of the communication infrastructure, which ensures the transfer of metering data from the electricity smart meter to the MC at DU. This involves primarily the reliability of the PLC system of the DU, whereas the implicit responsibility for the reliability of data transfer from (to) the data concentrator in the distribution substation to (from) the MC of the DU may lie with the telecommunication provider contracted for these services. The DUs are also responsible for the data concentrator and the multi utility interface in the electricity smart meter. Non-electricity DSOs will be charged for the service of data transfer at reasonable prices by the electricity DSO which will be entitled to payment due to its responsibility by law.[30]

4.2.3 Organisational options in model A

From the organisational point of view the model A may be established by two different options.

Option 1 of model A (hereinafter model A1)

In Option 1 of model A the SCSN is organized as an independent entity completely separated from DUs and DSOs. The following figure shows the model A1.

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derived from the grid are traded among market participants on the basis of available grid capacity. This includes for example services related to demand response, energy efficiency or energy savings.
Applying this definition, the strong unbundling requirements for distribution and supply would also apply in the smart grid context. The grid (whether smart or not) is a natural monopoly that should accordingly be regulated and its efficient cost be recovered by network charges. Services offered on the (smart) market are provided in competition between different market actors (most notably the suppliers) and should not be subject to regulation (and not financed through network charges). For the issue of cost allocation see also chapter 10 of this report.
A short English summary of the concept of the Bundesnetzagentur can be found at:
http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/NetzzugangUndMesswesen/SmartGridEckpunktepapier/SmartGridPapier_EN.pdf?__blob=publicationFile&v=3

[30] The electricity DSO may then pass-on these payments to the DUs, who are responsible for the PLC communication infrastructure and the contracts with the telecommunication providers.

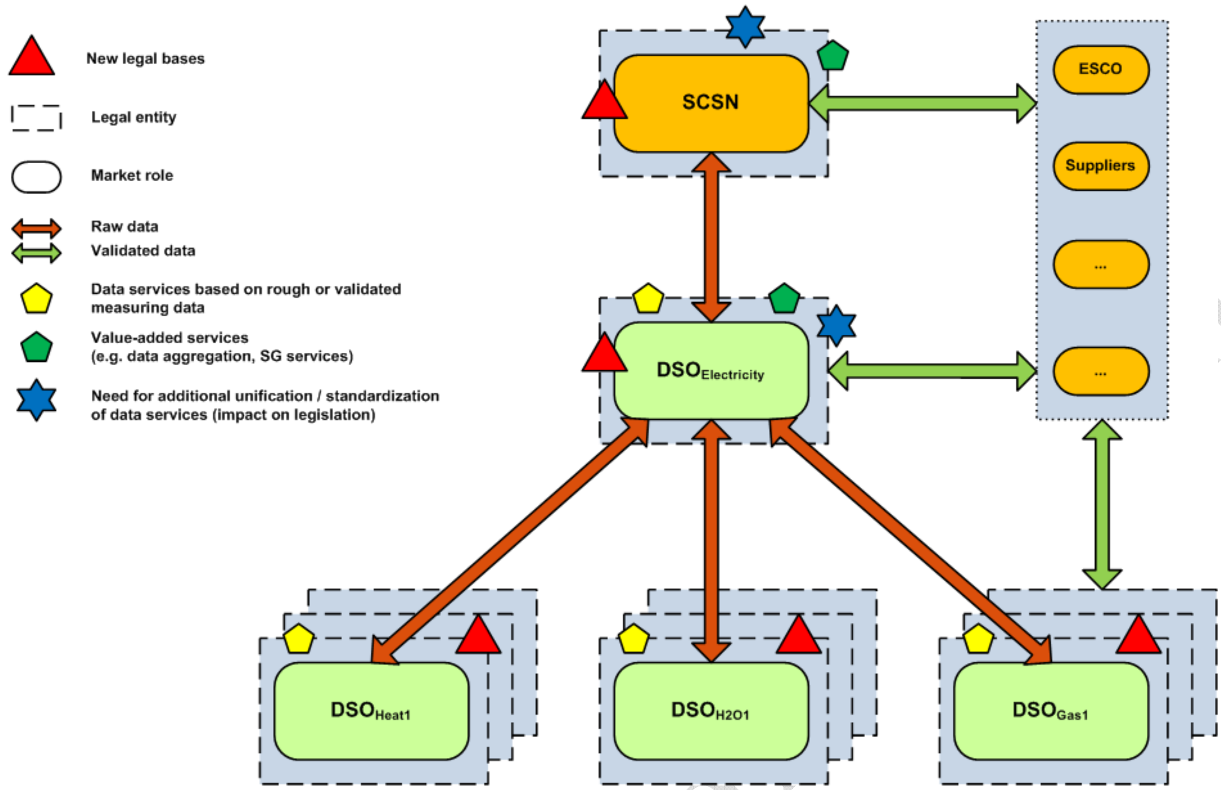

Figure 3: Model A1[31]

It may also be considered to further develop model A1 in the future so that the SCSN also takes over the responsibility of operating and maintaining the meters as well carrying out the meter reading; in that case the SCSN would act as an independent metering company for Slovenia (i.e. the independent metering system operator model described in section 4.1). Model A1 therefore provides additional flexibility for adjustments of the system following possible future changes of the metering market.

Option 2 of model A (hereinafter model A2)

In Option 2 of model A the SCSN is part of the electricity DSO. From the organizational, investment and legislative point of view this may be easier to implement than model A1, since existing resources and infrastructure may be used. It will furthermore facilitate non-discriminatory access to data and information to all market participants, since the electricity DSO is not affiliated to a holding company that is also active in the supply business. Effective unbundling requires that the same level of information is provided to all market participants without any advantages for the supply unit of a vertically integrated utility. The following figure shows the model A2.

[31] AGEN-RS, November 2013

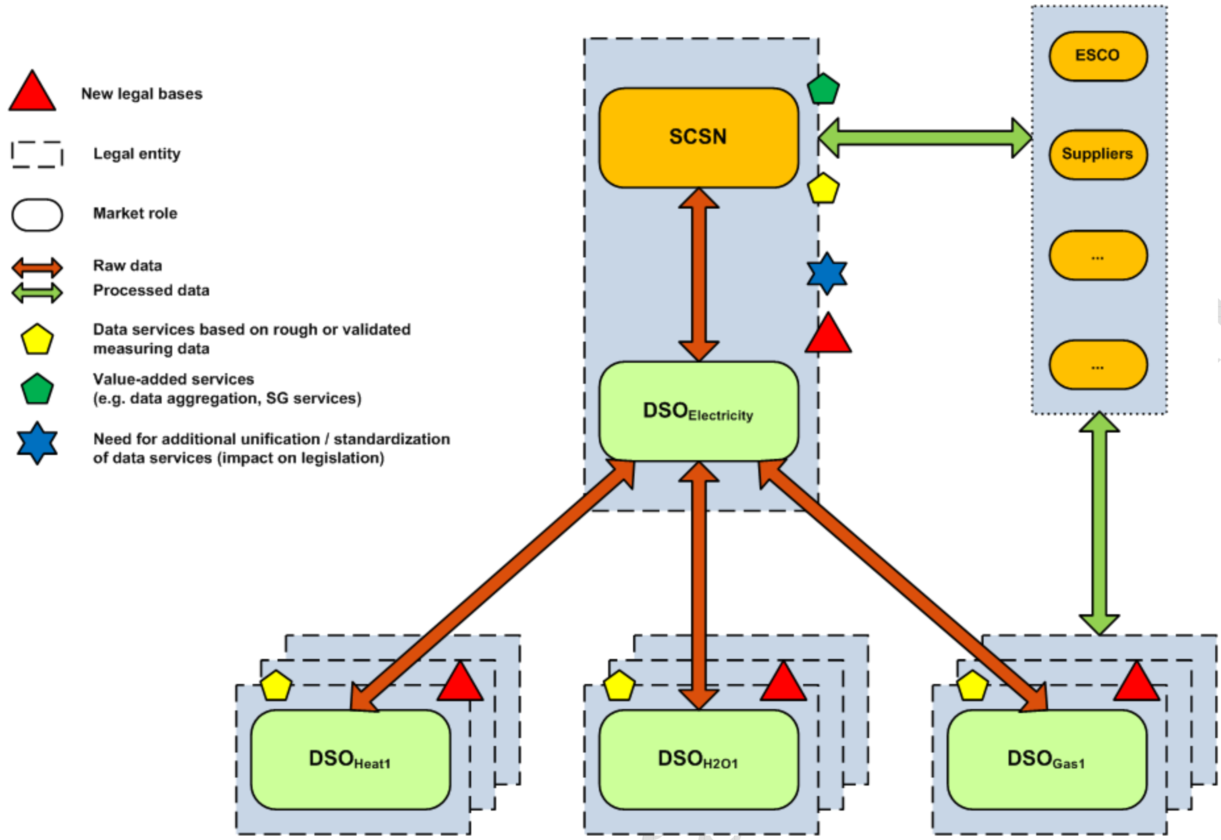

Figure 4: Model A2[32]

4.3 Roles and responsibilities in model B

4.3.1 Exchange of data in model B

Each DSO and DU (in electricity sector) is responsible for the collection and the transfer of data from (to) their meters to (from) their head end systems in their MCs. Metering data for gas, heat and water are transferred via separate communication channels most notably with the use of telecommunication networks. The electricity DUs use the communication network as described in basic model A.

The DSOs/DUs forwards the validated metering data to other stakeholders (e.g. suppliers, consumers, etc.) and to the SCSN. Smart metering services that are crucial for network operation will be developed at the level of DSOs, while the planning and provision of smart services on higher level will be conducted by suppliers and other market participants based on the data provided by the SCSN.

Alternatively all data is processed by each DSO and directly exchanged with other market participants by each DSO. In this case the SCSN is not established.

[32] AGEN-RS, November 2013

4.3.2 Responsibility for smart meters and communication infrastructure in model B

Each DSO and DU in electricity sector is the owner of the metering devices. Also the electricity DSO could (in principle) become the owner of the smart metering device if it would perform the procurement process for required quantity of smart meters needed on the national level itself.. It is also possible that the consumers are owners of the metering devices (where this is currently the case). The DSOs and implicitly DUs (according to the contract) are responsible for the installation, operation and maintenance of the metering devices and in the case of electricity sector also the PLC infrastructure for the communication between the meter and the data concentrator in the distribution substation. Each DSO/DU must ensure adequate availability of the telecommunication infrastructure (contract with the provider of telecommunication services, e.g. mobile telecommunications provider) for data transfer through the WAN.

4.3.3 Organisational options in model B

From the organisational point of view model B may be established by two different options.

Option 1 of model B (hereinafter model B1)

In Option 1 of model B, all metering data are exchanged between the MCs of each DSO/DU and the SCSN separately. This model is very similar to model A1; the only difference between the two models is that in model B1 no joint but separate (tele-) communication infrastructures for the data transfer are used. The following figure shows model B1.

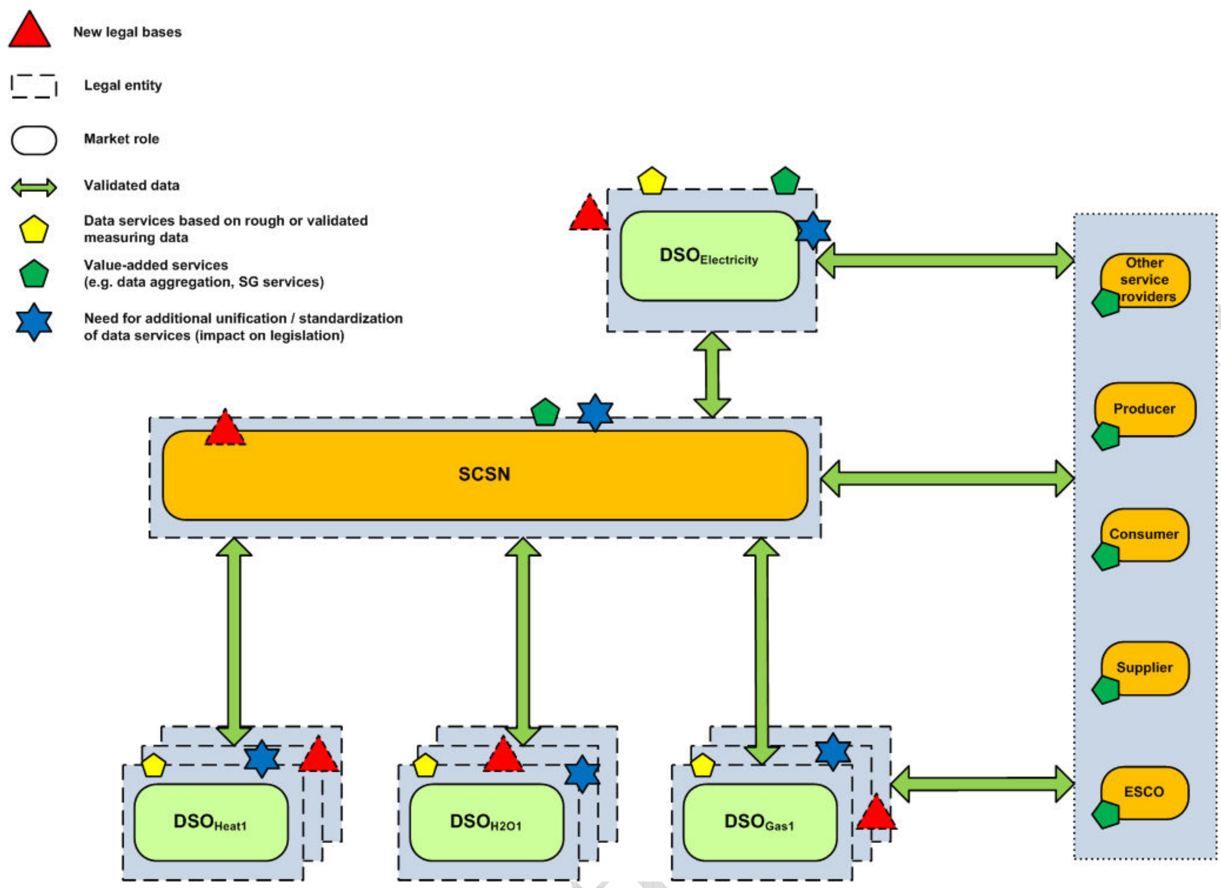

Figure 5: Model B1[33]

Option 2 of model B (hereinafter model B2)

This option does not include the role and establishment of a new legal entity named as SCSN. Each DSO/DU exchanges validated metering and all other data directly with the respective suppliers or other relevant market participants. The following picture shows model B2.

[33] AGEN-RS, November 2013

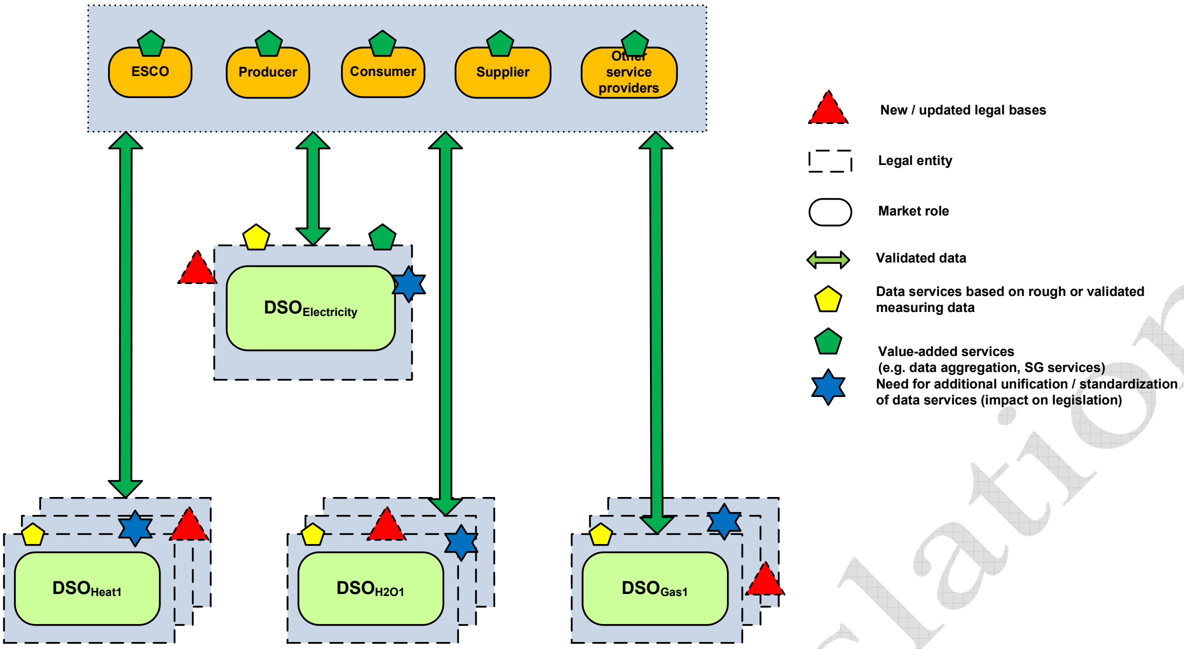

Figure 6: Model B2[34]

In this case there are no additional costs for establishing the SCSN. This model may come closest to today's organizational structure and may therefore be easier to implement (not requiring major changes in the legal framework). It may however increase the complexity of data exchange and the number of data interfaces, since suppliers and providers of (multi-utility) smart metering services would need to communicate with a large number of DUs/DSOs (which may in fact increase the costs compared to the other three models, which can realise the synergies and efficiencies of a central data aggregator). With the development of smart metering (and smart grid) services the amount of data to be exchanged between market participants is expected to increase significantly. Standardized and automated (B2B), non-discriminatory data exchange procedures will, therefore, be important for a successful implementation of this model, in particular where DUs are affiliated to supply business units or entities. Guidelines with a precise definition of procedures, timeframes and extent for data to be exchanged between the respective DUs/DSOs and other market participants are therefore crucial for this model to guarantee that the same level of information is provided to all market participants without any advantages for the supply unit of the vertically integrated utility the DUs is a part of (see also chapter 9).

4.4 Comparison of the four smart metering service models

The following table provides an overview on the different tasks of DUs/DSOs, SCSN and other market participants in the four smart metering service models. It emphasizes the central role of the electricity DUs in model A and the involvement of all DSOs in model B. Furthermore it shows the involvement of the SCSN in models A1, A2 and B1.

[34] AGEN-RS, November 2013

Tasks	Model A1	Model A2	Model B1	Model B2
Installation and operation of the meter	Each DSO or DU	Each DSO or DU	Each DSO or DU	Each DSO or DU
Ownership of the metering device	DSO and DU or consumer	DSO and DU or consumer	DSO and DU or consumer	DSO and DU or consumer
Financing of the smart metering infrastructure	Each DSO and DU for its own part SCSN for its own infrastruc-ture (HW & SW)	Each DSO and DU for its own part	Each DSO and DU for its own part SCSN for its own infrastruc-ture (HW & SW)	Each DSO and DU for its own part
Data collection	Each DSO and DU for its data; SCSN for aggregated data	Each DSO and DU for its data; DSO (implicitly SCSN) for aggregated data	Each DSO and DU for its data; SCSN for aggregated data	Each DSO and DU for its data
Forwarding data to MC	DU for all metering data sets (electricity, gas, heat, water etc.)	DU for all metering data sets (electricity, gas, heat, water etc.)	Each DSO/DU for its data	Each DSO/DU for its data
Data validation	Each DU and each DSO for its data	Each DU and each DSO for its data	Each DU and each DSO for its data	Each DU and each DSO for its data
Data storage	DSOs / DUs and SCSN	DSOs / DUs and SCSN	DSOs / DUs and SCSN	DSOs / DUs
Forwarding data to 3rd parties	DSOs / DUs and SCSN	DSOs (implicitly SCSN) / DUs	DSOs / DUs and SCSN	Each DSO / DU for its data
Ownership of data	DSOs / DUs and SCSN	DSOs / DUs and SCSN	DSOs / DUs and SCSN	Each DSO / DU for its data
Billing[35]	Suppliers	Suppliers	Suppliers	Suppliers
Need for adjustment of regulation	Establishment of SCSN as a new legal entity require ad-justments to existing regula-tion	The increased role of electric-ity DSO (playing a role of SCSN) require adjustments to existing regulation	Establishment of SCSN as a new legal entity requires ad-justments to existing regula-tion	In general in line with existing regulations

Table 1: Comparison of the four smart metering service models

[35] The electricity DSO also performs billing for all customers that require separate bills for network charge and energy …

4.5 Assessment of the four proposed smart metering service models

The evaluation of the four models proposed by AGEN-RS strongly depends on the specific details of the implementation of the four approaches and the regulatory framework. The following evaluation could therefore only provide a high level indication of a preference for one of the four smart metering service models. The following section describes the criteria based on which the four models are evaluated at high level.

Impact on operational and regulatory aspects

The proposed time frame for the implementation of smart metering is a crucial factor for the evaluation of the four models. Models which are in line with existing organizational, operational structures and interdependencies between market players can generally be implemented faster and at lower costs. Systems that do require major organizational efforts to be established (e.g. requiring the creation of a new entity) may require a longer timeframe to be implemented.

Data needs to be provided in a transparent, non-discriminatory and easy accessible way for all market participants. A single point of contact is generally more transparent and less costly for market participants than a model where exchange of metering data is conducted bilaterally between all market participants. Assigning an independent entity with the task of data exchange may further strengthen effective unbundling between distribution and supply, but does also require precise definitions of the tasks and responsibilities of the SCSN and the DUs/DSO and of the procedures for data exchange. Also, a new regulatory framework would be required for the assessment of the costs and the tariffs of the SCSN.

The four smart metering service models are evaluated as regards their impact on operational and regulatory aspects according to the following criteria:

- Relation to existing organizational structure of metering services (special emphasis is on the current organization of the electricity sector)
- Integration of the system
- Single point of access to data for all market participants
- Regulatory requirements

Impact on market development and energy savings

In an integrated system, there is no additional need for additional data standardization and the development of new services may, therefore, be easier. Highly integrated systems with centralized MDM may also be more flexible and may be able to react quicker to market demands. Furthermore since the development of new services will be led by a single entity, implementation of these services may happen more quickly and successfully.

Where metering services are provided by different entities, competition between manufacturers of metering equipment tends to be facilitated. Since the revenues of the DSO/DU partly depend on the amount of electricity and gas that is transmitted / transported over its network, the DSO/DU has no incentives to promote energy savings by customers. Assigning the metering task to a different entity whose revenues do not depend on energy levels would, on the other hand, facilitate energy savings by customers. The impact on market development and energy savings of the four models is therefore assessed for the following criteria:

- Facilitation of new services
- Flexibility to adapt to changing market requirements
- Facilitation of competition between equipment manufacturers
- Energy savings

Impact on safety, reliability and vulnerability of the system

In a smart metering system, large amounts of data are going to be exchanged with other subsystems and applications of the DSOs. Data security and privacy, as well as reliability and compatibility of the exchanged data, are, therefore, crucial parameters (see also chapter 9).

Robust infrastructure can assure a safe and reliable transfer of metering data. Diversified infrastructure may be able to provide increased reliability and reduced risk of data loss. A smaller number of interfaces between the market participants may, therefore, reduce the vulnerability of the data system (i.e. redundancy through parallel communication infrastructures). Safety, reliability and vulnerability of the system in the four models are evaluated according to the following criteria:

- Robustness of infrastructure
- Vulnerability of data system

Impact on implementation costs

The implementation of smart metering will cause additional investment costs for the installation of the smart metering infrastructure as well as changes in the maintenance and operational costs of the metering costs. All four models are therefore evaluated as regards their impact on the following two criteria:

- Investment costs
- Maintenance and operational costs

Need for adjustments of the legislation

Larger organizational changes may require further adjustments to the legislative and regulatory framework which may need some time before they can be implemented.

The compliance of the four smart metering service models described in the previous subchapter with the above criteria is shown in the following table.

Model	Pros	Cons
A1	• Integration of metering services (multy-utility) may facilitate a faster implementation of smart metering • Assigning the independent SCSN with the task of data exchange may further strengthen effective unbundling between distribution and supply • New services will be developed and implemented more quickly and successfully with a central data hub (the SCSN) that provides easy and non-discriminatory access to all necessary data • A separate (independent) SCSN has no incentives to hinder the provision of data to other market participants (e.g. data to facilitate energy savings by consumers)	• May require larger adjustments to the existing legislation and a new framework for the regulation of the SCSN • Requires precise definition of the tasks and responsibilities of the SCSN and the DSOs/DUs and the procedures for data exchange • Dividing services on the level of DSOs/DUs and on the level of SCSN/suppliers can lead to organizational confusion, duplication of data and information and, consequently to higher costs
A2	• The integration of SCSN and electricity DSO may lead to a single point of contact model, where all market participants are mostly in touch with the electricity DSO/SCSN, tends to be more transparent and understandable and may be associated with less cost for market participants • Integration of metering services (multy-utility) may facilitate a faster implementation of smart metering • Assigning the independent SCSN with the task of data exchange may further strengthen effective unbundling between distribution and supply • Integrated SCSN and electricity DSO may be more flexible and faster to adapt to changing market requirements • New services will be developed and implemented more quickly and successfully with a central data hub (the SCSN) providing easy access to all necessary data	• May require larger adjustments to the existing legislation and a new framework for the regulation of the SCSN • Integration of SCSN and electricity DSO may reduce energy savings since the electricity DSO has no incentives to provide data to other market participants that facilitate energy savings by customers as this will result in lower revenues for the electricity DSO • Integration of metering services for different metering goods require a standardization

Model	Pros	Cons
B1	• Assigning the independent SCSN with the task of data exchange may further strengthen effective unbundling between distribution and supply • May provide a higher level of competition between equipment manufacturers (mostly between the IDIS members in the electricity sector) • New services will be developed and implemented more quickly and successfully with a central data hub (the SCSN) providing easy and non-discriminatory access to all necessary data • Diversified infrastructure may provide increased reliability and reduced risk of data loss (i.e. redundancy through parallel communication infrastructure) • A separate (independent) SCSN has no incentives to hinder the provision of data to other market participants (e.g. data to facilitate energy savings by consumers)	• Requires precise definition of the tasks and responsibilities of the SCSN, the DSO and the DUs and the procedures for data exchange • Installation of additional communication infrastructure may result in higher investment costs • More diversified communication infrastructure may result in higher maintenance and operational costs • May require larger adjustments to the existing legislation and a new framework for the regulation of the SCSN
B2	• Closest to today's organizational structure and therefore easier to implement • May provide a higher level of competition between equipment manufacturers (mostly between the IDIS members in the electricity sector) • Model does not require the creation of a new entity, which avoids any additional costs related to this new entity • Diversified infrastructure may provide increased reliability and reduced risk of data loss (i.e. redundancy through parallel communication infrastructure) • A smaller number of interfaces between different market participants may improve data security and privacy	• Parallel solutions for different meters (e.g. electricity and gas) may cause compatibility problems when the system is further developed • Installation of additional communication infrastructure may result in higher investment costs • More diversified communication infrastructure may result in higher maintenance and operational costs • DSO/DU has no incentives to provide data to other market participants that enable energy savings by customers as this will result in lower revenues for the DSO/DU • In the gas sector DSOs and suppliers are only accounting unbundled, in which case the availability of commercial data may provide opportunities for discriminatory behaviour

Table 2: Assessment of the four smart metering service models proposed by AGEN-RS

4.6 Recommended smart metering service model

The benefits of models A and B strongly depend on whether smart metering is only rolled-out for electricity meters or whether smart metering is also rolled-out for gas (and other meters). In case the CBA provides a positive net benefit for both electricity and gas, model A may be the preferred option since the additional investment and operational costs for communication services of model B may be avoided.[36] The two options of model B, on the other hand, have the advantage that they may facilitate more competition between equipment manufacturers (although in the electricity sector mostly only between the IDIS members) and that redundancies in the communication infrastructure may provide increased reliability and reduce the risk of data losses. Different communication solutions for different types of meters (e.g. electricity and gas) may cause compatibility problems when the system is further developed (however for electricity meters have to comply with the specifications of the IDIS members).

If the lower costs for the communication infrastructure are to be considered the most significant factor, model A may provide benefits over model B; a joint communication infrastructure may also be faster to be set up and thereby facilitate a faster implementation of smart metering. The integration of the SCSN and the DSO within a single entity (model A2) may lead to a single point of contact model, being more transparent and understandable for market participants, but also supporting more efficient (less costly) exchange of metering data for suppliers and other stakeholders. An integration of SCSN and DSO may, on the other hand, set incentives not to provide data to other market participants that facilitate energy savings, since energy savings by customers will reduce the revenues of the DSO, whereas a separate SCSN (as in model A1) would not face such incentives. Model A2 may also have the advantage that it is easier and quicker to implement since it may require smaller adjustments to the existing legal framework and since some of the existing infrastructure and resources of the electricity DSO may partly be used for the set-up of the SCSN.

Similar arguments as for the A1 and A2 models do also apply for the B models, as the main difference between the two models depends on the creation of an independent SCSN (in the case of B1). Model B2 has the advantage that it comes closest to today's organizational structure well-known to all market participants and that it may therefore be easier to implement. Furthermore, model B2 also avoids any costs that may be associated with the set-up of the SCSN, as well as any legal and regulatory requirements such as a precise definition and separation of the tasks and responsibilities of SCSN and DSO/DU. If each data is dealt with separately (e.g. exchanged between the respective DU/DSO, supplier and customer for each type of energy or for water separately) data security and privacy might be better protected.

It is, however, difficult to tell whether the establishment of the SCSN does increase data security and improves data privacy – by reducing the number of communication interfaces between market partici-

[36] As pointed out above, each smart meter would require an individual communication module in model B and non-electricity smart meters would need to use more expensive GPS/GPRS modules to communicate with the head-end system instead of PLC.

pants and the establishment of a central data hub through which data access is provided – or whether, on the contrary, the establishment of such entity, in fact, decreases data security and data privacy – by separating data provision to third parties from the DUs/DSOs, who may have a better overview on which data access (by whom) is justified.

The establishment of a central data hub, with the set-up of the SCSN, has, on the other hand, the advantage to provide easy and non-discriminatory access to all necessary data, which may particularly facilitate the development of multi-utility smart metering services. A single point of contact for suppliers and other market participants may also be more transparent and understandable and may be associated with less cost for market participants. It will also allow to realise synergies and cost efficiencies within the metering system operators. The establishment of the SCSN may also further strengthen effective unbundling between distribution and supply, and facilitate the provision of data to market participants (e.g. no incentive to hinder the provision of data that enables energy savings by consumers).

Within EU Member States, we can identify three different models through which information is exchanged between the metering operator (usually the DSO) and the supplier.

1. Most commonly information is exchanged directly and bilaterally; all market parties directly send one another standardized messages. This model is, for example, currently applied in IT, NO, FI, ES, SE, DE, FR, HU and GR.
2. Alternatively messages are sent to a central data hub, where messages are checked and then forwarded to the final addressee (e.g. CZ, NL, and DK).
3. Data hubs can also be organized as a central database where the exchanged data is not only checked, but also stored. This provides added value in the form of record keeping and data storing (e.g. UK).

While bilateral direct data exchange seems to be still the dominant model throughout Europe, we can observe a trend towards more centralized solutions in recent years, in line with the development of smart metering and smart grids.

In a case of a joint roll-out of smart metering for both electricity and gas, model A2 may provide the largest benefits. If only a roll-out for electricity is decided on and the number of smart meters for other commodities (gas, district heating, water, etc.) remains low, then model B2 may provide advantages over model B1. It will, however, also be beneficial to aggregate meter data at the level of the DSO (in model B2) in order to facilitate retail market competition and the provision of smart metering services for electricity. In this case, the DSO would take over some of the tasks that would be conducted by the SCSN in the other 3 models. In the following, we provide further details on the properties of model A2 and its consideration with the CBA framework. However, the specific details of the option intended to be implemented as well as the accompanying framework for smart metering services will determine which option does indeed provide the largest net-benefit.

4.7 Consideration of the proposed smart metering service model within the CBA framework

Based on the above evaluation service model A2 has been applied in the CBA models of this project. With the establishment of the SCSN and by strong unbundling requirements, it is possible that smart services, enabled by smart metering, will be available efficiently non-discriminatorily to all interested parties. In case the new SCSN will be established as a completely separate entity (as is planned in model A1), substantial costs may be required for its establishment.[37] In addition also the annual costs for operating the SCSN need to be taken into account. The exact costs of the establishment and operation of the SCSN will depend on the specific details of the final model of the SCSN and can at this stage only be roughly estimated. When the existing resources and capacities of the electricity DSO can be used, i.e. when the role of the SCSN is integrated with the electricity DSO, investment and operational costs of the SCSN can likely be saved.

The following sections provide further details on the elements of the proposed smart metering service model within the CBA model (see chapter 7 on the general approach and the specific parameters of the CBA).

4.7.1 Smart meter

In the proposed model A2 the smart meter is the key element to the consumer's premises. When a multi-utility interface (P2)[38], is already integrated into the electricity meter the communication infrastructure could easily be shared. The P2 interface for the connection of gas (water, heat) meters is generally provided as standard functionality of current smart meters on the market and comes therefore at no extra costs. Within the CBA (see chapter 7) we therefore consider the costs of smart electricity me-

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[37] Separate entities for meter data aggregation have also been established in Great Britain. For Great Britain a license for a Data and Communications Company – with the key task to contract managing the services which it needs to communicate with smart meters – has been appointed through a competitive process in October 2013 for € 211 million by the British Department of Energy and Climate Change (DECC) for a period of 12 years. A Data Service Provider contract, for developing and operating the system controlling the movement of messages to and from smart meters has been awarded for € 90 million by DECC. In addition, two Communication Service Provider licenses for the North and the South of Great Britain have been awarded by DECC. Since these entities conduct however many more tasks in addition to meter data aggregation, being also involved in data collection and the communication infrastructure. These figures cannot be applied to Slovenia, where the DSOs will be responsible for data collection and parts of the communication infrastructure.

[38] The standardization mandate of the European Commission to standardization bodies has been provided with European Commission (2009): Standardization mandate to CEN, CENELEC and ETSI in the field of measuring instruments for the development of an open architecture for utility meters involving communication protocols enabling interoperability, M/441 EN.

Functional requirements for smart metering have been defined in: CEN, CENELEC and ETSI (2011): Technical Report – Functional reference architecture for communications in smart metering systems.

ters that include such a multi-utility interface. It is furthermore assumed within the CBA that the smart meters are owned by DUs/DSOs, who also conduct the installation and maintenance of the smart meters.

4.7.2 Communication infrastructure

The responsibility for the establishment of the communication infrastructure in the proposed model lies with the DUs. The communication infrastructure connects the metering devices to the consumer's home appliances (e.g. the in-home display), and also to the head-end system in the MC. The standardized P1 interface in the electricity meter, for the data interchange with other appliances at the consumer's premises using home area network (HAN), can be considered a standard functionality and with no significant impact on the price of the electricity smart meter.

In the proposed model, lower communication infrastructure costs are to be expected for the use of power line communication (PLC), which connects the smart meter with the data concentrator in the distribution transformer substation. PLC is also the collective name for communication techniques which enable telecommunication using the electricity distribution network as a communication channel from the smart meter and the substation. A common application of PLC is the reading of metering data from the (smart) meters. For bi-directional communication the P3 interface in smart meters is used. The P3 interface is actually the communication port which can use different technologies (PLC, GSM/GPRS, ZigBee, etc.). The price of a communication interface (or module) with PLC protocol is to be expected lower than the price for an interface (or module) with the GSM/GPRS protocol.

The data concentrator in the distribution transformer substation can connect several hundred smart meters via the PLC protocol. Use of data concentrators are recommended in more densely populated areas. The data concentrators bundle, check,[39] process and store meter data, and transmit and receive data to and from the head-end system in the MC. The data concentrator is owned by the DUs, who are also responsible for their installation, operation and maintenance.

For the communication between the data concentrator and the head-end system of the MC the wide area network (WAN) is used. WAN is the common name for the connection between the smart meter or/and the data concentrator and head-end system of the MC. For this connection various media and protocols are used. The most optimal connection with the minimum costs is the connection which uses the infrastructure of the DUs. This could be a (tele-)communication connection with use of IP/Ethernet switches on DU's optical network or telecommunication connection with use of WiMAX DU's network. In both of these cases the (tele-)communication network would be owned by the DU, who is responsible for procurement of the network elements (active and passive telecommunication equipment and goods), installation and for operation and maintenance of the network. In most cases such communication networks owned by the distribution network operator would need to be established first, whereas public (tele-)communication networks would already be in place.

[39] For example for fraud detection a check could be made to determine if the sum of supplied energy (sum of all individual meter readings) equals the sum of consumed energy (in total, measured at a substation).

More expensive ways for WAN include the use of the public networks of mobile (GSM/GPRS/UMTS) operators. In that cases the costs for communications are higher, especially when each of the meters uses a GSM/GPRS communication. Responsibility for data transmission is in such cases on the side of the public telecommunication operators. Only the modems on both sides of telecommunication connection are in the responsibility of DUs.

The relationship between the use of PLC networks and GSM/GPRS connections is an important parameter in the calculation costs and benefits within a CBA, since the communication technology has largely only an impact on the level of costs and not the benefits to be expected from smart metering. Within this CBA we will assess and compare different scenarios with different shares of communication technology as well as the different costs associated with these technologies.

4.7.3 Balancing meters

Balancing meters are used to detect and properly assess the possible imbalances in the amount of the transmitted electricity. Balancing meters measure the quantity of the electricity, which is transmitted to a certain transformer station. The measured value is then compared to the amount of consumed electricity, which is measured by smart meters. After comparing the values, possible inconsistencies can be identified and proper actions can be taken (e.g. actions in order to eliminate frauds).

4.7.4 Information systems and data exchange

A brief description of the information systems at the DU, DSO and SCSN will outline the functionalities, relationships/dependencies and data interchange processes between the information systems, which are already in operation or are expected to be installed and will start to operate with the implementation of smart metering (please see Figure 7 further below).

The existing information systems should be reused in a smart metering implementation if their upgrade and integration with new systems installed can be assured at reasonable costs. Therefore, it should be analysed if the existing systems could be upgraded to assure needed functionalities of AMI. Otherwise, the existing systems should be replaced with new products that conform to AMI requirements.

Most of the existing systems operate at the level of the metering centres (DU or DSO (gas) domain). AMI IT infrastructure comprises the following systems[40]:

- Head-End System (HES) is responsible for the collection of metering data transferred to the DU (or DSO) through the communication infrastructure. Head-end systems perform a limited

[40] The information systems described in the following, have – in so far as they can be reasonably quantified – been included in the CBA assessment (see chapter 7). It is not the intention of this report to give a detailed technical description of the individual information systems potentially applied for smart metering. The following provides therefore only a rough description of the purposes the relevant information systems are used for.

amount of data validation before these data are available for other information systems. This system provides the access to metering data for higher level information systems. The main HES functions comprise: data interface for communication with smart meter gateway (directly (in case of GSM) or via communicator (in case of PLC)), acquisition of smart meter data, plausibility and preparation of data, providing access to data for upstream level information systems, data encryption, load balancing, sending requests to smart meters (setting the tariffs, etc.), initialization of specific data queries, etc.

- Metering Management System (MMS) manages monitors and administers the installed smart meters. It provides the overview on the status of the equipment and data exchange with smart meters/ gateways and communicators manage the relevant information (operational status, notifications, protocols etc.) The main MMS functions comprise: management of smart meters and prepaid systems, status management of installed smart meters, gateways (GW) and other equipment, control of disturbances and errors, creating and managing event logs, configuration and maintenance, updating/version managing of installed software, remote operations (remote service switching, changing power limitations, tariff settings etc.), determining schedules and arrangements of meter readings.
- Meter Data Management Systems (MDMS) is the core function of the IT infrastructure of the AMI and it is mainly responsible for data validation, post-processing, storage and assuring the validated metering data on a long term-use. The main MDMS functions comprise: verification/validation and normalization of the metering data, management and processing of data, long term storage of metering data sets (load profiles), monitoring and reporting for the purpose of consumption analysis and prognosis, providing service layer for data visualization, planning DSM/DR campaigns, service layer for integration with SCADA/Distribution Management System (DMS).
- Energy Data Management System (EDMS) provides the services of storage, validation and management of energy consumption/generation data for the market participants. The EDMS is expanding the MDMS with the analytical and presentation layer for the processed energy data. EDMS can also provide functions for the process of conventional meters replacement management during the roll-out. It provides the B2B data exchange services for synchronization with CMDAS (please see description of CMDAS below).
- Customer Relationship Management System (CRMS) processes and manages contractual and customer data and supports customer services through different communications channels (call-centres, e-mail, web-portal). Besides, CRMS manages also some specific consumption and behavioural information that can be used for customer classification for performing specific communication campaigns. With the implementation of smart metering, the frequency and the in-depth of customer related information will increase significantly. The new ways and new processes of communication with consumers will need to be established with smart metering implementation, as well as more advanced data-security is to be assured.

- Workforce Management System (WMS) optimizes the organization and planning of needed human and other resources and their activation, supports the logistics and communication (using mobile devices etc.) in order to maximize the productivity of the workforce. Smart metering implementation increases the scope of work for technical personnel, for example, planning of meter replacement, installation of new equipment, monitoring the operation, resolving operational problems and assuring the maintenance of smart metering infrastructure.
- Billing-Pricing System (BPS)[41] is used by market participants in billing processes and for setting the tariff models. BPS is performing data aggregation and provides the required information for billing. It basically performs "meter-to-cash" processes. Billing in AMI is performed with higher frequency (shorter accounting interval) and will be based on more sophisticated and dynamic tariffs (bigger amount or detail of billing data). The reuse of existing BPS depends heavily on their flexibility to adapt to new requirements. The implementation of BPS may be centralized (at the level of DSO/SCSN or distributed (at the level of DU).
- Web Portal (WP) is mainly used as self-presentation of company's activities, services and product portfolio on the internet. It can serve as a communication channel for sales activities. Especially with the introduction of AMI, it can provide the e-services for data access on consumption and information related to accounting. New or upgraded WP functions, due to the implementation of smart metering, comprise: more complex visualization of consumption/production (e.g. normalization per hour, per smart appliance or generation units), capability to process bigger amount of data with higher frequency, offering event-driven tariffs and providing e-services with added value (new energy services).
- Central Metering Data Access System (CMDAS) supports the performance of the essential tasks of the SCSNIt provides the common access point for validated metering data (on energy consumption/production) on the national level by covering all metering points (of network users) in Slovenia. It communicates B2B (using web services) with MDMS/EDMS that are operating in existing metering centres (DU/DSO_{GAS} level). Raw/validated metering data reconciliation process is triggered by CMDAS on a daily basis (the frequency of synchronization may be raised as needed in the future) and assures the data synchronization between the CMDAS and MDMS/EDMS. The copy of the existing metering data at DU/DSO_{GAS} level (collected, stored and processed in their metering centres) is therefore stored in the CMDAS database for a longer period of time (several years). CMDAS provides the standardized access to actual and historical metering data to authorized users in the detail according to their rights.

  The main CMDAS functions comprise:

  - Central database and common access point for metering data for all users or metering points in Slovenia,

[41] The implementation of BPS could be centralized (at the level of DSO) or distributed (at the levels of DU)

- acquisition, aggregation and centralized storage of measurement data at national level achieved through the synchronization with MDMS/EDMS,
- integration with BPS and other back-end systems,
- aggregation and post-processing of metering data for provision of "multi-utility" services,
- data analysis for provision of smart grid services, provision of the added-value services as provision of aggregated data on energy consumption/production (electricity, gas …) per user or user's metering points, performance of specialized analysis/operations and forecasts (supporting imbalance settlement and accounting processes etc.).

From the information gathered within the assessment of the actual state of the current implementation of AMI in Slovenia, it was identified that some of the systems described above have been already installed and put into operation to support the remote meter reading, validation and processing of metering data retrieved from existing (smart) meters. Whereas latter stand for electricity, there is no evidence of such systems within the metering centres of gas DSOs. Some of them support also some more advanced functions (remote operations (remote service switching, changing power limitations, tariff settings etc.), billing functions etc.)). However the functionality of those systems and the number of smart meters integrated differ significantly between the metering centres of DUs. Most of the existing systems (HES, MDMS, EDMS) in use could be upgraded by means of integrating new smart meters that are to be installed in the future. Some existing solutions can be upgraded with new more advanced functions if necessary. It is also obvious that software solutions from different smart meter manufacturers are used within the same metering centre – the integration of upgraded existing systems and new systems with the data-exchange service layer for B2B communication with CMDAS using standardized interfaces will be essential for achieving efficient interoperability of these systems.

Besides the systems described above there are many other systems incorporated in the IT infrastructure of different market players (i.e. enterprise resource planning, identity management, risk management, access control etc.). Implementation of AMI may require specific adjustments that should not be underestimated.

The tables below show the responsibility for implementation of AMI information systems according to AMI roles for electricity and gas.

Information system	SCSN	DSO	DU	Supplier
HES	-	-	+	-
MMS	-	-	+	-
MDMS	-	-	+	-
EDMS	-	-	+	-
CRMS	-	+	+	+
WMS	-	+	+	0
BPS	0	+	0	+
WP	+	+	+	+
CMDAS	+[42]	+[43]	-	-

Table 3: The responsibility for implementation of AMI information systems according to AMI roles in the field of electricity[44]

Information system	SCSN	DSO (!)	Supplier (!)
HES	-	-	-
MMS	-	0	-
MDMS	-	-	-
EDMS	-	+	-
CRMS	-	+	+
WMS	-	+	0
BPS	-	+	+
WP	-	+	+
CMDAS	-	-	-

Table 4: The responsibility for implementation of AMI information systems according to AMI roles in the field of gas[45]

Legend:

+	the role implements the function
-	the role does not implement the function
0	the role conditionally / partially implements the function .
(!)	in the gas market the roles of DSO and supplier are played by same actor/legal entity. The efficient informational unbundling has to be assured in all IT systems that are shared between both roles.

[42] CMDAS could also be implemented by SCSN

[43] CMDAS could also be implemented by DSO

[44] AGEN-RS, August 2013

[45] AGEN-RS, August 2013

At this stage, it is quite difficult to predict the initial scope of services of the SCSN. The default services should comprise the common access point to the metering data at the national level, data aggregation and provision of basic value-added data services using CMDAS. Besides, SCSN should provide the means for the development of new energy services by providing a standardized and centralized access to the metering data. In the case of proposed model, where the SCSN is implemented within the role of electricity DSO, it is necessary to efficiently assure adequate data protection of the metering data related to other energy products (authorized access, encryption, etc.).

It can be expected that independent service providers (today known as energy service companies (ESCO)) will offer new energy services on the market in the future. As depicted in the following figure, which shows the smart metering architecture of the proposed service model, also the communication between the set of AMI users (ESCOs, suppliers and others) and smart appliances connected to the HAN over the ICT services provider's network is predicted. For efficient management of the smart appliances at the consumer's premises, ESCOs will also require information derived from metering data, which they will receive exclusively through the common access point at the SCSN. However, the variety, scope and specifics of additional smart metering services, which may develop with the introduction of smart metering, and the details of the according interfaces within the smart metering infrastructure remain somewhat open at this stage.

Within the CBA, the smart metering infrastructure architecture outlined within this section and (in particular) the costs of the above information systems and their expected benefits – in so far as they can be reasonably quantified – have been included in the CBA assessment (see chapter 7).

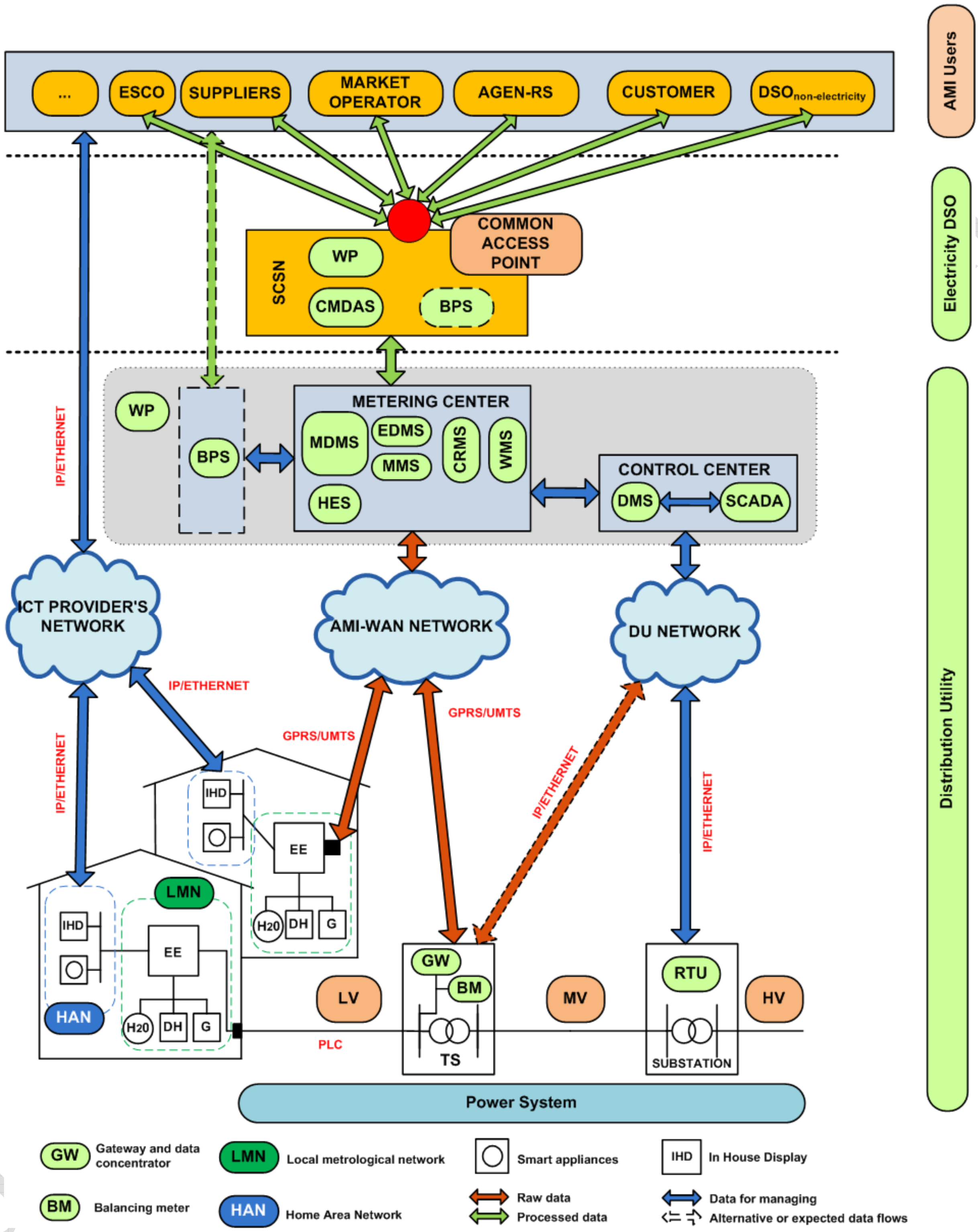

Figure 7: Smart metering architecture of proposed service model [46]

[46] AGEN-RS, November 2013

5 ASSESSMENT OF SMART METER FUNCTIONALITIES AND SERVICES

In addition to the assessment of a roll-out of smart metering for electricity and gas in Slovenia within the CBA framework, we also provide a qualitative assessment of different smart meter functionalities (in line with the tender documents) on their contribution to the maximum use of the advanced metering system, the provision of smart metering services and the generation of benefits.

Smart metering services are strongly correlated to the smart metre functionalities which can be provided by the smart meter. In the following chapter we will therefore evaluate different smart metering services within the context of the smart meter functionalities they depend on.

Basically we can observe the following differences for the existing electronic meters already installed in Slovenian distribution network:

1. Meters without communication module
2. Meters with uni-directional communication module
3. Meters with bi-directional (two-way) communication module and basic functionalities
4. Meters with bi-directional (two-way) communication module, basic functionalities and with advanced functionality (meters have: circuit breaker (i.e. remote connection/disconnection), communication interface (connection to HAN with use of P1 interface))

For the roll-out of smart metering, existing electronic meters satisfying the definitions of item 3 and 4 will be considered compliant with smart metering services and functionalities discussed within this chapter. The services that are associated with smart meter functionalities will be described in the following subchapters. At the end of this chapter an overview of the smart meters functionalities will be provided, indicating how standard smart meters currently available on the Slovenian market satisfy the requirements described under item 4.

5.1 Minimum functionalities of smart meters in Slovenia defined by AGEN-RS

The table below summarizes the required (basic) functionalities of smart meters according to the Guidelines of AGEN-RS.[47] The following minimal functionalities for smart meters reflect the recommendations provided by DG ENER and DG INFSO of the European Commission:[48]

[47] AGEN-RS (2010/2011): Guidelines for the introduction of advanced metering in Slovenia.
[48] A joint contribution of DG ENER and DG INFSO towards the Digital Agenda, Action 73: Set of common functional requirements of the SMART METER, October 2011

No.	Requirements
1	Remote meter reading
2	Registration of 15 minutes load profiles (ability to store information for a minimum of at least 40 days)
3	Options of new (innovative) tariff schemes
4	Remote managing of smart meter (remote testing, remote parameterization of meter, remote upgrade of software etc.)
5	Information about the current tariffs
6	Multi-utility option
7	Accurate time and clock synchronization
8	Detection of malicious interference in smart meter
9	Interoperability of the chosen equipment
10	Forwarding the alarm status of smart meters (watchdog)
11	Providing secure communication

Table 5: List of smart meter basic functionalities

In addition, AGEN-RS defined a set of smart metering functionalities and services provided with the use of functionalities which should be assessed on their contribution to the provision of smart metering services and the generation of benefits.

No.	Requirements	Notes
1	Data access required by market participants	Local access to the smart meter (e. g. local access to the smart meter's built-in WEB server)
2	Control circuit breaker integrated in smart meter or installation possibility of control circuit breaker	
3	Power quality monitoring	
4	Remote connection/disconnection option and option of limiting or increasing of the permissible power	
5	Communication interface for connection with IHD and "home-automation" devices	
6	IHD - In Home Display. Displays information on household energy consumption and various other information	It is also possible to monitor information on WEB portal, but this option is available only to internet users
7	Possibility of prepaid mode of work	

Table 6: List of smart meter functionalities which needs to be assessed

5.2 Optional functionalities and services of smart meters proposed by AGEN-RS

5.2.1 Data access to the smart meter

The data access to the smart meter enables readings directly by the consumer and any third party designated by the consumer. This functionality is essential in a smart metering system as direct consumer feedback is essential to ensure energy savings on the demand side. There is a significant consensus on the provision of standardized interfaces which would enable energy management solutions in 'real time', such as home automation, and different demand response schemes and facilitate secure delivery of data directly to the customer. Accurate, user-friendly and timely readings provided directly from the interface of customer's choice to the customer and any third party designated by the consumer are strongly recommended since they are the key to running demand response services, taking 'on-line' energy-saving decisions and effective integration of distributed energy resources. In order to stimulate energy saving, it is strongly recommended to ensure that final customers using smart metering systems are equipped with a standardized interface which provides visualized individual consumption data to the consumer.

5.2.2 Circuit breaker

The circuit breaker allows remote on/off control of the supply and/or flow or power limitation. It provides additional protection for the consumer by allowing grading in the limitations. It speeds up processes such as when moving home; the old supplier can be disconnected and the new supplier connected quickly and simply. It is needed for handling technical grid emergencies. It may, however, introduce additional security risks which need to be minimized.

5.2.3 Power quality monitoring

Power quality monitoring is a task of the DSOs, who use task-specific devices (phasor measurement units and network analysers).[49] Deviations in quality of power can cause different problems (blackouts, damaged or destroyed equipment, etc.), which result in higher costs for stakeholders. For real time monitoring of the quality of power, very expensive devices are required. Deployment of these devices would have a significant financial impact and may not be economically viable. For that reason, hundreds of clients are usually monitored by a single network analyser; in case of deviations of power quality it is, therefore, difficult to identify the exact location of problems.

The above requirements, which correspond to the recommendations of EN 50160, may not be fully achieved by smart meters; nevertheless smart meters can significantly contribute to the power quality monitoring. If the smart meters are equipped with sensors that enable power quality monitoring, the quality monitoring can be done by consumers, who can also detect potential misbehaviour of electric devices. Also, DSOs have their benefits from smart metering power quality control since it can show the quality of the power delivered to the consumer. With smart metering power quality monitoring, DSOs can further perform better analytics and improved network stability. Early identification of problems and preventive maintenance is also possible.

For the tasks of power quality monitoring described above, meters must be equipped with according sensors to measure the required parameters. For standard power quality monitoring tasks, which can generate significant benefits to the consumer and the DSO, smart meters with bi-directional communication and advanced functionalities are generally equipped for detecting the following parameters: instantaneous voltage and current, under and over voltages, phase voltage faults, voltage unbalance, daily peak and minimum voltage for each phase, number of short power-downs (less than 3 minutes) and total time without power supply. Since such capabilities are built in standard smart meters currently available on the market, they are generally not associated with significant higher costs. Some smart meters with such capabilities have already been installed in Slovenian distribution network.

It is important to stress that despite the fact that smart meters can detect all these parameters, these power quality measurements are not according to international standards for such measurements like EN50160[50], IEC 61000-4-30[51] and others[52]. Smart meters with the capabilities described above would

[49] EN 50160 Voltage characteristics of electricity supplied by public distribution systems, CENELEC 2007
[50] EN 50160 Voltage characteristics of electricity supplied by public distribution systems, CENELEC 2007

however provide significant benefits for DSOs compared to traditional energy meters in terms of enhanced control over the electrical power system.

5.2.4 Remote connection/disconnection option

Smart meters enable remote connection/disconnection option if proper switch is integrated to the meter. Remote operation of connection/disconnection brings benefits related to the reduction of the costs that are incurred with disconnecting and reconnecting of the customers in debts. Because of remote operations, no physical presence of the personnel on the site is required.

In the area of gas, there is also possibility of remote activation or deactivation of supply. Physical presence of personnel in case of gas supply activation is required on site due to safety reasons. Expected benefits with remote operations are therefore lower than in the case of electricity.

5.2.5 Communication interface for connection with Home Area Network (HAN)

For communication with the IHD displays and new smart appliances, the smart meter must have an embedded HAN communication interface. In this case, the standardised HAN interface is available to auxiliary equipment (generally able to connect up to 5 appliances), and this can bring some additional benefits to the smart metering process. HAN uses many different technologies (ZigBee, M-Bus, Wi-Fi, Z-wave). Some smart meters have proprietary solutions for IHD displays and not necessary communicate with HAN through the standardised HAN interface but via proprietary interface.

The use of HAN brings energy saving benefits to the households. They can manage their energy consumption on the base of the information received from IHD and the use of smart home devices (house automation systems, smart home systems) that are connected to the HAN.

If the smart meter is allowed to control the operation of devices with high electricity consumption (washing machines, heating systems, air conditioning, heat pumps, etc.), energy savings can be expected. The heating or cooling systems can be disconnected for a short time (one hour) without causing comfort problems to the users. There are many ideas about different services regarding the combination of smart metering infrastructure and smart home appliances.

5.2.6 IHD – In home display

The reduction of the energy consumption is expected with the implementation of smart metering. IHD devices can help to raise awareness of consumers about their energy consumption and help them to take proper actions in order to reduce consumption and costs. The base of so called direct feedback is

[51] IEC 6100-4-30 Ed.2 Electromagnetic compatibility (EMC) Part 4-30: Testing and measurement techniques – Power quality measurement methods
[52] SINTEF Energy Research: Power quality measurement capabilities of “Smart” energy meters; ICREPQ’10, March, 2010

that the end users are equipped with a special display, which communicates with the meter and provides real time information about the consumption and the consumption related costs. The IHDs could be very effective in their purpose and cost efficient if they can be equipped only with red and green light emitting diode which will light-on in the event of high or normal consumption of energy.

Data from the meter can be transferred via Wi-Fi, PLC, Bluetooth or Ethernet. The information can be displayed in kWh, Sm3, currency (prices), or the emission and price of the CO2. The handling with display and data visualization must be user friendly and easy to understand. Besides IHD, also TV, PC or smart phones can be used, but the use of TV/PC requires some extra effort from consumers to access to the information, so the use of PC or TV is considered as indirect feedback. Separate standalone IHD would bring higher benefits.

The consumers with high energy consumption will probably react more responsively than the consumers with low consumption.

5.2.7 Prepaid option

The new smart meters also enable the use of prepayment system without additional manual installations and interventions. Prepaid mode of work can also be applied to different commodities (electricity, gas, heating, etc.). Some European countries use a prepayment billing system (UK, Ireland, etc.). Prepaid energy meters base on microcontroller application, which accepts the number of units that are recharged by the customer. The microcontroller counts the number of units consumed. When the number of the units becomes zero, the signal for the interruption of the supply is sent by the microcontroller to the switch, which cuts off the supply until the recharge.

Prepaid mode has many benefits. The money for energy is collected in advance, so there is a positive cash flow for DSOs, energy resellers and suppliers. There are no costs with the creating and delivery of the bills. The process of billing can be centralized, and the cost of manpower required to perform the billing related operations is reduced. The problems with evaders and disconnection of power supply in case of unpaid bills are also eliminated.

Many different payment systems are used (smart cards, applications on different mobile devices, calling the supplier customer care line, credit cards, bank accounts, electronic or paper vouchers). The units in the meter are decreasing during the demand for energy. At a certain level, the consumers must be alerted to recharge the money. The recharging must be available anywhere and anytime.

Higher costs of the meters and payment process bring higher tariffs for the prepayment customers. The main additional cost on the side of the smart meter is a power switch[53]. Other costs of the introduction of prepayment models are related to its implementation (with prepayment models not being common

[53] This is a standard function of smart meters which are installed in Slovenia today (i.e. a power switch is included in the standard configuration of smart meters in Slovenia); accordingly smart meters equipped with such functionalities are considered in this CBA. The additional costs of a power switch – when comparing a prepaid meter with a standard smart meter – do therefore not apply for the situation in Slovenia.

in Slovenia today), such as the development and implementation of robust prepayment models or necessary adaptions of the IT hardware and software.

5.2.8 Registration of 15 minutes load profiles and forwarding these data to the consumer

This functionality relates only to the end-consumer. In order to respond with energy savings to consumption information provided by the smart metering system, consumers need to see frequent information on their current consumption. The frequency at which this information is provided has to be adapted to the response time of the energy-consuming or energy-producing products. The general consensus is that an update rate of every 15 minutes is needed at least. Further developments and new energy services are likely to lead to faster communications. It is also recommended that the smart metering system should be able to store consumption data for a reasonable time, in order to allow the consumer and any third party designated by the consumer to consult and retrieve data on past consumption. This should make it possible to calculate costs related to consumption.

5.3 Qualitative assessment of smart meters functionalities and services

The table below summarizes the pros/cons of smart meter functionalities and the associated smart meter services:

FUNCTIONALITY	PROS	CONS	COMMENT
Data access required by market participants	+ Provide information directly to the customers and other stakeholders + Information enables energy savings and wide range of smart services	– May be associated with additional costs	Prerequisite for the establishment of smart metering; standardisation and automation of data exchange can limit additional costs.
Circuit breaker (electricity)	+ Remote on/off of the supply + Remote flow/power limitations + Fast and simple disconnection of the old supply (or connection of the new)	– Security risks – Potentially additional cost	Quite standardised functionality which is integrated in smart meters already installed in the Slovenian network.
Power quality monitoring (electricity)	+ Detection of the problematic location + DSO's need to proof the quality of the delivered power + Early identification of the problems and preventive maintenance + Improved reliability and quality of supply for consumers	– Advanced power quality services may result in higher cost of meters	Basic power quality analyses functions are integrated in smart meters already installed in the Slovenian network.
Remote connection/disconnection	+ Reduced costs with disconnection/connection + No physical presence of staff on-site (electricity) + Fast and simple	– Additional costs for switching device – Physical presence of staff on-site required (gas supply activation)	Benefits from this functionality bring additional costs.
Communication interface for connection with HAN	+ Energy savings + Connection with smart appliances + Connection with house automation	– Additional costs – The effects depend on the user type (those with high consumption will probably save more energy)	This functionality is almost necessary for demand response and other benefits from saving energy. Benefits are higher than the costs for this functionality.
IHD – In Home Display	+ Energy savings + Different real time	– Additional costs	Benefits of IHDs may also be provided by

FUNCTIONALITY	PROS	CONS	COMMENT
	information	– The effects depend on the consumer type (those with high consumption will probably save more energy)	smart phones, tablets and PCs; in any case, it will be necessary to have a connection interface. IHDs will generate additional costs.
Prepaid mode of work	+ Positive cash flows of the suppliers, DSOs and resellers (money collected in advance) + Different payment systems + Avoids costs with creating and delivering the bills + No costs with connection/disconnection	– Recharging – Higher costs of meters – Unwanted stop of supply – Physical approach to the meter is required	Benefits from this functionality are expected to be higher than additional costs for smart meters with such an option. Regarding the situation in Slovenia the introduction of this service may lead to additional costs[54]. Physical approach to the meter could be an obstacle at the introduction.
15 minutes load profiles	+ Energy savings + Shift of consumption from peak to off-peak + Usage and billing relate to actual consumption	– The effects depend on the consumer type – Low effect on consumption shifting in case of low bill impact	Standardised functionality

Table 7: Smart meter functionalities and their pros/cons

5.4 Conclusions regarding functionalities and services of smart meters

There are many different functionalities of smart meters, which can provide new services for consumers. The following table shows a comparison of the functionalities of two types of electricity smart meters from different vendors (IDIS compliant). These two types of meters are most often installed in the Slovenian distribution network; the set of smart meter functionalities specified in this table is, however, also generally representative for standard smart meters of other vendors.

[54] The prepaid mode of work is not common in Slovenia. The introduction of this system brings costs that are necessary for its implementation, such as the development and implementation of robust prepayment models or adoptions of the IT hardware and software, etc.).

FUNCTIONALITY	SM type 1 from Vendor 1	SM type 2 from Vendor 2
Remote data reading	yes	yes
15-minute load profiles registration	yes	yes
Possibility for innovative tariff schemes	yes	yes
Remote operation of the meter (software update, parameterization and tests)	yes	yes
Information on current tariff	yes	yes
Possibility of connection with other utility meters	yes	yes
Control circuit breaker integrated in system counter or installation possibility of control circuit breaker	yes	yes
Basic power quality monitoring	yes	yes
Real time clock and time synchronization	yes	yes
Detection of malicious interventions	yes	yes
Two-way communication	yes	yes
Remote connection/disconnection option and option of limiting or increasing permissible power	yes	yes
Communication interface for connection with IHD and "house-automation" devices	yes	yes
LCD display	yes	yes
Possibility of hardware upgrade (modularity)	no	no
Identification of measuring devices with identification key GS1 GIAI	yes	yes
Interoperability	yes	yes
Prepayment mode of work	yes	no
Provision of safe communication connection	yes	yes
Information on the status of the measuring equipment – alarming	optionally	yes

Table 8: Comparison of the functionalities of two types of electricity smart meters[55]

[55] Sources: Iskraemeco and Landis&Gyr

As we can see from the table, the two types of smart meters have most of the required functionalities already installed or integrated in the meter. The functionalities listed in the table can provide all types of services which are required from smart metering today. More or less these functionalities describe a standard range of smart meters currently available on the market. The price difference between those two types of smart meters is relatively small and varies only slightly between different smart meter manufacturers. The main difference in the meter costs is not in the listed functionalities but in the communication interfaces (GSM/GPRS or PLC) and in the number of measured phases (one phase or three phase meters). Smart meters with very distinctive / selective sets of functionalities will, however, come at an extra cost since smart meters currently on the market tend to be very much standardised across manufacturers and would need to be specifically calibrated by the manufacturers.

Comparison of gas smart meter functionalities between different vendors have also been made (see the following table). Functional requirements for gas and electricity smart meters are very similar. In the gas area, consumption measurement intervals are usually longer (1 hour), but gas smart meters enable to forward consumption data in shorter intervals (15 minutes) for the purpose of direct feedback (IHD). Gas smart meter often communicate with electricity smart meter, which can be used as a gate-way for further communication (e.g. with IHD and for exchange of the metering data with the gas DSOs).

FUNCTIONALITY	SM type 1 from Vendor 1	SM type 2 from Vendor 2
Remote data reading	yes	yes
Two-way communication	yes	yes
Possibility for innovative tariff schemes	yes	yes
Possibility of remote activation/deactivation of supply	optionally	yes
Communication with IHD	optionally	yes
Data access required by market participants	yes	yes
Load profiles registration	yes	yes
Prepayment mode of work	optionally	yes
Remote operation of the meter (software update, parameterization and tests)	yes	yes
Information on current tariff	optionally	yes
Real time clock and time synchronization	yes	yes
Detection of malicious interventions	yes	yes
Mechanical upgrade (modularity)	yes	no data
Identification of measuring devices with identification key GS1 GIAI	yes	yes
Interoperability	yes	yes
Provision of safe communication connection	yes	yes
Information on the status of the measuring equipment – alarming	yes	yes

Table 9 Comparison of the functionalities of two types of gas smart meters[56]

Emphasis of smart meter functionalities is on all services which can reduce the energy consumption. The reduction of consumption does, however, depend on behavioural changes of the consumers, which is only exactly known after a roll-out and can only be estimated based on results from pilot projects and international experiences in advance. The full advantage of new functionalities of smart meters can only be achieved with educated and well informed consumers. Consumers can be well informed only when the data provided by the meter and other display devices will be clear and easy to understand, so the consumer could interpret them easily. All the data, which would bring considerable reduction of consumption, should be free of charge for the consumer in order to foster a change of consumer behaviour.

Smart meters could be effective in its purpose and available at reasonable costs only with strictly standardized functionalities which will provide easy understandable, reliable and secure services to the

[56] Sources: Elster-Instromet and Landis&Gyr

average consumers. Very advanced set of meter functionalities may in principle be able to provide very sophisticated services. If these are, however, not easily understood and accepted by customers, actual usage of these services might be poor.

All the functionalities of electric and gas smart meters, which are listed in the tables above (Table 8 and Table 9), have been taken into consideration in the calculation models of this CBA.

6 COMPARISON OF RECENT COST-BENEFIT ANALYSES CONDUCTED IN OTHER COUNTRIES

6.1 Introduction

In line with the requirements of Directives 2009/72/EC and 2009/73/EC cost-benefit analyses for a roll- out of smart metering have by now been made in most European countries. Based on the results of these assessments several European countries have already decided for and in a few cases against a roll-out of smart metering (e.g. Belgium, Czech Republic and Lithuania). In some countries, a decision for a roll-out of smart metering has been driven by the DSOs independently from the results of a CBA (e.g. in Italy or Sweden). The following map provides an overview on the results of CBAs for electricity smart metering conducted in Europe as well as the status of the roll-out decisions.

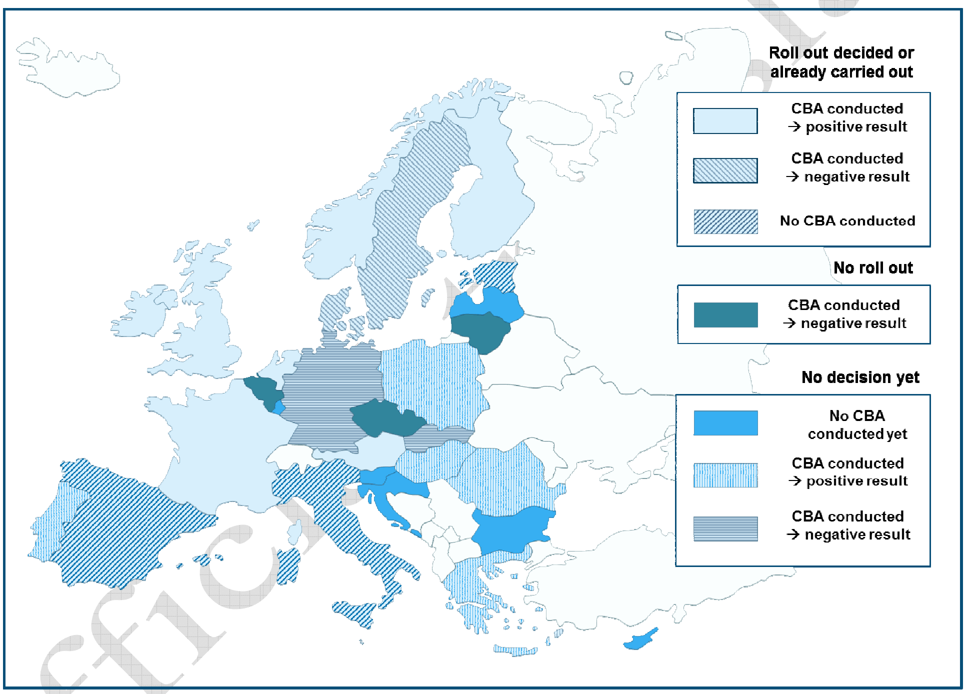

Figure 8: CBA results and status of roll-out decisions for electricity smart metering in Europe[57][58]

[57] Please note that some of the CBA results shown on the map have been taken from CBAs conducted in the respective countries that do not comply with the requirements of EU Directive 2009/72/EC, which explains why for some countries no decision on a roll-out for smart metering has been made yet.

[58] Sources: JRC IET (2013): Scientific and policy report - Smart Grid projects in Europe: Lessons learned and current developments (2012 update); Council of European Energy Regulators (2013): Status Review of Regulatory Aspects of Smart Metering; Smart Regions Project (2013): European Smart Metering Landscape Report 2012 (update May 2013); ERGEG (2011): Summary of Member State experiences on cost benefit analysis (CBA) of smart meters; Results from individual CBAs conducted in the respective countries where publicly available.

For smart metering in the area of gas, a smaller number of CBAs has been conducted yet. Positive CBA results for gas smart metering are reported for the Netherlands, UK, Ireland, France, Austria, Italy and Luxemburg. Negative CBA results have been observed in Belgium, Portugal, Spain, Denmark, Czech Republic and Slovakia, who have rejected a roll-out for gas smart metering based on their CBA results. The following map shows the CBA results for gas smart metering in the European Union.

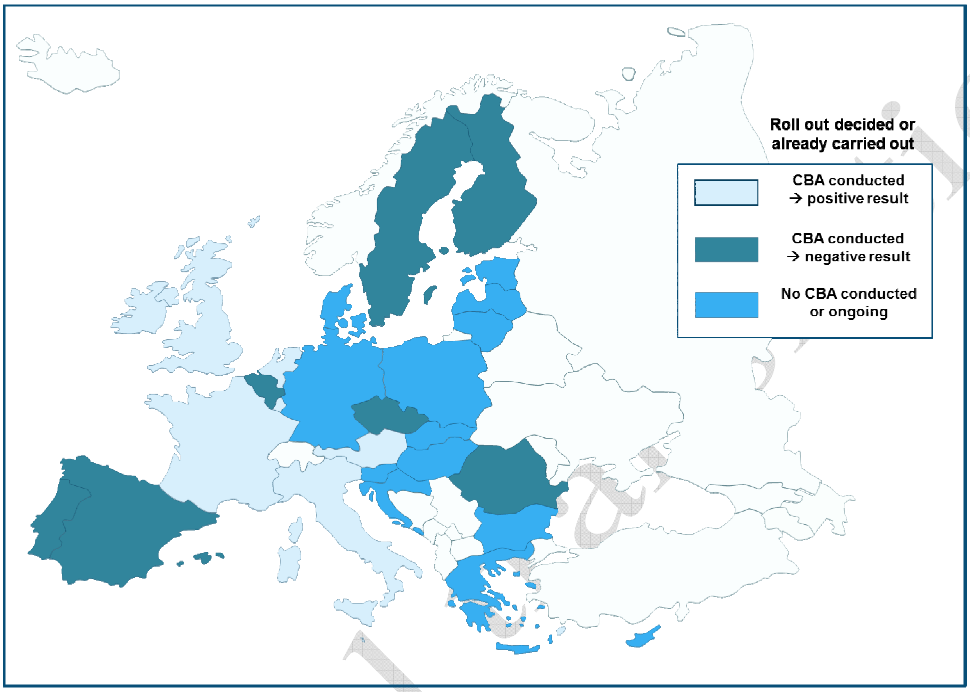

Figure 9: Outcomes of CBAs for electricity smart metering throughout Europe[59]

The specifics of the existing electricity and gas systems, as well as the existing metering infrastructures in a country can, however, have a strong impact on the costs and benefits of a smart metering roll-out. The gas markets, for example, show quite different levels of development throughout Europe. Also, differences in the set-up of the CBA models, such as the extent of costs and benefits assessed within the model or the smart metering implementation scenarios, can be observed. A CBA on the roll-out of smart metering carried out in one country can lead to completely different results in another country. A transfer of CBA results from one country to another may, therefore, be misleading. Possible country specifics that could be important factors for a positive or negative outcome of a CBA are, for example:

- Differences in the level of energy consumption and consumption patterns

[59] Sources: Council of European Energy Regulators (2013): Status Review of Regulatory Aspects of Smart Metering; Smart Regions Project (2013): European Smart Metering Landscape Report 2012 (update May 2013); ERGEG (2011): Summary of Member State experiences on cost benefit analysis (CBA) of smart meters; Results from individual CBAs conducted in the respective countries where publicly available.

- Differences in the metering markets and customer satisfaction with the existing metering and billing system
- The condition (obsolescence) of the existing meters and replacement / recalibration programs conducted for the existing meters
- National energy strategies
- Level of commercial losses (energy theft / fraud)

Since the assessed smart metering roll-out scenarios and the results of the CBAs are strongly influenced by these country specific parameters, we compare in the following only those CBA parameters, which can generally be expected of comparable value in different countries, including, for example, the procurement prices of smart meters. In our comparison, we focus on the recent CBA assessments for smart metering conducted for Austria, Germany, Hungary Lithuania and Ireland. All of these CBAs have been published between 2010 and 2013 and provide, therefore, very recent data that can be compared in detail and which can be regarded as a good benchmark for the input parameters to be applied in the CBA for Slovenia.

	Unit	Austria	Germany	Hungary	Lithuania	Ireland
CBA conduced for electricity only		-	YES	-	YES	YES
CBA conducted for gas and electricity		YES	-	YES	-	-
Price of smart meter (1 phase)	€	85	80	-	66 -150	75-100
Price of smart meter (3 phase)	€/unit	-	-	-	104 - 233	105-110
Conventional meter price (1 phase)	€/unit	25	25	-	20	-
Conventional meter price (3 phase)	€/unit	-	-	-	64	-
Lifetime of smart meters	years	15	13	15	15	15
Installation costs of smart meter	€ /unit	30	30-100	102	8-16	48-72
Average time for meter reading	h	0.25	-	-	-	0.13
Average costs for reading per hour	€/h	16	3 €/meter	-	0.82 €/meter	-
Costs for data concentrator	€	-	900	1.107	631	-
Number of meters per concentrator	#/concentrator	200	20-200	200	-	44
Cost of in-home display (IHD)	€	-	40	-	25.2	40
IHD installation costs	€/unit	-	15-25	-	-	-
Assumed reduction of electricity consumption	%	3.5	1-2	2	2.3-4.5	3
Shifting electricity consumption from peak to off-peak hours	%	2.5	-	-	4.50	-

	Unit	Austria	Germany	Hungary	Lithuania	Ireland
Communication fee per concentrator	€/month	-	2.09	3.09	-	-
Communication fee per meter GPRS	€/month	0.9	2.09	-	-	0.83
Reduction of non-technical losses (theft)	%	-	20	70	-	30
Non-technical losses	%	-	0.05	1	-	0.5
GPRS module price	€/module	20-50	40 (25-70)	-	-	-
PLC module price	€/module	-	20 (5-70)	-	-	-
Costs of data collection system (Head End)	M€	-	-	-	1.1	4.6
Costs of MDM System	M€	-	-	-	5.8	11.4
MDM System maintenance costs	%	-	-	-	23	
SAP-ERP System costs	M€	-	-	-		6.5
Social discount rate	%	4.15	5	8/10	5 (financial analysis) 5.5 (economic analysis)	4
CO_2 Prices	€/ton	15.67	6.5	-	-	-
Observation period[60]	years	15 (electr.) 12 (gas)	20	10	15	21

Table 10: Comparison of input parameters from recent CBAs

In the following chapters we provide a summary of the scenarios applied in the CBAs and the results of the CBAs in the five countries.

[60] Please note that the observation (or modelling) period is often not clearly defined within the CBA publications; timeframes may furthermore vary according to the respective roll-out scenarios.

6.2 Germany[61]

The electricity smart metering CBA for Germany was published in July 2013. Within the CBA the following main costs related with a roll-out of smart metering have been considered:

- Investment in the meters, concentrators and other smart metering infrastructure
- Smart metering communication infrastructure procurement and installation costs
- IT system implementation costs
- Operational and maintenance costs of IT systems and smart metering infrastructure
- Costs of IHDs
- Data transmission costs
- Billing costs
- Costs with replacement of faulty meters
- Staff training costs
- Electricity consumption costs of meters

As main benefits the following items were taken into account:

- Savings related to the reduction of electricity consumption
- Benefits from delayed investments regarding conventional meters and power system infrastructure
- Benefits from improvements of the whole metering related processes (call centre, billing, meter readings, etc.)
- Positive impacts of reduced greenhouse gas emissions

Within the German CBA five different scenarios have been assessed:

- a roll-out of smart metering for at least 80% of all final consumers until 2020 ("EU scenario") – smart metering penetration remains constant between 2020 and 2032 (end of modelling period)
- a roll-out according to the current legal and regulatory framework ("continuity scenario"), which requires the installation of smart meters for large consumers (>6,000 kWh/a), for new solar and small scale CHP plants with more than 7kW connected load, for new buildings and for flats undergoing thorough renovation, resulting in a smart metering penetration of 29.4% in 2032
- a roll-out according to the current legal and regulatory framework (as above) and for all meters reaching the end of their technical lifetime ("continuity scenario plus"), however, for the later only smart meters (with in-home displays) and not a smart metering communication infrastructure are installed; as a result a smart meter penetration of 65.6% will be reached in

[61] Kosten-Nutzen-Analyse für einen flächendeckenden Einsatz intelligenter Zähler, Ernst & Young, 2013

2022, whereof only around 34% of the smart meters would be connected to the smart metering communication infrastructure

- an adjustment of the existing framework, requiring a roll-out for all solar and small CHP plants (including existing ones and those with a connected load below 7 kW which supports load management and the regulation of the feed in from renewables ("roll-out scenario"), resulting in a smart metering penetration of 32.1% in 2032
- an adjustment of the existing framework (as above) and a roll-out of smart metering systems to all metering points able to contribute to network peak load and of smart meters (without a connection to the smart metering communication infrastructure) for all isolated metering points or for those customers who do not value a connection to the smart metering communication infrastructure and therefore opt for a basic smart meter only ("roll-out scenario plus"); as a result, a smart meter penetration of 68% will be reached in 2022, whereof only around 34% of the smart meters would be connected to the smart metering communication infrastructure

Within the CBA for Germany the assessment of the above scenarios resulted in the following net present values (NPV), which were calculated for the period from 2012 to 2032. The main parameters for the calculation of cash flows are the investment and operating costs.

	"EU scenario"	"Continuity scenario"	"Continuity plus scenario"	"Roll-out scenario"	"Roll-out scenario" with ability to regulate 5% of annual generation of each renewable plant	"Roll-out scenario plus"
NPV	€ -100 million	€ -600 million	€ -1,000 million	€ -1,100 million	€ +1,600 million	€ +1,500 million

Table 11: Summary results of the different scenarios in the German smart metering CBA

The EU scenario is said to be not economically viable because of high installation (large roll-out volume) and operation costs that cannot be compensated with benefits of implementation in Germany. Customers would have to pay higher distribution charges over years without benefiting from smart metering.

In the long term, the Continuity scenario results in a lower NPV compared to the EU scenario. Additional system charges are economically viable for users with high annual consumption and operators of distributed energy sources. On the other hand, for small houses and apartments, that are included in mandatory roll-out, additional costs would be higher than benefits.

The ability of the smart metering system to control the generation of renewable sources cannot be applied within the current legal framework. Within the current legalisation, benefits are not sufficient to achieve economic viability; the Roll-out scenario is therefore not economically viable under the current legalisation.

In the Roll-out scenario plus the implementation of smart metering would be required only for metering points that can contribute to grid efficiency, other metering points would be equipped with cheaper intelligent meters, which could be upgraded later. Roll-out scenario plus is recommended from the economic aspect and also brings many additional advantages.

In summary only a much targeted roll-out of smart meters, i.e. rolling out smart metering (and a smart metering infrastructure) only to those metering points that contribute most to system peak load so that network investments can be reduced by regulating/disconnecting metering points (in particular those where renewable generation is fed into the grid and large consumers), and rolling out smart meters with in home displays to all other customers (without an external communication module) has been recommended by the Consultants of the German CBA (Roll-out scenario plus).

6.3 Austria[62]

The CBA for a roll-out of electricity and gas smart metering in Austria was published in 2010. The main benefit items assessed within the Austrian CBA have been:

- potential savings for the consumer and also for other market participants
- alternative pricing models (peak/off-peak) for consumers
- savings for consumers through simplified processes of billing, troubleshooting, suppliers switching and higher quality of services

The main costs items within the Austrian CBA have been the following:

- acquisition, installation and operating costs of smart meters
- capital and operating costs for data centres and data concentrators
- costs for data transmission (PLC modems, GPRS, Wireless)
- costs for provisioning the information to the consumers (especially costs for web portal and information about monthly consumption)
- saving effects from more efficient processes in meter reading (the omission of the computational meter reading, lower balance energy expenditure and lower grid losses)

Furthermore, the impacts on the market model and competition have been investigated within the CBA. All factors have been evaluated in monetary terms, so that an appropriate comparison of costs

[62] Studie zur Analyse der Kosten-Nutzen einer österreichweiten Einführung von Smart Metering, PwC Österreich, 2010

and benefits is possible. Four different scenarios were defined for the introduction of smart metering for electricity and also for gas. These scenarios are characterized by:

- different deployment periods
- different deployment targets (different target shares of installed new smart meters)

The following scenarios have been assessed in the Austrian CBA:

- Scenario I: 95% of all meters shall be replaced by smart meters from 2011 to 2017
- Scenario II: 95% of all meters shall be replaced in the following periods:
  - replacement of electricity smart meters from 2011 to 2015
  - replacement of gas smart meters from 2011 to 2017
- Scenario III: 95% of all meters shall be installed in the following periods:
  - replacement of electricity smart meters from 2011 to 2017
  - replacement of gas smart meters from 2011 to 2019
- Scenario IV: 80% of all meters shall be replaced by smart meters from 2011 to 2020

The Scenario II has the fastest meter implementation with the highest penetration rate of 95% and Scenario IV has the longest period with only 80% of all meters replaced by smart meters.

All calculations have been conducted for the following stakeholders:

- Consumers (households, industry, agriculture)
- Network operators
- Energy suppliers

The results of the CBA for a roll-out of electricity smart metering in Austria show a positive net benefit in all four scenarios. For the network operators' higher costs than benefits are observed in all scenarios. Similarly, in a separate analysis for electricity and gas, the net effects are positive for all scenarios, while consumers have the greatest benefit.

When comparing the four scenarios, scenario II – the fasted implantation scenario (with an installation of 95% of smart meters until 2015 for electricity and 2017) of the four scenarios – provides the largest net benefit. The largest benefits for consumers from the implementation of smart metering generate from lower energy consumption and lower costs due more efficient metering processes of the network operator.

Total NPV values for all scenarios (observation period was 15 years for electricity and 12 years for gas – determined by the life time of electricity and gas smart meters) are shown in the following table:

	"Scenario I"	"Scenario II"	"Scenario III"	"Scenario IV"
NPV	€ +496.890 million	€ +556.449 million	€ +461.145 million	€ +290.720 million

Table 12: Summary results of the different scenarios in the Austrian smart metering CBA

6.4 Hungary[63]

The CBA for a roll-out for electricity and gas smart metering in Hungary has been published in 2010. Within the study different smart metering market models have been analysed a mixed independent metering company model, a DSO cooperation model and a model with competing metering companies.

In independent metering company model the installation and reading of the meters is between the DSOs (installation and ownership of meters) and an independent metering company (reading, information management of reading data). Within the DSO's cooperation model synergies between the communication and operations between DSOs and independent metering company could be realised. The competing metering companies' model anticipates the increased competition between the companies holding concessions for metering.

In addition another concept for smart metering with the following features is assessed. Within the area smart metering data acquisition and service company model, smart meters will be operated by the DSOs. The owners of the smart meters will be the DSOs, who will also install, operate and maintain the smart meters. As a new market player in this model however an area smart metering data acquisition and service company will be set up, which will be responsible for remote data collection and forwarding of these data to other players on the market in the given region of the country. It will operate under concessions and will be strictly regulated.

Within the Hungarian CBA the following main costs and benefits related with an implementation of smart metering have been taken into account.

Main costs assessed have been:

- Smart meter and concentrators procurement and installation costs
- Data storing, processing and management costs
- Operational costs of smart meters (direct and cost of repair)
- Meter inspection and remaining manual meter reading costs

Expected benefits assessed have been:

[63] Assessment of Smart Metering Models: The case of Hungary, AT Kearney, 2010

- Reduction of technical and non-technical losses
- Benefits regarding reduced physical local operations
- Reduction of bad debt
- Environmental benefits
- Energy consumption reduction

The goal of the CBA was to assess the four smart metering market models and three smart metering implementation scenarios. These scenarios are differentiated as regards the implementation schedule, the geographic implementation and different replacement rates in different phases of implementation.

Three different roll-out implementation scenarios have been assessed:

1. Balanced roll-out

In this scenario a deployment period of 2011-2020 and a constant replacement rate of meters for every year is applied.

2. Fast roll-out

In the fast roll-out scenario all meters shall be installed until the year 2015 with the following replacement rates:

- 2011: 10 % of meters
- 2012: 30 % of meters
- 2013: 30 % of meters
- 2014: 20 % of meters
- 2015: 10 % of meters

3. Delayed roll-out

In the delayed roll-out scenario all meters shall be installed between 2015 and 2020 by applying the following replacement rates:

- 2016: 10 % of meters
- 2017: 30 % of meters
- 2018: 30 % of meters
- 2019: 20 % of meters
- 2020: 10 % of meters

The assessment of the four smart metering models provided the following results in the CBA (10 year period 2011- 2020).

	"Balanced Roll-Out"	"Fast Roll-Out"	"Delayed Roll-Out"	Model
NPV	€ +354.9 million	€ +345.1 million	€ +316.4 million	DSO basic model
NPV	€ +473.2 million	€ +474.6 million	€ +422.8 million	DSO cooperation model
NPV	€ +473.2 million	€ +474.6 million	€ +422.8 million	The central smart metering operator model
NPV	€ +514.5 million	€ +522.2 million	€ +456.4 million	The area smart metering operator model

Table 13: Summary results of the different scenarios in the Hungarian smart metering CBA

Regarding the implementation schedule the shortest possible deployment period provides the largest net benefit and has therefore been recommended. Among the market models the basic DSO model provided the lowest NPV; as reasons for this the higher prices of the meters and the lower benefits (absence of remote connection/disconnection technology, significantly lower consumption and GHG emission rates) have been specified. The DSO cooperation model provides benefits related from the harmonization of smart metering, which results in lower investment and operational costs and eventually higher NPVs. The central smart metering operator model provides the largest NPVs, relating to the high synergies between gas and electricity that can be realised in this model, which result in lower investment costs and higher benefits. Lower NPVs have been calculated in the area smart metering operator model relating to higher investment and operational costs since additional data processing centres are required in this case.

6.5 Lithuania[64]

The CBA for a roll-out of electricity smart metering in Lithuania has been published in 2012. Within the CBA the following main costs have been taken into account:

- Costs for the purchase and installation of smart metering infrastructure (meters, concentrators, balancing meters)
- IT system implementation costs (MDM System, data collection system)
- Multi metering controllers
- In home displays (IHDs)
- Project management and public awareness program costs
- Staff training

[64] Cost-benefit analysis of the roll-out of smart electricity metering grid in Lithuania / Cost-benefit analysis of the smart metering roll-out Scenarios, Ernst & Young, 2012

- Operating and maintenance costs of the smart metering infrastructure (data transmission costs and IT maintenance costs, equipment troubleshooting costs, electricity consumption of smart meters and concentrators)

As main benefits from the implementation of smart metering the following items have been considered in the Lithuanian CBA:

- Avoided costs of the replacement of conventional meters and conventional electricity meters costs
- Reduced costs in the operation of call centres
- Savings due to improved cash flow management
- Meter reading savings
- Reduction of electricity consumption, reduction of technical and non-technical losses
- Savings related to remote connection or disconnection of customers
- Reduction of greenhouse gas emissions

Within the CBA three alternative roll-out scenarios with different parameters have been compared: a base case scenario, an advanced functionality scenario and a multi-metering scenario. Furthermore two different market models have been defined. In all three scenarios GPRS and PLC for the last mile are anticipated as communication technologies. Also time of use pricing is assumed to be obligatory in all three scenarios.

In the DSO model, the DSO is responsible for installation of smart meters, data collection, data transmission and processing other information. This model is the easiest and fastest model to implement. As regard the deployment target and timing a roll-out of 80% of smart meters until 2020 is assumed.

In the advanced functionality scenario more advanced meter functionalities and a larger time frame for the smart metering roll-out are assumed. Also in this model the use of HAN and IHD for showing the electricity consumption to customers in real time are expected. As regards the penetration rate, 100% coverage with smart meters by 2020 is considered.

The multi-metering scenario provides options to combine electricity, gas, water and heating metering systems. In this scenario also the establishing a specific company for the data management is expected. This company would be responsible for collecting, transmitting and processing the metering data. The basic meter functionality would be used with HAN function, the in-house display and the option to combine separate heating, hot and cold water and gas metering systems. The deployment target for this scenario is 80% coverage of consumers by the year 2020.

The CBA is divided in two parts a financial and an economic analysis. The costs and benefits for the project operator (the DSO) are assessed in the financial analysis. The economic analysis assesses the total benefits for the project operator as well as for any other stakeholders (consumers, the state, etc.).

The results of the economic and financial analysis, which were calculated for the years 2014-2029, are presented in the following tables.

	"Base case scenario"	"Advanced functionality scenario"	"Multi-metering scenario"
NPV	€ -120.0 million	€ -151.0 million	€ -129.5 million

Table 14: Summary results of the different scenarios in the Lithuanian smart metering CBA (economic analysis)

	"Base case scenario"	"Advanced functionality scenario"	"Multi-metering scenario"
NPV	€ -210.1 million	€ -315.0 million	€ -260.5 million

Table 15: Summary results of the different scenarios in the Lithuanian smart metering CBA (financial analysis)

Within the Lithuanian CBA a negative NPV (i.e. net costs) have been calculated in all three scenarios within the economic analysis. Also the financial analysis shows that none of the scenarios would provide a positive return of investment to the DSO. As reasons for the negative results in the Lithuanian CBA a low price of electricity, large spare capacities in the transmission and distribution network and small peaks in electricity consumption can be considered.

6.6 Ireland[65]

The CBA for electricity smart metering in Ireland has been published in 2011. The main costs items taken into account in the CBA have been:

- Smart metering infrastructure purchase and installation costs (smart meters, concentrators, communication infrastructure costs)
- Costs of resolution of technical issues at installation
- IT system implementation costs (Head End, MDM, SAP-ERP System, Web Portal, Security Systems, Deployment Logistics and Materials Management)
- IT system operational and maintenance costs
- Project management costs
- Communication costs for data transmission
- Costs of business and networks operations centre

[65] Cost-Benefit Analysis (CBA) for a National Electricity Smart Metering Rollout in Ireland, CER, 2011

- Costs regarding failures in the equipment
- IHD costs

The main benefits expected with a smart metering rollout for Ireland have been:

- Savings due to reduction of manual meter readings
- Reduction of meter visits and inspections
- Avoided conventional meter replacement costs
- Postponed network reinforcement costs
- Reduced voltage complaints investigation
- Reduced non-technical losses
- Benefits of pre-payment option

In the CBA 12 scenarios for a roll-out have been analysed. The differentiation between the scenarios was made as regards the billing, communication technologies and the use of IHDs. For billing, monthly (options 10-12) and bi-monthly billing scenarios (options 1-9) have been distinguished. As communication technologies PLC-RF[66] (options 1, 2, 3 and 10), PLC-GPRS (options 4, 5, 6 and 11) and GPRS only (options 7, 8, 9 and 12) have been assessed. The use of IHD was only considered in some scenarios (options 2, 5 and 8).

For the different scenarios the following NPV results for years 2011-2032 have been calculated within the Irish CBA.

	"Option 1"	"Option 2"	"Option 3"	"Option 4"	"Option 5"	"Option 6"
NPV	€ +174 million	€ +170 million	€ +26 million	€ +135 million	€ +131 million	€ -13 million
	"Option 7"	"Option 8"	"Option 9"	"Option 10"	"Option 11"	"Option 12"
NPV	€ -33 million	€ -37 million	€ -181 million	€ +282 million	€ +242 million	€ +74 million

Table 16: Summary results of the different scenarios in the Irish smart metering CBA

Overall substantial net benefits have been calculated for a deployment of smart metering in Ireland. An important factor of the Irish CBA has been the change in the billing frequency. In Ireland bi-monthly billing frequency used to be the standard and an increase of billing frequency to a monthly interval has been assessed. The option with no roll-out and an increase in billing frequency to monthly was assumed to be the business as usual scenario.

[66] RF = radio frequency

Within the Irish CBA the main factor for positive or negative results has been the communication technology. The use of GPRS technology was only positive in one scenario. It has however to be noted that a GPRS/G3 modem was predicted to be use in this case and that the annual fee for GPRS communication has been reported quite high (twice as high as in Great Britain).

6.7 Summary

Based on the above descriptions for different recent CBAs the following observations can be made. The time schedules for a roll-out of smart metering have been more or less the same in all CBAs. Accounting for the fact that the year 2020 is already defined in the EU Directive, it is almost always considered as a base case roll-out scenario. In most cases two additional scenarios (or in some cases even more) with a longer deployment period, but no longer than 2030 have been specified. In these additional scenarios a higher penetration rate of up to 95% or more has very often been assessed. Given the fact that the year 2020 is not that far in the future, faster roll-outs than the 2020 80% target have usually not been considered.

A second similarity among the recently conducted CBAs, have been the meter functionalities and the communication technologies. This reflects the standardization efforts taken place on European level, the recommendations for a roll-out of smart metering provided by the European Commission and ERGEG as well as developments on the manufacturers side towards a standard set of functionalities.

What distinguishes the scenarios of the different CBAs, are mostly the country specific factors. In the case of Germany the existing legislation and regulatory framework, in the case of Hungary organizational questions of the metering market and in the case of Ireland particularities in the billing frequency have been given particular importance in the CBAs. Furthermore consumption patterns and assumptions as regards the future development of input parameters distinguish the different CBAs. In addition, also the level of detail up to which benefits are included in the CBA are different among the recent studies. As a consequence positive as well as negative results have been observed in the different CBAs. Because of these country specificities it is also not possible to transfer the results from one country to another, even if we consider many input parameters and scenarios as largely comparable.

7 METHODOLOGY OF THE CBA

In line with EU legislation (see chapter 2.1) an assessment of costs and benefits of a roll-out of smart metering should be conducted in the form of a cost-benefit analysis. A CBA is a common tool used to provide criteria for investment decision making by systematically comparing the benefits with the costs over the life span of an investment project. It is widely applied on the societal level (collective impact) as well as the company (i.e. the investor's) level (individual impact).[67] Whereas in the private sector, appraisal of investments and financial analysis of company's costs and benefits takes place against maximizing the company's net benefits, the economic CBA focuses on the overall long-term costs and benefits taking a broader perspective and including externalities, such as environmental impacts and costs and benefits to third parties, to broader groups of stakeholders. This gives the economic CBA a wider economic character with the objectives of maximizing welfare of a society (or country) as a whole.

An economic (or social) CBA generally consists of the following parts, which are further described in the following sections:

1) Selection and definition of input data and assumptions on their future development
2) Assumptions on model parameters
3) Definition of potential costs and benefits for different stakeholders
4) Definition of alternative (smart metering roll-out) scenarios (e.g. regarding the deployment strategies and type(s) of smart meters)
5) Assessment of the monetary effects (financial and monetized indirect (external) effects of a smart metering roll-out) for different stakeholders
6) Calculation of the total net benefit for different scenarios discounting future costs and benefits with an appropriate rate
7) Sensitivity analysis of the results in order to determine critical input variables

Since the impact of smart metering on some cost and benefit categories may be dependent on the country characteristics of Slovenia, we have applied specific Slovenian data wherever possible. For this purpose we have sent questionnaires with detailed data requests to the DUs and DSOs and suppliers. Wherever sufficient and credible data has been provided to us by the DUs, DSOs suppliers, we have included these in our assessment. The response rate of suppliers to the questionnaire has however been quite limited. Furthermore information provided by AGEN-RS as well as information from pub-

[67] A system wide cost-benefit analysis is also foreseen at European level by *Regulation (EU) No 347/2013 on guidelines for trans-European energy infrastructure* for the identification of Projects of Common Interest, i.e. for cross-border (electricity, gas or oil) infrastructures or infrastructures with significant cross-border impact. Such projects may benefit from accelerated permit granting, financial support and specific regulatory measures. The CBA frameworks currently developed by ENTSO-E and ENTSO-G will also be applied for the ten-year network development plans in the future.

licly available sources for Slovenia has been considered for the level and future development of the various input parameters of the CBA. Wherever such country specific information has not been available, international data for comparable countries has been considered.

Besides the Slovenian data, in particular the following sources have been taken into account, when specifying input parameters, assumptions and scenarios of the CBA model:

- European documents, including the specification of the EU Directives (2009/72/EC and 2009/73/EC) and the Guidelines of the European Commission Joint Research Centre Institute for Energy and Transport and of ERGEG[68]
- other CBAs for smart metering conducted in comparable countries in recent years
- expertise from DNV KEMA and KORONA gained in previous projects, including experience from previous economic CBAs for a roll-out of smart metering conducted by DNV KEMA
- data from internal databases of DNV KEMA and KORONA as well as other international studies, including experience from pilot projects

All major assumptions on model input parameters and the definition of the roll-out scenarios have been presented to, discussed with and agreed by AGEN-RS prior to the conduction of the CBA.

7.1 Definition of input data and assumptions on their future development

The selection and definition of input data to be considered in the assessment of costs and benefits and the assumptions on their future development may already predetermine the outcome of a CBA. It is therefore of particular importance that no bias is shown in data selection and definition in order to avoid any bias in favour or against a roll-out of smart metering. Assumptions on the future development of input parameters determine the future occurrence and extent of possible costs and benefits of smart metering. When assessing a roll-out of smart metering in the framework of an economic CBA, assumptions on future development have particularly to be made in the following areas:

- Development of procurement, installation and maintenance costs for smart meters and smart metering infrastructure
- Future development of consumption levels of different types of customers and the number of households
- Future development of average, peak- and base-load end-user tariffs for households and small commercial customers and of wholesale prices
- Future development of carbon emissions per household and per small commercial customer and the development of CO_2 prices

[68] European Commission Joint Research Centre Institute for Energy and Transport (2012): Guidelines for cost-benefit analysis of smart metering deployment; ERGEG (2011): Final Guideline of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas.

The assumptions on the future development of input data should also include the definition of maximum, minimum and base (average) levels for each parameter, so that their impact on the final outcome of the economic CBA can be assessed in a sensitivity analysis.

As regards major input parameters the following assumptions have particularly been made for the CBA.

Inflation rate

For the period 2013-2015 we do apply the inflation rate provided in the network charges act, since these levels are also applied in the regulatory framework up to 2015. Accordingly we do apply an inflation rate of 1.8% for 2013 and a rate of 1.9% for 2014 and 2015. For the period after 2015 an inflation rate of 1.7% per annum (minimum 1.5%, maximum 2%) has been taken from information provided UMAR.[69]

Annual electricity consumption growth rate

Based on figures provided by ELES in their transmission network development plan 2013-2022 we predict an average annual consumption growth rate up to 2022 between 1.4% and 2.6%. Between 2022 and 2030 we assume a linear growth of around 2% based on the ELES figures for the middle scenario as shown in the table below.

Electricity consumption in GWh											
Year	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2030**
Low scenario	12,363	12,592	12,822	13,051	13,281	13,511	13,740	13,970	14,199	14,429	15,980
Middle scenario	12,462	12,649	12,963	13,276	13,589	13,903	14,216	14,530	14,843	15,156	17,664
High scenario	12,966	13,372	13,896	14,302	14,696	15,106	15,434	15,805	16,210	16,549	18,795

Table 17: Expected annual electricity consumption for Slovenia up to 2030[70]

For the years after 2030 we assume a further annual growth of electricity consumption of 1%. Within the sensitivity analysis also figures for the high and low scenario will be applied.

Annual gas consumption growth rate

Based on figures provided by the gas TSO of Slovenia (Plinovodi) in its 10-year network development plan 2014-2023[71] we assume an annual average increase in gas consumption of 0.42 % until 2023. For the years after 2022 we will assume a constant natural gas consumption of customers (i.e. a growth

[69] UMAR – Institute of Macroeconomic Analysis and Development of the Republic of Slovenia (2013): Slovenian economic mirror, June 2013

[70] Source: ELES (2012): Transmission network development plan 2013-2022 (Razvojni načrt prenosnega omrežja RS 2013-2022), based on Elektroinštitut Milan Vidmar (2012): Updating the forecast of electricity consumption by 2040 (Ažuriranje napovedi porabe električne energije do leta 2040).

[71] Plinovodi d.o.o. (September 2013): Gas transmission network development plan 2014-2023 (Desetletni razvojni načrt prenosnega plinovodnega omrežja za obdobje 2014-2023)

rate of 0%). From 2030 onwards an annual decrease of natural gas consumption by households of 0.5% will be assumed reflecting a gradual substitution of natural gas by renewable energy sources.

Population growth rate

As regards future population growth of Slovenia we apply the middle scenario of the projection of the Statistical Office of the Republic of Slovenia[72], as shown in the following table. For the years in-between we assume a linear growth.

Year	2008	2010	2020	2030	2040
Population	2,022,644	2,034,220	2,058,003	2,022,872	1,957,942

Table 18: Expected population of Slovenia up to 2040

CO_2 price evolution

For the development of CO_2 prices we do apply figures used by the European Commission (EC) for those countries participating in the Emission Trading Scheme (ETS).[73] Accordingly carbon values of 16.5 €/tCO_2eq for 2020 and 36 €/tCO_2eq for 2030 are considered in the CBA model. Starting from the present level of 3.6 €/tCO_2eq, we assume a linear growth for the modelling period.

Development of average end user prices for electricity

According to AGEN-RS, evolution of end user prices for typical residential (household) customers in Slovenia will be very similar to the prices provided in the EU energy trends to 2030.[74] Within the CBA a development of end-user prices of around 1.67% per year is therefore assumed. For small commercial customers, a price evolution similar to the category "services" in the EU Energy trends data of around 1.41% per year is applied.

[72] Statistical office of the Republic of Slovenia (SURS) (July 2009): Slovenia's population today and tomorrow, 2008-2060: EUROPOP 2008 population projections for Slovenia (Prebivalstvo Slovenije danes in jutri, 2008–2060, Eurostatova projekcija prebivalstva EUROPOP 2008 za Slovenijo)

[73] European Commission Impact Assessment to the Roadmap for moving to a competitive low carbon economy in 2050, SEC (2011) 288 final

[74] DG ENER (2009): EU energy trends to 2030

	2000	2005	2010	2015	2020	2025	2030
Average	96	104	110	127	140	146	144
Industry	59	71	77	92	101	104	98
Services	123	124	124	139	152	159	159
Household	127	133	144	164	180	191	192

Table 19: Development of end-user prices for electricity in the European Union (after tax electricity prices in EUR/MWh, base case scenario)

Different scenarios for the development of future end-user gas prices will be assessed within the sensitivity analysis.

Development of average end user prices for gas

We will assume an annual decrease of natural gas prices for average household customers of -1.25% in Slovenia up to 2020, based on figures provided for Europe by the International Energy Agency in their World Energy Outlook.[75] Similar figures are also provided by the World Bank in their commodity forecast price data (for European natural gas) from July 2013.

After 2020 we will assume stable natural gas prices on average (i.e. neither a decrease nor an increase of natural gas prices). Different scenarios for the development of future end-user gas prices will be assessed within the sensitivity analysis.

Development of network charges for electricity

As regards the average electricity distribution and transmission network charges for household and small commercial customers we have been provided with the following levels and shares in 2012 by AGEN-RS.

[75] International Energy Agency (2012): World Energy Outlook 2012

	Average household customer	Average small commercial customer	Weighted average household and small commercial customer	Average household customer	Average small commercial customer	Weighted average household and small commercial customer
Energy price and suppliers margin	62.21	68.31	63.53	41.06%	44.23%	41.76%
Transmission network charge	15.14	12.84	14.64	9.99%	8.31%	9.62%
Distribution network charge	40.32	39.25	40.09	26.61%	25.42%	26.35%
Other charges and taxes	33.84	34.03	33.88	22.33%	22.03%	22.27%
Total end-user price	151.51	154.42	152.14	100%	100%	100%

Table 20: Average electricity end-user tariffs for household and small commercial customers (in €/MWh) and their shares (in %) in 2012

For the years 2013 to 2015 we assume the following developments of transmission and distribution network charges, based on the levels of allowed revenues for transmission and distribution specified by AGEN-RS for these years:

- annual increase in average DSO network charges of +0.57%
- annual decrease in average TSO network charges of -1.54%

For the years 2015 to 2020 – taking into account the above figures – we assume an

- annual increase in average DSO network charges of +1%
- stable average TSO network charges

From 2020 onwards we apply an

- annual increase in average DSO network charges of +2%
- annual increase in average TSO network charges of +1%

Within the sensitivity analysis higher and lower changes of network tariffs will be assessed.

Development of network charges for gas

As regards the average gas distribution and transmission network charges for household and small commercial customers we have been provided with the following levels and shares in 2012 by AGEN-RS.

	Average household customer	Average small commercial customer	Weighted average household and small commercial customer	Average household customer	Average small commercial customer	Weighted average household and small commercial customer
Energy price and suppliers margin	39.1	44.0	40.1	59.15%	64.71%	60.30%
Transmission network charge (entry)	1.0	1.0	1.0	1.51%	1.47%	1.50%
Transmission network charge	4.0	4.0	4.0	6.05%	5.88%	6.02%
Distribution network charge	17.0	14.0	16.4	25.72%	20.59%	24.66%
Other charges and taxes	5.0	5.0	5.0	7.56%	7.35%	7.52%
Total end-user price	66.1	68.0	66.5	100%	100%	100%

Table 21: Average gas end-user tariffs for household and small commercial customers (in €/MWh) and their shares (in %) in 2012

For the years 2013 to 2015 we assume the following developments of transmission and distribution network charges, based on the levels of allowed revenues for transmission and distribution specified by AGEN-RS for these years and taken into account the restrictions for changes of transmission and distribution tariffs:[76]

- annual increase in average DSO network charges of +3%
- annual increase in average TSO network charges of +2%

For the years 2015 to 2020 we will – taking into account the above figures – assume an

- annual increase in average DSO network charges of +2%
- annual increase in average TSO network charges of +2%

From 2020 onwards we will assume

- annual increase in average DSO network charges of +1%
- annual increase in average TSO network charges of +1%

[76] Article 12 of Methodology for calculating the distribution network costs, restricts adjustments of transmission network tariffs in the next few years to changes to up to 3%.
Article 11 of Methodology for calculating the transmission network costs, restricts adjustments of transmission network tariffs in the next few years to changes between -5% to +5%.

Within the sensitivity analysis higher and lower changes will be assessed.

7.2 Assumptions on model parameters

An economic CBA should (ideally) assess all possible future costs and benefits of a smart metering roll-out. However, some costs and benefits of smart metering may have immediate effects, but others may be partial, or only take effect in the long-term. A further parameter to be decided ex-ante is therefore the length of the period considered in the economic CBA model. Some projects assessed in an economic CBA may require a fairly long period of time to repay their initial investment in order to first start seeing net benefits. The modelling period should generally be long enough to encompass all major benefits and costs occurring during the economic lifetime of the asset assessed in the economic CBA, i.e. at least the economic lifetime of the smart meters and the smart metering communication infrastructure. The modelling period is also dependent on the time frame for the roll-out of smart metering (in particular the end date). If deployment is expected to take place over a longer period of time (as may be the case for gas meters where no deadline for the implementation of smart metering has been set in EU legislation), also the modelling period may need to be longer.

Some costs of smart metering are significantly higher at the beginning of a roll-out (or only arise at the beginning), while some benefits will particularly be significant in the long term. If a too short modelling period is applied, the assessment of relevant costs and benefits may therefore be cut off too early. Possible drivers for short-term costs and long-term benefits may be the following:

- many investment costs arise at the beginning of a smart metering roll-out, including investments in the smart metering infrastructure, while benefits do arise over the technical life-time of the smart meter (or even longer)
- additional (one-off) costs arise for the introduction of a smart metering system, including implementation program costs and costs of customer awareness and communications campaigns as well as additional costs relating to necessary revisits of smart meters due to technical problems that may occur after the initial installation (such as communication problems with the concentrators or central systems)
- hardware costs of smart meters and infrastructure are expected to decrease in the next years to come following technological progress as well as larger roll-out numbers of smart metering throughout Europe
- with rising CO_2 prices in the future also the benefits from reduced energy consumption will increase
- in case a deployment target below 100% is assessed, a natural roll-out for the remaining share of meters above the deployment target (e.g. 80%) is assumed, which will bring additional benefits over time

Considering the technical lifetime of smart meters, rolling out smart meters until 2020 or 2030 will mean that some smart meters will only reach the end of their first lifetime at around 2035 or 2045.

Applying a short modelling period (e.g. of 20 years or less) may cut-off benefits too early (i.e. at a point of time where some smart meters, installed at the end of the roll-out period, have not yet reached the end of their technical (or economic) lifetime) while the (investment) costs of smart metering would be fully included.[77]

Long-term developments of major input parameters, such as long-term price levels or the development of energy consumption, are on the other hand more uncertain than forecasts of the more immediate future. Also long-term technological developments of smart metering which may result in new functionalities and applications cannot be fully predicted. A very long time horizon may therefore require stronger assumptions on the future development of input parameters or a wider range of values as regards their possible development.[78]

To adequately balance both effects, and in line with experience from previous CBAs conducted by DNV KEMA, we compare the net benefits (or costs) of each scenario at the end of the first and the second investment cycle for smart meters within the CBA. This will make sure that we sufficiently consider all relevant costs and benefits arising from a roll-out of smart metering.

When discussing our results in chapter 8, we will furthermore provide information in which year each scenario will provide a positive net benefit (i.e. the break-even point from a negative to a positive net present value) as well as the distribution of discounted costs and benefits over time. Based on these results a political decision can then be made on whether the break-even point is regarded as too distant in the future to justify a roll-out of smart metering.

Future benefits or revenues and costs of smart metering may not have the same value as present benefits and costs. Future values have therefore to be converted into their value today (their present value) by an appropriate discount rate, so that they can be meaningfully used for comparison/evaluation purposes. The discount rate represents the minimum return that an investment project must earn to be economically feasible. In other words, selecting a high discount rate expresses a higher demand to the profitability of the investment. High discount rates can also be applied to express that benefits and costs achieved in periods closer to the smart metering investment have a higher value to the stakeholders than those occurring further in the future. Whereas a private financial investor would select a financial discount rate that considers the actual cost of borrowing and actual returns on alternative investments in the market (financial analysis), an economic CBA would require a social discount rate (reflecting society's point of view). Since the costs of a roll-out of smart metering predominantly arise at the beginning of the assessed period whereas some benefits only arise in the long term the selection

[77] When one observes constant average net benefits (or costs) over a period of several years, perpetuity could be calculated, which allows to quantify the net present value of future costs and benefits arising repeatedly with each investment cycle. However due to the above issues and the long time frame of a natural roll-out (in case of a 80% deployment target, a natural roll-out for the remaining 20% may take place until the 2040s or longer), such constant net benefits or costs will only be observed after several decades.

[78] This effect is however limited by the fact that the same assumptions for the future development of parameters do apply for any roll-out scenario as for the business-as-usual scenario, with which any roll-out scenario is compared with.

of the social discount rate is a crucial input parameter for the economic CBA. Social discount rates commonly applied at European level are those published in the guide to CBA for investment projects by the Directorate General for Regional Policy of the European Commission[79] and the Commission guidelines for impact assessment.[80] Following these recommendations and the Guidelines for CBA of smart metering deployment by the European Commission Joint Research Centre Institute for Energy and Transport[81] a social discount rate of 5% has been applied in the base case and rates of 5.5% and 3.5% been evaluated in the sensitivity analysis.

Roll-outs of smart metering already carried out or commenced in other European countries have often focused on electricity only, since the benefits of an application of smart metering tend generally be greater for electricity than for gas.[82] Whereas a specific deadline is defined for electricity within the EU Directive (80% roll-out until 2020 in case of a positive CBA result) no such deadline is specified in the legislation for gas. In line with the proposed smart metering service models we propose to assess a roll-out of smart metering for electricity only and for a joint roll-out of smart metering for electricity and gas in the CBA framework. When a joint roll-out is assessed within the CBA, we consider a shared communication infrastructure for both electricity and gas, which will avoid costly redundancy (as discussed in chapter 4, where we recommended to apply model A2 in the joint scenario and model B1 in case of an electricity only scenario). The shared communication infrastructure could either be achieved by providing one of the meters (the electricity meter) with an interface to connect additional meters, or by installing a multi utility communication controller able to connect several meters. In line with the specifications of the recommended smart metering service model A2 (discussed in chapter 4) we assume an interface at the electricity smart meter that enables the communication with other meters within the CBA.

7.3 Definition of Costs and Benefits

Major costs associated with smart metering are purchasing, instalment and operating (maintenance) costs of the smart meters as well as the investment costs for advanced data collection, data communication tools and implementation program costs. Major benefits typically associated with smart meter-

[79] European Commission, Directorate General Regional Policy (2008): Guide to Cost Benefit Analysis of Investment Projects

[80] European Commission (2009): Commission Impact Assessment Guidelines

[81] European Commission Joint Research Centre Institute for Energy and Transport (2012): Guidelines for cost-benefit analysis of smart metering deployment

[82] Benefits from load shifting for example are only applicable to electricity since fluctuations in electricity production and demand have to be balanced in much shorter time intervals than for gas, which generally varies at a much slower pace. Also the potential for energy savings tends to be smaller for gas consumption, as the purposes of electricity usage are manifold with plenty of individual and independent consumer decisions on whether or not use electricity on a daily basis, where constant or regular feedback will have the strongest effect. Furthermore network losses tend to be negligible for gas, whereas they can be significant for electricity, see also section 7.3.2.

ing are among others energy savings due to increased efficiency or sufficiency and due to load shifting, reduced metering costs, improved security of supply and reduced non-technical losses. The following subchapters describe the different cost and benefit categories we assessed within the CBA.

Costs and benefits of smart metering depend also on the technical specifications of the smart meters and the smart metering infrastructure rolled-out. More advanced smart metering systems with a larger range of functionalities could provide greater benefits and a larger range of benefits, but may also be more expensive than very basic smart metering systems (e.g. only allowing for remote meter reading). Typical standard functionalities of smart metering have for example been defined under the European standardization mandate M/441[83], in the Guidelines of Good Practice published by the European Regulators' Group for Electricity and Gas (ERGEG)[84] and in the European Commission's survey on common functional requirements.[85] Furthermore also AGEN-RS has prepared a number of studies, most notably the "Guidelines for the introduction of smart metering in Slovenia, July 2011", outlining roles and responsibilities for the implementation of smart metering and functionalities that advanced (smart) metering services should provide. Within these Guidelines AGEN-RS has defined a range of expected functionalities similar to the set of standard functionalities defined at European level. Standard smart meters currently on offer by manufacturers generally tend to offer all of the above functionalities. Differences in the cost levels of different types of meters are therefore of less importance (see chapter 5 for further details).

Costs and benefits arise directly to the DSO[86] replacing the old meter and to the customer whose old meter is replaced with a smart meter. However costs and benefits do (indirectly) arise to a much wider range of stakeholders. A complete assessment of possible costs and benefits therefore requires to investigate the impact of a roll-out of smart metering to all major stakeholders. In line with international best practice we therefore propose to assess costs and benefits of a roll-out arising to distribution and transmission network operators, suppliers, consumers and to the society as a whole. When calculating

[83] The standardization mandate of the European Commission to standardization bodies has been provided with European Commission (2009): Standardization mandate to CEN, CENELEC and ETSI in the field of measuring instruments for the development of an open architecture for utility meters involving communication protocols enabling interoperability, M/441 EN

Functional requirements for smart metering have been defined in: CEN, CENELEC and ETSI (2011): Technical Report – Functional reference architecture for communications in smart metering systems

[84] ERGEG (2011): Final Guideline of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas

[85] European Commission, A joint contribution of DG ENER and DG INFSO towards the Digital Agenda, Action 73: Set of common functional requirements of the SMART METER, Full Report, October 2011.

[86] As discussed in chapter 4, procurement, installation and operation of electricity smart meters will be carried out by the DUs and not by the electricity DSO. Here and in the following we do not differentiate between the DSO and the distribution network owners called distribution utilities (DUs), but rather distinguish costs and benefits of smart metering arising for distribution from those arising to transmission, supply, consumers and others (producers, society, government). From the use of the abbreviation "DSO" used here, it can therefore not be concluded whether these tasks shall be carried out by the DSO or by the DUs.

the aggregated net benefit of a roll-out of smart metering for all stakeholders, we weight all stakeholders equally. Since costs and benefits may however be unevenly distributed between different stakeholders and arise differently over time, we will also investigate the distributional effects of a roll-out when evaluating the results of the CBA (i.e. looking also at the distribution of costs and benefits for different stakeholders, see chapter 8).

The following sections outline and describe the main costs and benefit items and the respective parameters included in the electricity and gas smart metering rollout scenarios assessed within the CBA. Further details on the specific input data we considered in the domain of electricity and of gas within each of the cost and benefit areas are shown in 00.

7.3.1 **Electricity**

7.3.1.1 Costs

Costs of smart metering include the costs for the smart meters and the communication and data processing infrastructure required to establish a true smart metering system. Costs do also arise for additional applications, which foster the realization of benefits from smart metering, such as in-home displays or web portals. The conduction of a mandatory roll-out will furthermore cause program implementation costs for the planning and coordination of procurement, logistics and installation of the smart meters. To facilitate energy savings of customers also marketing campaigns should be conducted. In addition, the implementation of smart metering will also entail the replacement of conventional meters before the end of their economic lifetime, which will result in stranded costs. When conventional meters have been recently installed, such costs can be quite significant and should be taken into account when the maximum allowed revenues are set by AGEN-RS.

In summary the following cost items for electricity have been included within the smart metering CBA:[87]

- Procurement, installation and operational costs of smart meters
- Communication infrastructure costs
- Information systems costs
- Procurement and installation costs of in-home displays
- Global program implementation costs
- Marketing campaign costs
- Stranded costs of existing meters

The cost data applied in the CBA and presented below are primarily based on information and feedback provided by the Slovenian DSOs, DUs, suppliers, AGEN-RS and publicly available sources for

[87] Costs of the cost-benefit analysis itself are not included in the cost-benefit analysis, as they arise in any of the analysed scenarios, including the scenario to keep the status-quo and not roll-out smart meters.

Slovenia as well as expertise within the Consortium gained through previous project work for Slovenia. Where specific Slovenian data has not been available or in comparison not been regarded as reliable, international data obtained from other CBAs conducted in comparable countries and from pilot projects, manufacturers and energy suppliers, as well as from other international reports and publications have been taken into account.

We furthermore consider a decrease in procurement costs of smart meters and smart metering infrastructure in the future due to technological progress and economies of scale, reflecting an increasing deployment of smart metering across Europe as well as the impact of a large scale roll-out in Slovenia. Also the operating costs for the smart metering infrastructure are expected to further decrease with a mandatory roll-out in the future due to increased operational efficiencies and learning effects on the side of the s DUs. In the following paragraphs the main cost items are further described in detail.

Costs with procurement and installation of smart electricity meters

Smart meters have to be procured, installed, read, serviced and maintained resulting in substantial capital and operational costs. The costs of smart metering depend on the technical specifications of the smart meter (i.e. its functionalities) and on a number of country specific factors, such as the number of smart meters to be procured. As a result, exact prices of smart meters cannot be easily found on price lists published by the manufacturers, but are rather dependent on the exact specifications of the smart meters and a result of individual negotiations with the manufacturers. In particular, procurement prices commonly observed in pilot projects will likely be much higher than smart meter prices in case of a mandatory roll-out of smart metering to all household and small commercial customers in Slovenia.

Compared to international data observed for comparable countries and recent information obtained from smart meter manufacturers, smart meter price information provided to us by the DUs seem to correspond to typical prices submitted for smart meter pilot projects. Accounting for these effects and the economies of scale to be expected for a large scale roll-out of smart metering throughout Slovenia, smart meter prices used in this CBA are therefore obtained by adjusting the smart meter prices provided to us by the DUs. The capital costs of the smart meter (excluding the communication module) are thus estimated at € 60 for single-phase meters and € 90 for three-phase meters. These costs are consistent with DNK KEMA internal data base as well as international studies and recent CBAs on smart metering roll-out. The costs of meters to be installed on secondary side of the distribution transformers for energy balance are assumed to be at around € 264 within the CBA. A sensitivity analysis is done to these parameters by varying the smart meter prices between +/- 20%.

While the communication module is quite commonly integrated into the smart meter, we do consider it here as a separate cost item (see description further below). Since a roll-out of smart metering is always compared with a business as usual scenario (see section 7.4), where conventional meters are replaced with conventional meters, also the procurement, installation and operations of conventional meters are considered in the CBA.

Based on the figures received from the DUs and AGEN-RS, around 28% of the existing electricity meters are smart meters, which share the same functionalities as the smart meters considered in the roll-out scenarios for Slovenia – as described in chapter 5 – or which slightly deviate as regards some of the functionalities but only with a negligible impact on procurement prices. These existing smart electricity meters will not be replaced before the end of their economic lifetime. As their replacement time and costs will be the same in the business-as-usual as well as in any roll-out scenario, their number have been taken out of this CBA assessment. The replacement and operational costs of the existing smart meters would therefore not have an impact on the CBA results, as their costs would arise to the same extent in any roll-out and the business as usual scenario. It was however taken into account that some elements of the communication infrastructure and the necessary information systems are already partly be in place and that the smart metering infrastructure will be used by a larger number of smart meters and consumers respectively.[88]

In recent years an enormous development in the markets for electronic components and communications infrastructure could be observed. In this study we assume that an increasing deployment of smart metering will lead to continuing strong growth and significantly falling prices in the future. It therefore seems reasonable to expect an annual costs saving potential of smart meter procurement costs of 5% up to 2020.

The average installation costs of smart meters are estimated at € 20 per meter including labour and travelling costs. A sensitivity analysis was applied to this parameter between € 13 and € 29. A revisit rate of 0.5% is assumed due to access and technical problems.

Besides the procurement and installation costs of different types of meters also the following costs have been considered in the assessment:

- costs related to the meter failure rate of smart and conventional meters
- energy consumption of the meter – typically the smart electricity meters consume more energy than the conventional meters due to the communication module
- households' opportunity costs during meter readings – assuming that some percentage of meters are installed inside properties and would require a member of the household to be present when the metering takes place

Costs of the communication infrastructure

The communication infrastructure costs include the installation and commissioning of the PLC/GPRS and PLC/WiMAX data concentrators at the medium voltage substations as well as head end systems (hardware and software) to manage the bidirectional communication infrastructure including routers, firewalls, servers and licenses. Furthermore, it is necessary to consider the annual communication charges for GPRS meters.

[88] In other words, the number of smart meters already installed in Slovenia does only have an impact on the assessment results of the different smart metering roll-out scenarios, in so far as the utilization of the smart metering infrastructure (and the costs of the infrastructure per meter) does depend on the total number of smart meters in Slovenia (that is the number of smart meters currently installed plus the number of smart meters to be installed as part of the roll-out).

A communication module which is already integrated into the smart meter (i.e. in most cases – as also suggested in chapter 4 – into the smart electricity meter) can be acquired at lower costs than a separate communication module. While we present here separate costs figures for the communication module, we do assume that the communication module will indeed be integrated into the electricity meter.

GPRS/GSM-enabled devices are more expensive than meters with a PLC communication, because the modulation of a PLC signal is technically much easier than a GSM connection. DNV KEMA's observation of the European market is that most utilities consider comprehensive PLC as the most cost effective option, requiring a significant market penetration (up to 80% or more). Only for more isolated buildings (e.g. in rural areas) GPRS/GSM or WiMAX seem generally to be the most cost effective option.[89]

The maximum and minimum prices for the PLC communication module considered in this CBA are € 10 and € 60 respectively with a base value of € 20 per meter communication module. For GPRS the maximum and minimum prices for the communication module considered in this CBA are € 25 and € 80 respectively with a base value of € 40 per meter communication module.

The cost of the data concentrators including installation and commissioning is assumed to be at € 910 for PLC/GPRS and € 1,000 for PLC/WiMAX (with a range of € 631 to € 1,800 and € 900 to € 1,200 respectively to be assessed within the sensitivity analysis, based on data provided by the DUs and from other CBAs) considering an average of 50 PLC meters per concentrator.

In the case of GPRS meters the annual communication charges can vary between € 0.8/month and € 2/month according to information provided by the DSOs. These costs will mainly depend on the volume of meter data. The annual communication charges for the concentrators of GPRS/PLC are assumed in the range of € 2.2-3.4 per month.

The costs of implementing head end systems (including licenses and hardware costs) included in this CBA are € 2.6 million considering an implementation period of 2 years. Annual operational costs to cover the necessity of re-investments during the CBA analysis period are assumed to be at around € 520,000. A sensitivity analysis is applied to this parameter considering a variation between +30% and -30%.

In the case of WiMAX technology the radio base station cost is assumed in the range of € 15,000 - € 45,000 depending on the number of concentrators per radio base station. Costs of € 30,000 per radio base station considering 50 concentrators per radio base station are assumed.

Costs of the information systems

The information systems costs are mainly related to the implementation of a Meter Data Management System for the management of the smart meter data, processing, editing, validating and storage of the data (including server hardware and storage infrastructure) and meter data delivery to other corporate systems and market participants. This item includes investment in new information systems and up-

[89] Furthermore, the cost efficiency of the different communication systems also depend on the existing communication infrastructure and the size of the network area.

date of the existing information systems to handle new smart metering processes and functionalities as well as the management of all the market information.

Also the costs for a web portal to provide customers with secure access to their consumption data are considered. The suppliers may also have access to consumption data through this web portal depending on clients' permission and use it to improve or provide additional services. A total cost of € 13.5 million (new as well as integration/refurbishment of existing systems and costs for a web portal) is assumed with an implementation period of 3 years and operational costs of 15% to cover the necessity of re-investments. These costs are highly uncertain and therefore a sensitivity analysis was applied to this parameter considering a variation between +50% and -50%.

Costs with In-Home Display

The CBA also includes costs of In-Home Displays (IHDs) in a scenario considering the provision of real-time consumption information to customers. Within this CBA, we allocate the procurement costs of IHDs to the customers. In some studies these costs are covered by the DSOs or suppliers, which would also be possible to apply within our CBA model. It is assumed that the meter will have embedded HAN communications to provide secure communications with the IHD. It is estimated that the IHD will have power consumption below 2 W. There is a great level of uncertainty regarding the IHD functionalities and physical design and therefore the CBA includes a sensitivity analysis range between € 20 and € 55 for the hardware costs of the IHD with an average cost € 40. It is furthermore assumed that a significant number of households will use smart phones and tablets to access real-time consumption information rather than IHDs.

Global program implementation costs

A mandatory roll-out of smart metering will also result in implementation program costs – that include among others project management costs as well as costs associated with logistics, procurement processes and staff training. For the program implementation total costs of € 3 million have been assumed within the CBA. These costs will only arise with the planning and coordination of the mandatory roll-out; once the roll-out is completed, only regular smart meter replacements need to be conducted, when smart meters reach the end of their life-time.

Marketing campaign costs

The existence of the smart meter or some sort of consumption feedback itself may not necessarily result in substantial energy savings. The consumer may require further information on how to use the new and additional information in order to really achieve significant changes in consumption behaviour and sustainable energy savings. To raise consumer's awareness of energy efficiency, marketing campaigns should therefore be conducted together with the roll-out of smart metering. The campaigns should provide information to consumers on the potential impact of tariff changes and explain how to adjust consumption behaviour in order to reduce energy bills. Its cost will be driven by the amount of smart meters to be installed and the duration of the marketing campaign. Within the CBA we assume total costs of about € 1.5 million for the conduction of according marketing campaigns.

7.3.1.2 Benefits

Smart metering together with customer feedback mechanisms and according price signals (such as time-of-use tariffs) can provide strong incentives for consumers to reduce their consumption (increase energy efficiency) and to shift load from peak to off-peak periods. This has further consequences on customer bills and the revenues of all other stakeholders (e.g. suppliers, generators, transmission and distribution network owners and the state (impact on taxes)) as well as on carbon emissions. In addition it has also an impact on investments in transmission and distribution capacities (lower consumption in particular at peak times will require less capacities). More detailed metering information provided to consumers (to set the above incentives for energy savings) would increase paper billing costs; on the other hand smart metering may also facilitate and increase the percentage of electronic billing, which would subsequently reduce billing costs.

Benefits of smart metering can also be expected, since several tasks of the DU, which have been conducted manually by dispatching on-site staff, can now be conducted remotely at lower costs, such as remote meter reading, remote disconnection and reconnection of customers, voltage level and meter failure investigations. In case of outages, smart metering could improve failure detection and restoration of power, which is expected to reduce average outage times. Further benefits of smart metering can be expected through reduced non-technical (and technical) losses, since it allows to meter consumption more accurately (and thereby to identify where electricity theft takes place) and to automatically detect tempering of the meter.

In summary the following benefit items for electricity have been included within the CBA:

- Electricity consumption reduction
- Meter reading costs reduction
- Technical and non-technical losses reduction
- Billing costs reduction
- Electricity shift from peak to off-peak
- Local operations cost reduction
- Outage time reduction
- Reduced investment in transmission and distribution capacity

In the following paragraphs each of these benefit items as well as its underlying assumptions are further described in detail.

In addition, due to a lack of reliable data, some (smaller) benefits of smart metering – that have been included in some smart metering CBAs conducted for other countries – could only be assessed qualitatively outside the CBA, including the following three items:[90]

[90] While call centre costs and asset management costs have been included in some of the CBAs conducted by DNV KEMA, reduced generation capacity investments have generally been not, as the calculation of marginal

- Call centre costs reduction
- Reduced generation capacity investments
- Asset management cost reductions

We will discuss these as well as other potential costs and benefits in the context of the CBA results in chapter 8.

Electricity consumption reduction

Smart meters will provide consumers with better and more detailed information about their consumption levels and patterns as well as their individual tariffs for electricity. Actual and historic consumption data can, for example, be shown on an in-home display, smart phone or on a computer screen, either provided by a direct data link or on a web page fed with the meter data. Smart metering – together with price signals – can therefore make the overall costs of electricity consumption and individual consumption patterns more transparent to the customers. It also allows to provide customers with more accurate and detailed bills. Thereby customers are for example able to understand the impact of individual electricity devices or certain consumption behaviour on their energy bill. Such detailed information might also make the environmental effects of consumption behaviour, such as the resulting greenhouse gas emissions, more transparent for customers.

Constant feedback on consumption and associated costs will therefore increase the consumer's awareness and willingness to save energy. It allows customers for example to decide when and for how long to connect or disconnect some of their electric devices or to purchase more energy efficient household appliances.

By raising awareness on consumption levels and increasing transparency on expenditures for electricity by consumers, smart metering will allow the customers to reduce their consumption and their bill. This reduction does however correspond as well to a reduction on the revenues of the different stakeholders. Within this CBA different levels of consumption reduction are considered depending on the type of information provided to the customers. In the case of indirect feedback, it is assumed that the customers will reduce their consumption on average by 2% (sensitivity analysis between 1% and 3%). In the case of direct feedback, it is assumed that the customers will reduce their consumption on average by 3% (sensitivity analysis between 1.5% and 4.5%). Furthermore, also the impact of consumption reductions on reducing CO_2 emissions has been included within the CBA (taking into account the CO_2 price forecasts within the European emission trading scheme – see also section 7.1).

generation costs would require detailed information on generation capacities and the wholesale market in the specific market. In some other CBAs for smart metering conducted in other countries however less benefit items have been included as we assess here for Slovenia; also the level of detail how each cost-benefit items is assessed does vary between CBAs.

Meter reading savings

The standard manual meter readings will be avoided with the implementation of smart metering, since these can be carried out remotely. According to information provided by the DUs, the annual and monthly manual meter readings correspond approximately to 95% and 5% of the total manual meter readings respectively. In addition, it will also be necessary to perform additional (or special) manual meter readings occasionally (for example in case a customer is switching its supplier or moving out of a property). Depending on the location of the existing conventional meters (whether located outside a building or inside) smart metering may have also the additional benefit that it does not require a person of the household to be present when the meter reading takes place (the CBA therefore also takes these avoided household opportunity costs into account).[91]

Technical and non-technical losses reduction

The implementation of smart metering is expected to reduce significantly the number of households with cases of theft. Using smart meters and balance meters, makes it possible to compare whether the amount of transmitted electricity (measured in substations) matches the amount of consumed electricity (the sum of individual meter readings) taking into account the network losses. This will allow to quickly and relatively precisely identify where electricity theft takes place and consequently to stop the respective customer from doing so. As a consequence some of these households will continue to consume energy, but others will reduce their consumption, because they will have to pay for the energy. It is also considered that the fraud relative to contracted power will be completely avoided (including tempering of the meter) with the introduction of smart meters and that there will be requests to increase the contracted power after the installation of smart meters. More accurate metering – after the introduction of smart meters – will also reduce administrative losses. Within the CBA we assume a reduction of non-technical losses of 50% after the roll-out of smart metering; given the relatively low percentage of non-technical losses currently observed in Slovenia, these benefits can however expected to be relatively small.

Reductions in energy consumption will also subsequently reduce the technical losses observed in the transmission and distribution networks. According to information we received from the DUs and from AGEN-RS, current network losses in Slovenia are at around 1.5% on transmission and at around 4.5% on distribution level on average.

Billing costs reduction

End-users may choose between a paper and an electronic bill. Currently almost all customers in Slovenia receive a monthly paper bill (99.5%). In case of a smart metering roll-out it is expected that the costs of paper bills will increase, due to more detailed information provided to the customer,[92] while

[91] According to data provided by the DUs 37% of the existing conventional meters in Slovenia are located outside of the buildings.

[92] The size of which will depend on the type of feedback provided to customers and the development of smart metering services.

they will not change for electronic bills. It is also expected that the percentage of clients with electronic bill may also increase which will reduce the bill costs. In a scenario without smart meters it is expected that the number of clients with an electronic bill will increase over time, while the introduction of smart meters may increase the percentage of clients with an electronic bill even more (up to 50%). As for all other cost-benefit items the above assumptions are assessed within the sensitivity analysis.

Electricity shift from peak to off-peak

Customers can further contribute to energy savings if they are offered time-of-use or load-variable tariffs enabling them to save on their energy bills by shifting certain usage (e.g. dishwasher, washing machine, heating, cooling) to cheaper periods (requiring less generation capacities and production during peak-load periods). Within the CBA the bill reduction for customers resulting from a shift of consumption from peak to off-peak as well as the revenue impact for producers and network operators is assessed (for the impact on network investments see also further below). The extent to which energy is transferred from peak to off-peak periods depends on the number (or percentage) of customers that are able to shift electricity consumption as well as on the average percentage of their total electricity consumption that these customers are able to shift. Within the CBA we assume the percentage of clients that shift consumption from peak to off-peak to be at 3% in the base case.

Local operations cost reduction

Benefits of smart metering include the ability to handle customer disconnection and reconnection remotely and (partly) automatically, reducing the need to send out technicians to customer sites to suspend and resume electricity supply. Remote disconnection and reconnection may be necessary because a customer has been (temporarily) not paid his bill (debt management) or because a customer has moved out or into a property. The possibility of remote and instant disconnection of customers by the meter operator can also help to reduce the risk of payment default for the supplier. The introduction of smart meters is furthermore expected to reduce local operations relating to voltage level and meter failure investigations. These activities will be done remotely after the implementation of smart metering, which will reduce the costs of local operations. Calculations within the CBA for cost reductions of local operations have been based on the current numbers and costs for these services provided by the DUs.

Outage time reduction

The introduction of smart meters will increase the efficiency of the outage management system (failure detection and restoration of power) and it is expected a reduction on the outage time. Smart metering can help network operators to detect and locate faults and power outages more quickly. Reducing the time period between the time the fault occurs and the time the grid operator's control centre receives this information (automatically) via the smart metering communication infrastructure allows the network operator to immediately dispatch the technicians required to restore the fault. By identifying fault locations more quickly, the outage time can be reduced. This provides a direct benefit to consumers and savings to the DU from reduced costs by more accurately dispatching crews.[93]

Reduced investment in transmission and distribution capacity

Smart metering together with the application of time-of-use tariffs can provide customers with information on consumption and prices and encourage them to shift their energy consumption into times when energy prices are at a lower level. Peak load may also be reduced by the general incentive to reduce energy consumption by increased customer awareness on consumption levels and increasing transparency on their expenditures. In addition, lower peak load will also result in lower network losses at peak times. Smart metering can thus reduce the demand at peak times and thereby reduce the maximum network capacities required to distribute (and transmit) electricity at peak load, which in turn reduces the need for future investment in transmission and distribution capacity. Marginal costs for distribution and transmission have been calculated by dividing the respective eligible costs by system peak load.

7.3.2 **Gas**

Many of the cost and benefit items for natural gas are identical to those for electricity. However, some of the most significant benefits of smart metering, such as benefits from load shifting and energy savings, are much greater for electricity than for gas. Benefits from load shifting for example are only applicable to electricity since fluctuations in electricity production and demand have to be balanced almost instantly, whereas for gas variations take place at a much slower pace. Given the nature of gas usage for heating purposes, a load shift from peak to off-peak times would also make little sense. With regards to energy savings, the impact on gas consumption is more limited, as the purposes of electricity usage are manifold with plenty of individual and independent consumer decisions on whether or not use electricity on a daily basis, where constant or regular feedback will have the strongest effect. Benefits of cost savings for local operations are to be expected lower for gas, since remote reconnection cannot be conducted remotely in Slovenia due to safety reasons.

Also other benefits described above for electricity do not apply for gas. This includes in particular for benefits from a reduction of technical and non-technical losses and reductions of outage times (which can both be regarded as negligible for gas). In case of a joint roll-out for electricity and gas several synergies on the cost side can be realised (and costly redundancies be avoided). This applies in particular for the costs of communication infrastructure, implementation programs, in-home displays and marketing campaigns (which will generally only be counted once in the joint roll-out scenarios).

Differences between electricity and gas are also to be observed for the costs of procurement, installation and operation of the smart meters and the information systems. Separate costs for the smart meter-

[93] When a regulatory scheme for quality of supply is applied – linking the actual network reliability (number and duration of outages) to quality standards and penalties or a quality incentive scheme – network operators can also benefit from higher revenues following reduced outage duration times.

ing communication infrastructure will only arise in a gas only scenario as otherwise the electricity communication infrastructure will also be used for the gas smart meters (see also chapter 4).

Accordingly the following cost items have been included within the smart metering CBA for gas:

- Procurement, installation and operational costs of smart meters
- Communication infrastructure costs
- Information systems costs
- Procurement and installation costs of in-home displays (only for gas only scenario)
- Global program implementation costs
- Marketing campaign costs (only for gas only scenario)
- Stranded costs of existing meters

As regards the benefits of smart metering for gas the following benefit items have been included within the CBA for gas:

- Gas consumption reduction
- Meter reading costs reduction
- Billing costs reduction

As for electricity, some benefits of smart metering could only be assessed qualitatively outside the CBA, due to a lack of reliable data, including the following items:

- Call centre costs reduction
- Reduced investment in transmission and distribution capacity

We will discuss these as well as other potential costs and benefits in the context of the CBA results in chapter 8.

In the following we further explain only those cost or benefit items, where different assumptions have been made for gas compared to those for electricity described above. Since there are no (or hardly any) smart gas meters already installed in Slovenia that comply with the set of standard functionalities specified in chapter 5, less experience and subsequently less Slovenia specific cost data could be provided for smart gas metering than for electricity. As a consequence, some cost figures for gas are based more on international data, gained from other CBAs in comparable countries, from pilot projects, manufacturers and from other international reports and publications as well as on expertise of DNV KEMA and KORONA gained in previous projects.

Costs with procurement and installation of smart gas meters

The capital costs of the smart gas meter (excluding the communication module) are estimated at € 100, with minimum and maximum values of € 80 and € 120 assessed within the sensitivity analysis. This reflects also international data provided in other CBAs and studies for comparable countries as well as recent information obtained from smart meter manufacturers.

The average installation costs of smart meters are estimated at around € 38 per meter including labour and travelling costs (with values of € 30 and € 45 respectively assessed within the sensitivity analysis). The higher value than for electricity corresponds to the longer time expected on average for the installation of the smart gas meter; consequently also the households' opportunity costs for the installation are expected to be higher for gas than for electricity. Furthermore, a higher difference in electricity consumption of the smart and the conventional meter can be observed for gas, since conventional gas meter use the energy of the gas flow, i.e. in principle do not require any electricity supply at all. A revisit rate of 0.5% is assumed due to access and technical problems; while we assume the same revisit rate as for electricity, cost of revisiting are assumed to be slightly higher reflecting technical specifications and security issues of smart gas meters. In addition, costs related to the meter failure rate of smart and conventional meters have been taken into account.

Costs of the communication infrastructure

In case of a joint-roll-out for electricity and gas the same figures as for electricity do apply as the electricity and gas smart meters would share the same communication infrastructure. In case of a gas only scenario only GPRS technology is assumed to be applied. The price of the communication module and the annual communication charges are the same as for electricity (i.e. prices of € 40 per module and charges between € 0.8/month and € 2/month).

As regards the head end systems, implementing costs (including licenses and hardware costs) of € 1.6 million are considered within this CBA, considering an implementation period of 2 years. Annual operational costs of the head-end systems are assumed to be at around € 320,000. Within the sensitivity analysis variations between +30% and -30% are applied for communication infrastructure costs.

Costs of the information systems

Based on data from international studies (including other recent CBAs) and DNV KEMA internal data total investment cost for the information systems are assumed to be at around € 10 million, considering investments in new hard- and software as well as the integration/refurbishment of existing systems and the costs for a web portal.[94] Annual operational costs to cover the necessity of re-investments are expected to be at around 15% of investment costs. Since the costs for the information systems are

[94] Compared to the number for electricity these costs may appear high. However while the costs with storage capacity are variable (i.e. depend on the number of smart meters), total costs of the information systems – according to international studies – do generally not to vary proportionally with the metering points.
Fixed costs will be higher for gas, since a much larger number of DSOs operates for gas than for electricity in Slovenia. Furthermore, based on the status of the existing information systems – given the higher level of smart meters already installed for electricity as well as the generally more advanced IT infrastructure in the electricity sector – also much more investment per smart meter would be required for gas. Since these costs are difficult to estimate we have applied a relatively wide range of +/- 50% sensitivity analysis.
Since the data provided by the DSOs in response to the data requests has not been adequate, the base case of information system costs has been based on criteria from recent CBAs (including Germany, Austria, Ireland and Portugal) and DNV KEMA internal data.

highly uncertain, a sensitivity analysis was applied to this parameter considering a variation between +50% and -50%.

Gas consumption reduction

Taking into account the smaller number of applications for gas and the lower potential to reduce many of the gas applications (e.g. gas for heating purposes) is generally expected to result in smaller consumption reductions for gas than for electricity after the implementation of smart metering and the respective feedback mechanisms. Consequently, it is assumed that customers will reduce their consumption on average by 1% (sensitivity analysis between 0.5% and 1.5%) in the case of direct feedback. In the case of indirect feedback, it is assumed that customers will reduce their consumption on average by 0.5% (sensitivity analysis between 0.3% and 0.8%).

7.4 Definition of Smart Metering Roll-Out Scenarios

A sound economic CBA should not assess the net benefits of a single roll-out scenario but compare different scenarios regarding their total net benefits. The scenarios should assess the incremental impact of the roll-out against a continuation of the status quo (i.e. not carrying out a smart metering roll-out, but continuing to use conventional meters). It is however important that the status quo reference (or business-as-usual) case (continuing use of conventional meters) is not regarded as a static case, but that it also based on the same assumptions on future development of the input parameters made in the roll-out scenarios of the CBA.

The scenarios should be based on technically and legally feasible alternative options. Scenarios for a roll-out of smart metering should include at least a realistic base case, an optimistic best case and a pessimistic worst case. One of the scenarios should also assess a "natural" roll-out, where all conventional meters are replaced by smart meters at the end of their life time.

The CBA should consider different scenarios for the implementation of electricity and gas smart metering. Variables commonly used in similar CBA projects, which have also been applied in this CBA for Slovenia, are the following:

- Smart meter functionalities: Different functionality levels may correspond to different costs and may lead to different benefits values. The multi-utility and remote connection/disconnection functionalities have relevant impact on the meter price. However, the development of smart metering technology has already reduced the significance of the incremental cost of these functionalities. Nowadays the incremental cost of functionalities is very low and difficult to quantify. Furthermore – as discussed in chapter 5 – more advanced functionalities are now commonly offered by manufacturers for standard smart meters as well as recommended by regulators on European and on Slovenian level.[95] Therefore, this CBA con-

[95] See for example ERGEG (2011): Final Guideline of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas; AGEN-RS (2010/2011): Guidelines for the introduction of advanced metering in Slovenia

siders only one level of functionality covering the standard functionalities defined in chapter 5.4.

- Scheduling of smart metering deployment: start date, duration and potential consumer segmentation. The postponement of the smart metering roll-out may benefit from smart metering technology development and economies of scale. However, such scenario corresponds to a more intensive roll-out of electricity smart metering in order to achieve penetration targets of 80% or 100% in 2020 or 2025 (in case of positive results) which may bring some significant logistics problems. For gas no deadline for a roll-out has been specified and a longer time frame could therefore in principal be considered. However, similar time frames for electricity and gas – in case of a joint roll-out – will allow to realise synergies and to avoid cost duplication. For the joint roll-out scenarios we will therefore apply the same penetration targets and time frames in the CBA. The segmentation of clients based on their consumption patterns (i.e. starting a roll-out for specific types of customers) is not commonly used as a scenario in order to avoid discrimination among different consumers. Non-discrimination has also been stressed by ERGEG who recommends that all customers should benefit from smart metering in the sense that all customers shall be eligible to obtain smart meters except to geographical or other special national circumstances.[96] We therefore do not distinguish between different customer groups as regards the deployment of smart metering within this CBA.
- Communication systems between meters and users of the meter data: different communication systems shall be considered in order to analyse which are the most technically and economically adequate communication systems. It is common to use different penetration levels for the different technologies taking into account the population density per geographical area. In some cost benefit analysis projects of smart metering, the decision of the optimal communication infrastructure to implement is left to the entity responsible to manage the communication infrastructure (DSO or other). However, this decision may not be the best decision for the society as a whole. In most of the cost benefit analysis projects, the penetration of meters with PLC modems is significant higher than the penetration of meters with GPRS modems. The meters with PLC modems communicate with data concentrators installed at the electricity distribution grid. The communication infrastructure between the meters and the concentrators is usually called Local Area Network (LAN). These data concentrators communicate via GPRS with the central systems. The communication infrastructure between the concentrators and the central systems is usually called Wide Area Network (WAN). The meters with GPRS modems communicate via GPRS directly with the central systems. The GPRS communication is particularly used in areas where PLC is not technically or economically feasible. Other LAN technologies such as ZigBee and WAN technologies such as WiMAX or optical fibre have been also analysed in some cost benefit analysis projects of smart metering worldwide, although generally with a very small share.

[96] ERGEG (2011): Final Guidelines of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas.

- Type of information provided to the consumer: different levels of information have different costs and may lead to different potential savings values. Consumers may have access to more detailed information about their real energy consumption and recommendations for energy savings as well as cost reductions based on historical data. This information can be available in new bills increasing bill paper costs or on a web site. The real time devices such as the In-Home display allow the consumer to take decisions about consumption in real time and see the consequences in real time as well. This may change consumer's awareness leading to reduction on its consumption and transfer of energy from peak hours to off-peak hours. Several studies demonstrate that the frequency, quality and type of information provided to the consumers have influence on the consumer's behaviour. The electricity reduction values used in several cost benefit projects range between 2% and 8%, although this tends to be quite country specific.

As pointed out above, all scenarios will be compared to the business as usual scenario in order to calculate the incremental costs.

Smart metering implementation scenarios

Based on the main variables defined above the following scenarios for a roll-out of electricity and gas smart meters have been defined.

Scheduling of smart metering deployment

As pointed out in section 7.3.1 there are already a number of smart electricity meters installed in Slovenia, which share the same or very similar functionalities to the smart meters considered in the roll-out scenarios (as described in chapter 5). These existing smart electricity meters will not be included within the roll-out scenarios as well as the business-as-usual scenario within the CBA. The penetration targets of the different roll-out scenarios described below, therefore describe the percentage of all meters that will be replaced with smart meters as part of a mandatory roll-out *excluding* the number of existing smart meters that already comply with the required functionalities. In other words, a penetration target of 80% would therefore correspond to around 85% of all meters installed in Slovenia for household and small commercial customers.[97]

Roll-out 1: In this scenario the deployment of smart metering will start in 2015 (in the case of positive results) with the target of 80% smart metering penetration in 2020. For the remaining 20% conventional meters a natural replacement at the end of their lifetime or due to failure. This scenario corresponds to an intensive roll-out in order to comply with 80% penetration target defined in the EU Directive. The annual evolution of the number of smart meters is considered to be linear corresponding to approximately 90,000 smart electricity and 18,000 smart gas meters (in case of a joint or a gas only roll-out scenario) per year.

[97] That is 80% of the total number of meters minus the existing smart meters (which is around 525,000 meters) plus around 260,000 existing smart meters.

Roll-out 2: Starting in 2015 (in the case of positive results) a smart metering penetration target of 80% will be achieved in 2025; the remaining 20% conventional meters are replaced naturally at end of their lifetime or due to failure. This scenario corresponds to a less intensive roll-out. The annual evolution of the number of smart meters is considered to be linear corresponding to approximately 50,000 smart electricity and 10,000 smart gas meter installations per year.

Roll-out 3: Starting in 2015 (in the case of positive results) with the target of 100% smart metering penetration to be achieved in 2025. This scenario corresponds to a more intensive roll-out. The annual evolution of the number of smart meters is considered to be linear corresponding to approximately 65,000 smart electricity and 13,000 smart gas meter smart meters installations per year.

Roll-out 4: Starting in 2015 (in the case of positive results) with the target of 100% smart metering penetration to be achieved in 2030. This scenario corresponds to a less intensive roll-out. The annual evolution of the number of smart meters is considered to be linear corresponding to approximately 47,000 smart electricity and 10,000 smart gas meter installations per year.

Roll-out 5: Starting in 2015 considering the natural replacement of all conventional meters with smart meters corresponding to an average annual installation of approximately 29,000 smart electricity and 5,000 smart gas meters.

Communication systems between meters and metering centres

As regards the communication technology the following scenarios are assessed:

1) 95% of the smart meters are equipped with PLC communication modules and communicate with the concentrators installed at the distribution grid. These concentrators communicate via GPRS with the central systems. The remaining 5% of the meters are equipped with GPRS communication modules in order to communicate directly with the central systems. The GPRS meters are installed in locations where the PLC communication is not technically feasible.
2) 85% of the smart meters are equipped with PLC communication modules and communicate with the concentrators installed at the distribution grid. These concentrators communicate via GPRS with the central systems. The remaining 15% of the meters are equipped with GPRS communication modules in order to communicate directly with the central systems. The GPRS meters are installed in locations where the PLC communication is not technically feasible.
3) 85% of the smart meters are equipped with PLC communication modules and communicate with the concentrators installed at the distribution grid which communicate via GPRS with the central systems. 5% of the meters are equipped with GPRS communication modules in order to communicate directly with the central systems. The remaining 10% of the smart meters are equipped as well with PLC communication modules communicating with the concentrators installed at the distribution grid; the concentrators however communicate via WiMAX with the central systems. The GPRS meters are installed in locations where the PLC communication is not technically feasible.

Type of information provided to the consumer

Indirect feedback: Consumers have access to more detailed information about their real energy consumption and recommendations for energy savings as well as cost reductions based on historical data. This information can be available in new bills increasing bill paper costs or on a web site. It is assumed that the percentage of clients with indirect feedback will be 80%.

Direct feedback: Besides the indirect feedback described above, the consumers will purchase real time devices (IHD) which allow the consumers to take decisions about their consumption in real time and see the consequences in real time as well. It is assumed that the percentage of clients with direct feedback will be 20%.

Percentage of clients shifting energy from peak to off-peak

It is assumed that 3% of the households will shift energy from peak to off-peak by changing to a multi-tariff option.

The following two figures show the key properties of the smart metering roll-out scenarios assessed for electricity and for a joint roll-out for electricity and gas. In addition, we did also assess a gas only scenario with 100% GPRS for comparative purposes.

Parameters	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Percentage of PLC/GPRS	95%	85%	95%	85%	85%	95%	85%	95%	85%	85%
Percentage of PLC/WiMAX	0%	0%	0%	0%	10%	0%	0%	0%	0%	0%
Percentage of GPRS	5%	15%	5%	15%	5%	5%	15%	5%	15%	15%
Roll-out scheduling (start in 2015)	80% by 2020	80% by 2020	80% by 2025	80% by 2025	80% by 2025	100% by 2025	100% by 2025	100% by 2030	100% by 2030	Natural roll-out

Table 22: Scenarios of electricity smart metering implementation

Parameters	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Percentage of PLC/GPRS	95%	85%	95%	85%	85%	95%	85%	95%	85%	85%
Percentage of PLC/WiMAX	0%	0%	0%	0%	10%	0%	0%	0%	0%	0%
Percentage of GPRS	5%	15%	5%	15%	5%	5%	15%	5%	15%	15%
Roll-out scheduling – Electricity (start in 2015)	80% by 2020	80% by 2020	80% by 2025	80% by 2025	80% by 2025	100% by 2025	100% by 2025	100% by 2030	100% by 2030	Natural roll-out
Roll-out scheduling – Gas (start in 2015)	80% by 2020	80% by 2020	80% by 2025	80% by 2025	80% by 2025	100% by 2025	100% by 2025	100% by 2030	100% by 2030	Natural roll-out

Table 23: Scenarios of electricity and gas smart metering implementation

7.5 Calculation of Net Benefits

The economic CBA applies dynamic investment appraisal methods commonly used in the financial analysis of an investment project, such as the Net Present Value (NPV) and the Internal Rate of Return (IRR).[98] The calculation of the economic NPV or IRR of a smart metering roll-out includes the monetary costs and benefits incurred by the (smart metering) investor, by other stakeholders and by the society as a whole.

The economic NPV is the difference between all discounted (social) benefits and costs of smart metering over the modelling period. The economic assessment of a smart metering roll-out (for society as a whole) will be positive if the NPV is positive (i.e. if the NPV > 0). When comparing different scenarios for a smart metering roll-out in a CBA, the scenario with the highest NPV should be selected. Net benefits (i.e. a positive NPV) or net costs (i.e. a negative NPV) indicate that the respective roll-out scenario is associated with incremental (additional) benefits or costs compared to a business-as-usual scenario. In other words, a negative NPV would recommend not to invest in smart metering, but rather to keep the current share of conventional and smart meters (assuming the same future development of the input parameters as in the roll-out scenarios).

The economic IRR describes the discount rate at which the present value of the projects costs equals the present value of the projects benefits. In this case, the project with the highest social IRR should be selected when deciding between different alternative infrastructure projects.[99]

As specified in the terms of reference for this project we intend to apply both the economic NPV and the economic IRR within the CBA framework.

[98] In the investment analysis the NPV takes all cash flows associated with a project and reduces (discounts) them to a common denominator (present value) by using an appropriate interest rate (sometimes called the cost of capital or the cost of finance) to take into account the time value of money. The assessment of an investment project is positive if the NPV is positive (NPV > 0), i.e. it has a return which is greater than the interest rate (cost of capital) applied.

[99] The IRR calculates the rate of interest (discount rate) at which the expected future cash flows must be discounted to equate them with the initial project cost, i.e. to produce a NPV of zero; in other words the interest rate at which the project will exactly break even. The assessment of an investment project with the IRR is positive if the opportunity cost of capital (also known as hurdle rate) is less than the calculated internal rate of return.

8 RESULTS OF THE COST-BENEFIT ANALYSIS

8.1 Explanatory notes on CBA results

When interpreting the CBA results, applying the methodology explained in the previous chapter, the following issues should be taken into account.

The assessment of a smart metering roll-out within the CBA framework is conducted from an overall economic point of view (i.e. from the perspective of the society as a whole). It, therefore, assesses the costs and benefits arising to all stakeholders affected by a roll-out in Slovenia. In doing so all stakeholders are weighted equally. The costs and benefits of smart metering are, however, unevenly distributed between the different stakeholders.

Clearly costs and benefits directly affect the DSO replacing the old meter with a smart meter and the customer whose old meter is replaced with a smart meter. But costs and benefits also affect (indirectly) other market participants, such as suppliers, the TSO, electricity producers and society as a whole (e.g. environmental impacts such as carbon emissions). As described earlier, different stakeholders are however likely to benefit to different extents from a deployment of smart metering. Also within a stakeholder group, net costs or benefits may be unevenly distributed (e.g. not all consumers will realise the same bill reductions since not all consumers will be able to achieve the same energy savings). It may also be the case that the benefit for one stakeholder equals the costs of another stakeholder so that their economic impact (i.e. the redistribution of wealth) does not show up in the aggregate view of the CBA. A positive NPV or IRR does, therefore, indicate that a smart metering roll-out would be positive for Slovenia, but it does not say, whether it would actually be beneficial for each individual stakeholders (which is likely not the case). It is, therefore, possible – if not likely – that the economic assessment presented here provides a different result than an assessment carried out by the DSOs, looking only at the impacts for the smart metering investors in Slovenia.

The results of the CBA model also do not specify how the costs of the smart metering investment are allocated among the stakeholders, that is how they are treated within the regulatory framework (e.g. whether and to what extent efficient costs can be passed through from DSOs to consumers). We address this issue further in chapter 10.

The main costs and benefits related to smart metering could be assessed within the CBA framework described above. However, due to a lack of reliable data, some (smaller) benefit items, as pointed out in the previous chapter, could not be included within the CBA. It is also difficult to precisely quantify and monetise some indirect and external effects of smart metering – such as wider environmental and macroeconomic impacts or consequential knock-on effects – which is a requirement for their inclusion within the CBA.[100] In addition to the CBA results – described in the next subchapters – we, therefore,

[100] Also some indirect costs and benefits have only a minor impact on the overall results, which may not justify significant efforts for their monetization.

also provide a short description and qualitative evaluation of some of the more significant effects of smart metering that can only be assessed outside the CBA (see section 8.6).

Furthermore, some benefits of smart metering cannot be precisely estimated before making a roll-out decision. New services and functionalities are likely to arise in the future, which may provide additional benefits that cannot be properly estimated before a large scale roll-out has taken place. Manufacturers of products such as household appliances and the service industry, for example, will adapt to smart metering technology and are expected to develop and offer a wide range of specially designed products and services, e.g. further increasing energy efficiency by intelligent household control or enhancing consumer welfare with increased comfort. Also, the link between the smart meter and the smart grid cannot be fully evaluated within this study. In order to assess the impact on critical input parameters on the CBA results, we have also conducted a sensitivity analysis, whose results are discussed in section 8.5.

8.2 CBA results for electricity only roll-out scenarios

Considering a time-frame of two investment cycles (i.e. up to 2048) the following results have been calculated with the CBA model for the 10 electricity (only) roll-out scenarios.

	Discounted Benefits	Discounted Costs	Net Present Value (NPV)	Internal rate of return (IRR)	Payback period
	M€	M€	M€	%	years
Scenario 1	342.84	-304.60	38.24	6.57%	16.0
Scenario 2	342.34	-326.38	15.95	5.83%	25.0
Scenario 3	291.14	-265.44	25.70	6.61%	20.1
Scenario 4	290.70	-283.96	6.74	5.63%	27.8
Scenario 5	290.70	-265.14	25.56	6.59%	20.1
Scenario 6	341.40	-305.78	35.62	6.81%	16.8
Scenario 7	340.90	-327.42	13.48	5.88%	23.6
Scenario 8	298.98	-274.97	24.01	6.67%	21.0
Scenario 9	300.10	-293.99	6.11	5.67%	25.9
Scenario 10	225.51	-219.27	6.24	5.87%	26.1

Table 24: CBA results for electricity only roll-out scenarios

The summary table shows that a roll-out for smart electricity meters does provide positive net benefits in all 10 scenarios – showing a positive net present value (NPV), as well as an internal rate of return (IRR) above the social discount rate of 5% (that is applied in the base case). The results show furthermore that the payback period, that is the number of years after which discounted benefits will outweigh the discounted costs of smart metering (i.e. the break-even point), is longer than the economic lifetime of the smart meters (which has been assumed at 15 years) in all scenarios.

From the above results the following impacts of the scenario parameters can be observed:

- With the exception of scenario 9, all mandatory roll-out scenarios show a higher NPV than the natural roll-out (scenario 10); a natural roll-out is therefore not recommended unless it is conducted on a voluntary basis
- Scenarios with a high percentage of PLC/GPRS (scenarios 1, 3, 6, 8) provide larger net benefits than scenarios with a more significant share of GPRS (scenarios 2, 5, 7, 9); being more costly, GPRS results in higher levels of discounted costs, while discounted benefits are largely unaffected by the communication technology
- Changes in the shares of PLC/GPRS (scenario 3) and PLC/WiMAX (scenario 5), i.e. replacing PLC/GPRS with PLC/WiMAX do not have a significant impact on the CBA results
- Faster roll-outs (i.e. earlier roll-out completion dates, as in scenarios 1, 2, 6 and 7) show much higher discounted costs, but (even more so) also much higher benefits; consequently resulting in higher net benefits than slower roll-outs (scenarios 3, 4, 5, 8 and 9)
- Higher smart metering penetration targets (scenarios 6-9) can, all other things equal, create higher net benefits than scenarios with lower penetration targets (scenarios 1-5)
- The natural roll-out has by far the lowest level of discounted costs, but at the same time also the lowest level of discounted benefits, relating to the fact that the natural roll-out takes place over a very long time period; in addition synergies of a coordinated roll-out will not arise under a natural roll-out

In additional analysis within the CBA model it can be shown that for scenarios with percentages of GPRS above 25% negative net present values are to be observed (all other things equal as in scenario 1, which provides the largest net benefit). Providing higher percentages of household customers with direct feedback and assuming higher percentages of clients that shift parts of their consumption from peak to off-peak periods will each further increase net benefits. When differences in consumption reduction between consumers provided with direct and indirect feedback are not so large (e.g. 2% and 3% as in the base case), this increase of net benefits would not be so substantial since the larger consumption reductions of direct feedback would partly be outweighed by the additional costs for the procurement and installation of in-home displays (even accounting for the fact that in the base case 60% of consumers with direct feedback will use their smart phones or tablets rather than IHDs).[101]

Based on the above results, scenarios 1, 3, 6 can be identified as the most beneficial ones. We, therefore, assess and compare these scenarios in further detail.

The subsequent figure shows the total number of meters installations per year in the three scenarios, as well as the different reasons for meter replacements. Assuming a start date for the smart metering roll-out of 2015, new conventional meters will only be installed in 2014 since, from 2015 onwards, all meters will either be replaced as part of the mandatory roll-out or – if they fail or reach the end of their lifetime – due to a natural replacement. Furthermore, in all three scenarios clear investment cycles can be distinguished, that is periods of 6 or 11 years where large numbers of smart meters are installed followed by 11 or 6 years where much smaller numbers of smart meters are installed. An effect that is particularly strong in scenario 1 and which will continue in the future (although to a smaller extent). The figures also show that the decrease in population expected for Slovenia from 2020 onwards (see section 7.1), will result in a decrease in the total number of meters installed in Slovenia.

We can also observe that conventional meters will still be in use and replaced naturally in scenarios 1 and 3 (the 80% mandatory roll-out scenarios) up to 2048, due to regular reassessments of the technical state of a conventional meter that take place at the end of the meter's lifetime. If the meter is still in good order, its lifetime and its usage are further extended. Naturally, no conventional meters will still be in use in scenario 6 after 2025 (the 100% mandatory roll-out scenario until 2025). Please note that the total number of meters assessed within the CBA, and shown in the figures below, does not include the existing smart electricity meters already installed in Slovenia, which already comply with the required smart metering functionalities (see sections 7.3.1 and 7.4 for further details).

[101] Increasing the percentage of clients that shift parts of their consumption from peak to off-peak periods will also be more significantly, when the consumption reduction associated with this switch is larger.

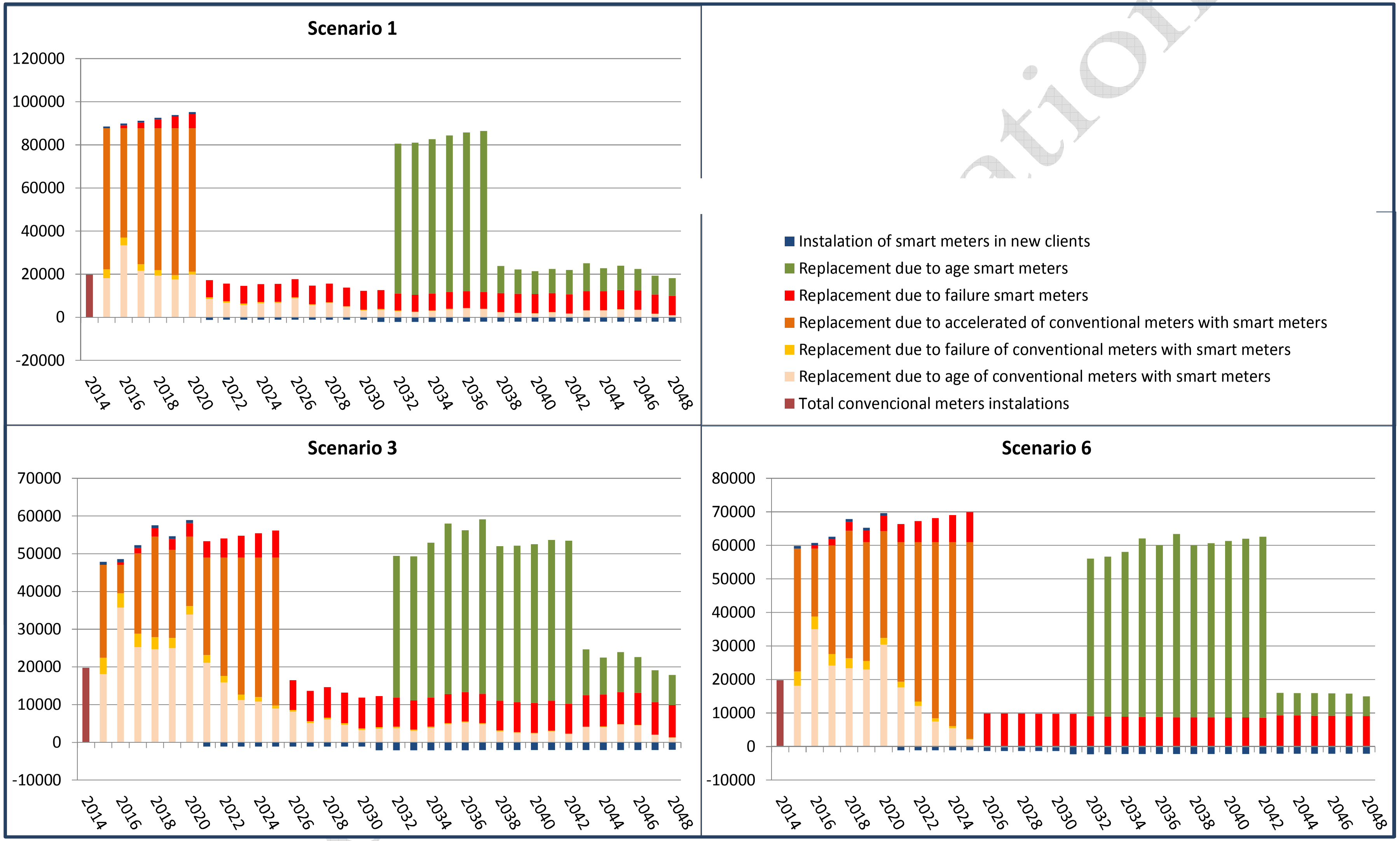

Figure 10: Total number of electricity meters installations per year in scenarios 1, 3 and 6

The discounted costs of the three scenarios are particularly high during the roll-out period, reflecting the large number of smart meters and smart metering infrastructure that will be installed in a short period of time (as well as the smaller impact of the social discount rate), but also a number of costs that only arise with the initial investments in the smart metering infrastructure such as program implementation costs and costs of marketing campaigns. Furthermore, it is also assumed (as discussed in chapter 7) that the prices for smart metering hardware will further decrease over the next years to come, due to economies of scale and technological progress, which will also result in lower costs with future replacements of the existing smart meters. The figures below (Figure 11) also show that costs and benefits which arise early in the observation period have a higher value than costs and benefits that arise in future decades (social time preference approach).[102]

Comparing the distribution of discounted costs and benefits of the three scenarios over time shows that a faster roll-out (scenario 1) and a higher penetration rate (scenario 6) are associated with higher initial costs, but will also generate larger benefits at an earlier point of time. Accumulated cash flows (the difference between discounted costs and benefits) will be particularly negative during the first years of the roll-out where large investments in the smart metering infrastructure need to be conducted, but only part of the consumers will already be equipped with smart meters and therefore benefits generated from smart metering will still be limited. Accordingly the largest discounted benefits are to be expected just after the roll-out is completed.

	Discounted Benefits	Discounted Costs	Net Present Value (NPV)	Internal rate of return (IRR)	Payback period
	M€	M€	M€	%	years
Scenario 1	208.35	-207.77	0.58	5.22%	16.0
Scenario 3	163.35	-172.29	-8.95	4.40%	-
Scenario 6	199.85	-205.12	-5.27	4.76%	-

Table 25: CBA results for electricity scenarios 1, 3 and 6 for a time frame up to 2032

Figure 11 also clearly depicts the impact of the smart meter investment cycles on costs, which can particularly be observed for scenario 1, where 80% of all existing conventional meters are to be replaced with smart meters in just 6 years. As a consequence of the initial and future (re-) investment cycles, accumulated cash flows will especially increase in the period between initial roll-out and the first reinvestment cycle, whereas they only increase marginally during the first reinvestment cycle. In scenarios 1 and 6 the break-even from net costs to net benefits would be achieved just after the average economic lifetime of smart meters (i.e. 15 years). On the other hand, this also shows that net benefits will only be generated in the long-term, which stresses the importance of a transparent and stable regulatory framework to provide the smart metering investors with the necessary investment security (see chapter 10). To further illustrate the impact of the observation period, also a shorter timeframe (i.e. up

[102] Since costs and benefits arise at different points of time in the different scenarios, they are discounted to the present value by the social discount rate, so that they can be meaningfully compared with each other. The social discount rate reflects the time value of money as well as the risk / uncertainty linked to future costs and benefits (see also section 7.2).

to 2032) has been assessed within the CBA model. Table 25 shows the NPV as well as the IRR for all three roll-out scenarios, when only one lifecycle of smart meters is considered. In this case, only scenario 1 provides a marginally positive NPV and an IRR only marginally above the social discount rate of 5%. All other scenarios (including a natural roll-out) would not generate a net benefit from a roll-out of smart metering within this timeframe. This could, however, change when the smart metering infrastructure could be procured at significantly lower prices and / or when much larger consumption reductions from smart metering would be realised as assumed in the base case.

Net benefits and net costs are distributed quite unevenly among the different stakeholders (Figure 12). Not considering possible reallocations between network operators and consumers through the regulatory framework (see chapter 10 for a discussion of the issues of cost allocation), DSOs will have to cover the smart metering investments in the first place, whereas consumers benefit from the various services and system improvements provided by smart metering as well as (most importantly) from bill reductions related to reductions of energy consumption. While producers and transmission system operators may benefit from avoided capacity investments, they will also earn less revenue, resulting from a reduced electricity production and a smaller amount of electricity transmitted over the network (following a demand reduction on the consumer side). Slightly lower revenues are also expected for suppliers (selling less electricity) and for the government (who will receive less tax revenues) when consumers reduce their consumption. Benefits will also arise to society as a whole through the positive environmental impact of reduced carbon emissions.

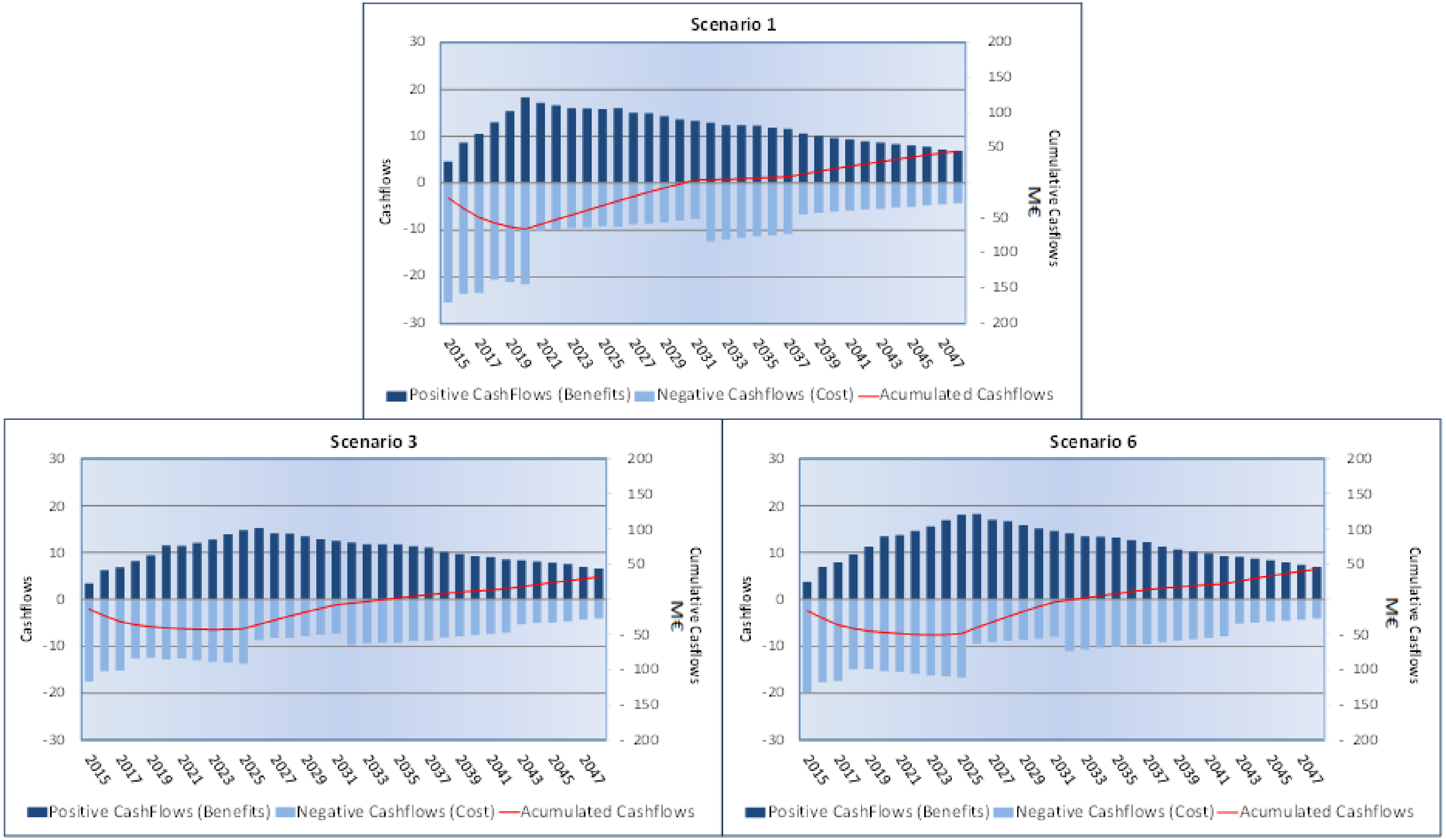

Figure 11: Positive and negative cash flows in scenarios 1, 3 and 6 (electricity only, in m€)

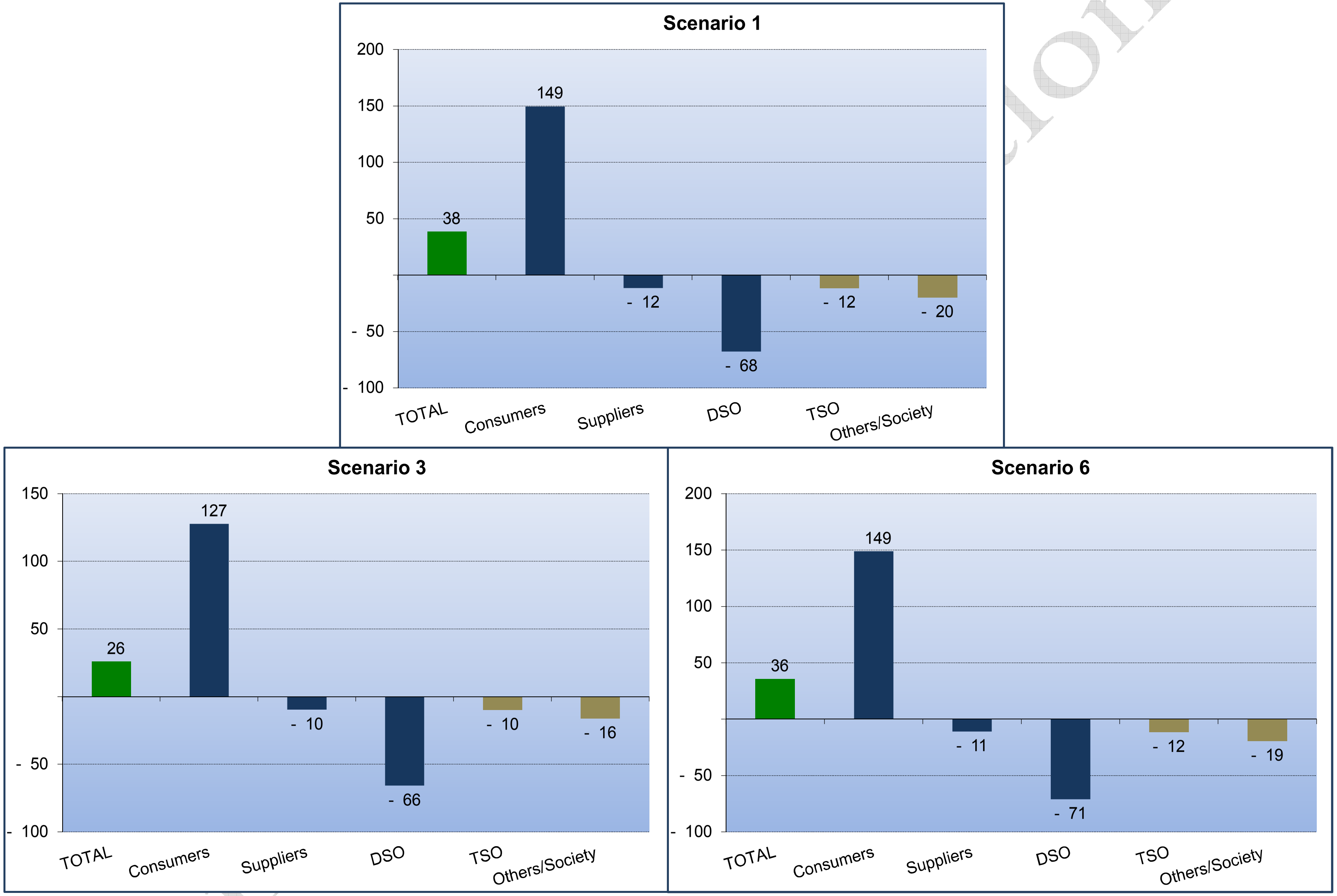

Figure 12: Distribution of net benefits and net costs among stakeholders in scenarios 1, 3 and 6 (electricity only, in m€))

8.3 CBA results for joint electricity and gas roll-out scenarios

For the joint roll-out of electricity and gas the following results have been calculated with the CBA for the different scenarios considering a time-frame of two investment cycles (i.e. up to 2048).

	Discounted Benefits	Discounted Costs	Net Present Value (NPV)	Internal rate of return (IRR)	Payback period
	M€	M€	M€	%	years
Scenario 1	378.90	-364.63	14.26	5.60%	26.0
Scenario 2	378.39	-386.41	-8.02	4.92%	-
Scenario 3	322.59	-320.58	2.02	5.26%	30.0
Scenario 4	322.16	-339.10	-16.94	4.37%	-
Scenario 5	322.16	-320.28	1.88	5.25%	30.0
Scenario 6	376.57	-364.35	12.22	5.63%	27.8
Scenario 7	376.06	-385.99	-9.92	4.80%	-
Scenario 8	329.81	-329.65	0.16	5.18%	29.9
Scenario 9	330.92	-348.67	-17.74	4.23%	-
Scenario 10	248.17	-266.04	-17.87	3.79%	-

Table 26: CBA results for joint electricity and gas roll-out scenarios

The summary table with the CBA results shows that not all joint roll-out scenarios for electricity and gas smart metering are expected to provide net benefits, even though synergies can be realised during the roll-out and the joint communication infrastructure be used for a larger number of meters and a larger amount of metering data. In particular, scenarios 4 and 9 as well as a natural roll-out would provide significant net costs for Slovenia. Scenarios 1, 3 and 6 provide positive net benefits, which are particularly significant for scenarios 1 and 6. As has been shown for an electricity (only) roll-out, scenarios with faster roll-outs of smart metering and higher shares of PLC/GPRS or PLC/WiMAX tend to provide net benefits. Faster roll-outs show much higher discounted benefits than slower ones since more benefits can be generated in the short term, while higher shares of GPRS are associated with higher discounted costs, reflecting the higher investment costs for this communication technology.

For all scenarios with positive NPVs, the payback period (i.e. the break-even point) is much longer (with 26 to 30 years) than in the electricity only scenarios. Long term projections of costs and benefits are, on the other hand, much more uncertain than costs and benefits arising in earlier years. This can particularly be crucial, where NPVs are only slightly positive, as is the case for scenarios 3, 5 and 8. Whether such time frames would be regarded as too long may be considered a political question.

The total number of gas meters (Figure 13) is much smaller than the number of electricity meters to be replaced over time. Consequently also the impact of the replacement of conventional gas meters with smart meters on the overall results of a joint roll-out for electricity and gas is much smaller than the costs and benefits of the replacement of electricity meters. Also, as pointed out earlier, consumption reductions – which provide one of the largest benefits of smart metering – are generally assumed to be much smaller in the area of gas.

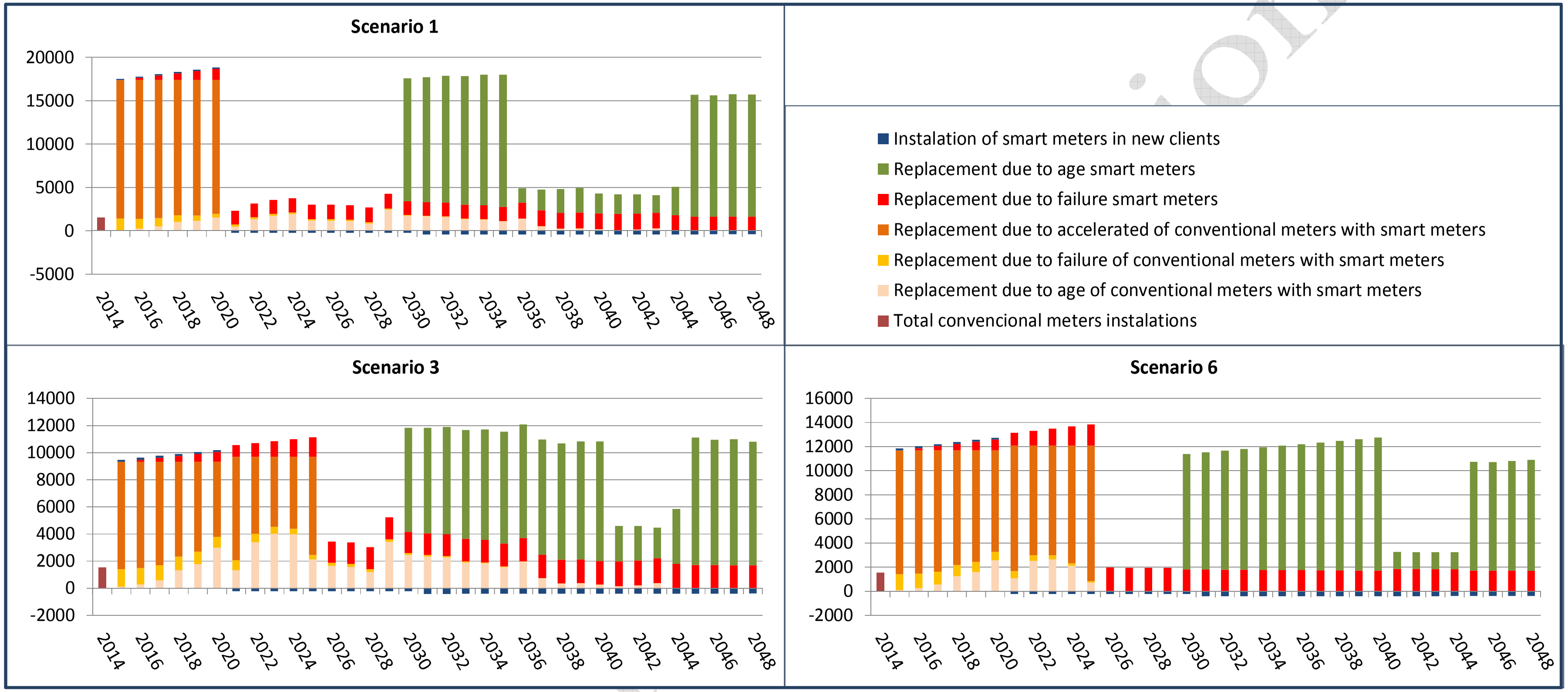

Figure 13: Total number of gas meters installations per year in scenarios 1, 3 and 6

Fast roll-outs of both electricity and gas smart meters will require large investments in the IT and communication infrastructure during the first years of the roll-out, which can only be used to its full extend when the roll-out of smart meters is completed. Accordingly large negative cash flows (or discounted costs) can be observed during the roll-out period. The benefits generated from smart metering will only pay-off at the end of the first reinvestment cycle of the smart meters (i.e. after more than 25 years), as can be seen from the following Figure 14.

Looking at the distribution of costs and benefits among stakeholders in scenarios 1, 3 and 6 shows that net costs for electricity and gas suppliers, TSOs, government, producers and the society a whole tend to be quite similar to the impacts in the electricity only scenario (Figure 15). Net benefits for consumers are somewhat higher, but net costs for electricity and gas DSOs are much higher in the joint roll-out compared to the electricity only scenarios.

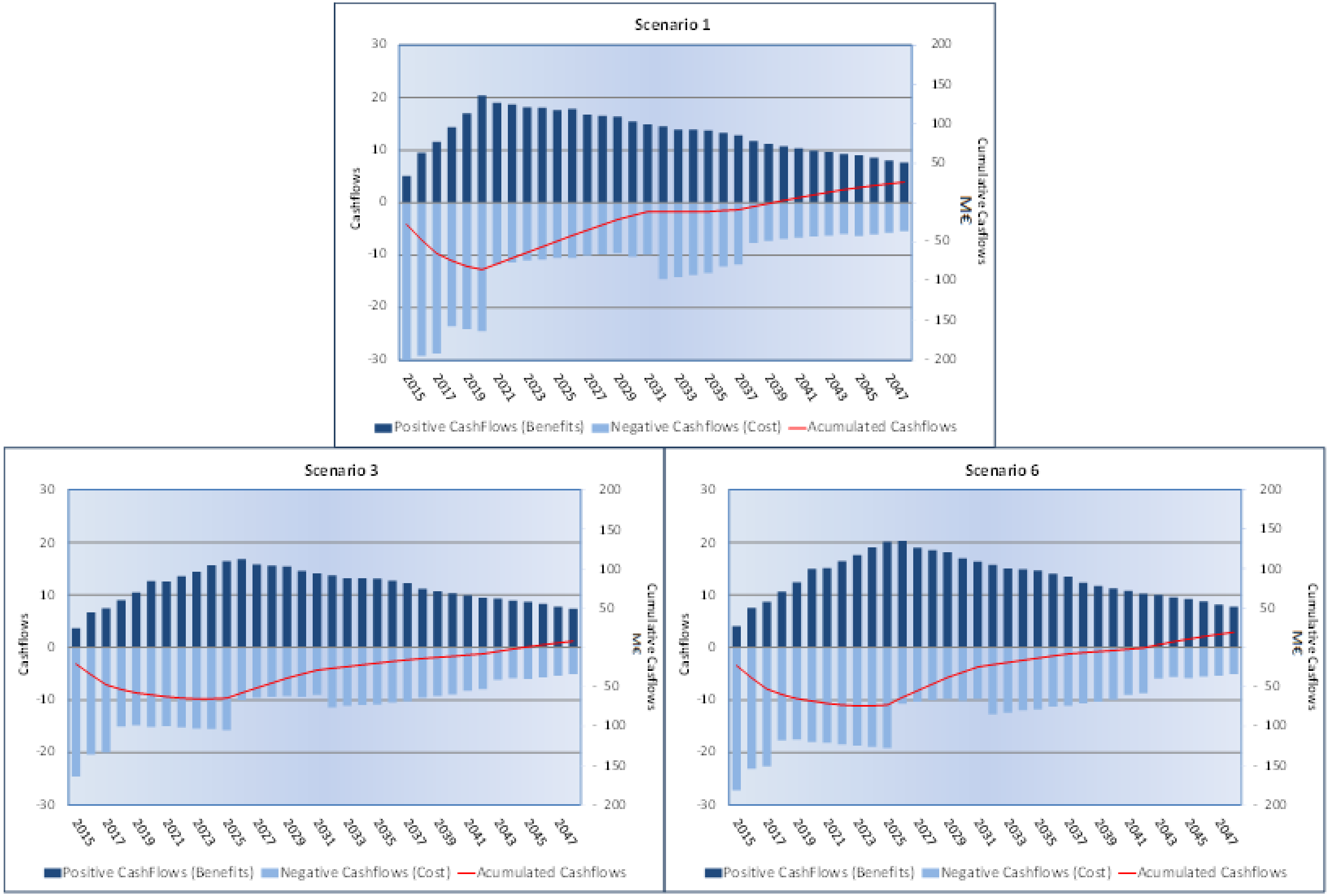

Figure 14: Positive and negative cash flows in scenarios 1, 3 and 6 (joint electricity and gas roll-out, in m€)

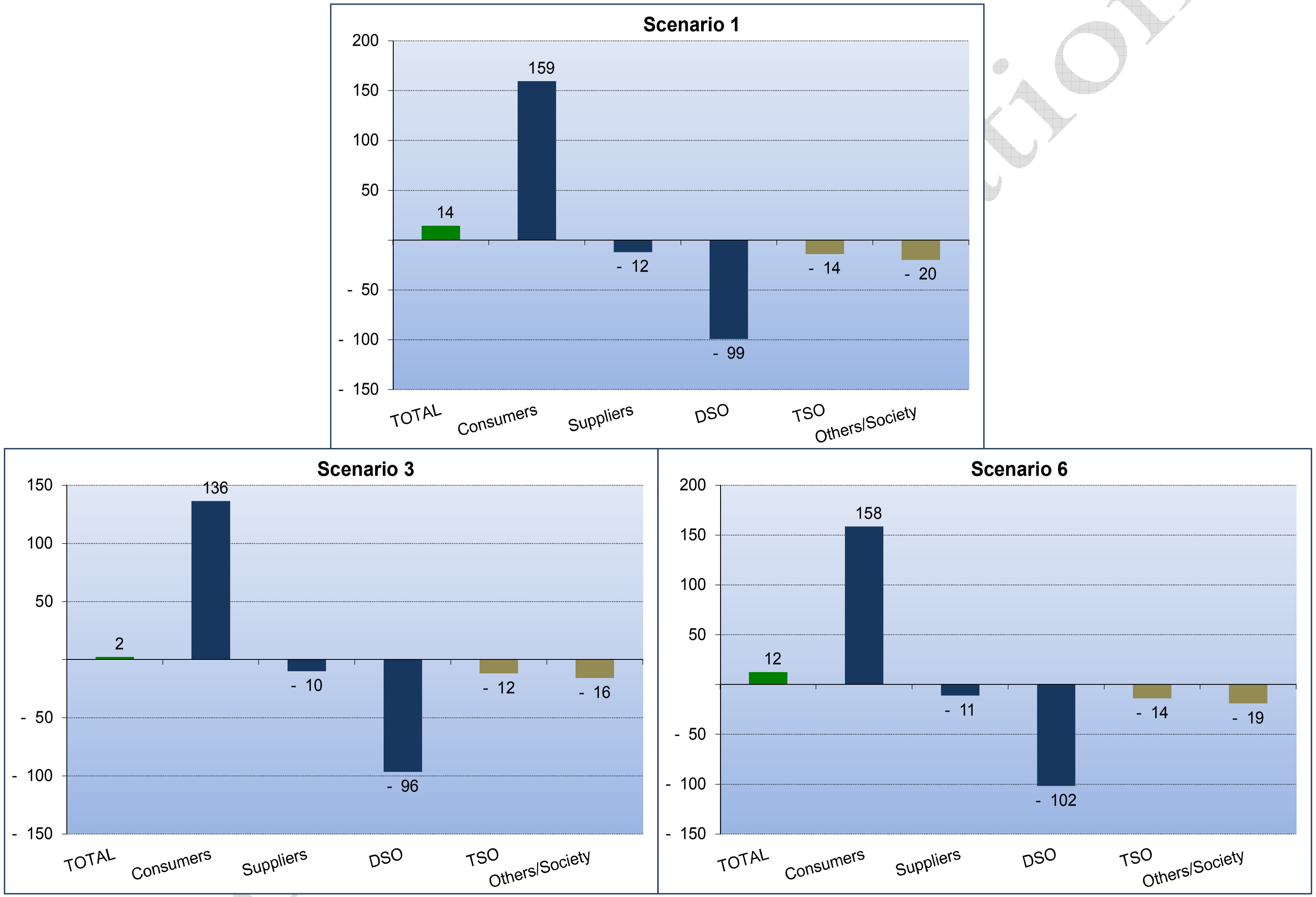

Figure 15: Distribution of net benefits and net costs among stakeholders in scenarios 1, 3 and 6 (joint electricity and gas roll-out, in m€)

When only a shorter time frame up to 2032 is considered, all joint roll-out scenarios will provide highly negative NPVs and very low IRRs.

	Discounted Benefits	Discounted Costs	Net Present Value (NPV)	Internal rate of return (IRR)	Payback period
	M€	M€	M€	%	years
Scenario 1	229.96	-250.80	-20.84	4.39%	-
Scenario 3	180.35	-210.54	-30.19	3.21%	-
Scenario 6	220.35	-246.67	-26.32	3.75%	-

Table 27: CBA results for scenarios 1, 3 and 6 for a time frame up to 2032 (joint electricity and gas roll-out)

8.4 CBA results for gas

Since much larger numbers of consumers are supplied with electricity than with gas in Slovenia, also a much larger number of electricity meters are installed and possibly replaced by smart meters than is the case for gas. As a consequence, positive results for a joint roll-out of smart metering (as in scenario 1), may be mainly driven by large net benefits on the electricity side that outweigh the net costs on the gas side. For comparative purposes therefore also a gas only scenario has been calculated within the CBA model.

Applying the same scenario parameters as in scenario 1, except that 100% GPRS is assumed in the gas only scenario, would result in discounted costs more than two times higher than discounted benefits. Even with more conservative assumptions on the level of costs, a negative NPV of around € -46 million has been calculated. Such negative results could be further confirmed when other gas only scenarios are assessed and when more optimistic values are considered within the sensitivity analysis. Even though when considering that some smaller (positive) impacts of smart metering could not be assessed within the CBA due to a lack of data (see sections 7.3.2 and 8.6), the negative results for a roll-out of smart gas metering in Slovenia calculated within the CBA tend to be very robust. Together with the CBA results for a joint roll-out discussed in the previous chapter, we therefore recommend not to progress with a roll-out of smart gas metering in Slovenia in the current situation.

8.5 Sensitivity analysis

When model input parameters and cost-benefit items have been selected and specified, also realistic minimum and maximum (as well as average) values for each item have been defined (see sections 7.1 and 7.3). Within the sensitivity analysis the NPVs are then (re-)calculated assigning the minimum and maximum values for individual input parameters of the model. Following this approach, the sensitivity analysis assesses the sensitivity of the NPV results on variations in the input data and, therefore, allows the determination of 'critical' input variables as well as the robustness of the results, for example, whether the results of the CBA only depend on strong assumptions of a single input parameter. The sensitivity of the CBA results on single input parameters is typically pictured in a Tornado-Diagram

(Figure 16 and Figure 17). It shows by how much the NPV would change when an input parameter is changed to its predefined realistic minimum or maximum value. The vertical line in the middle indicates the NPV calculated for the base (average) values of each parameter. The bars to the left specify the decrease in the NPV when minimum values for benefits or maximum values of costs (i.e. more pessimistic or conservative values) are applied. The bars to the right specify the increase in the NPV when maximum values for benefits or minimum values of costs (i.e. more optimistic assumptions) are applied. Furthermore bars in light blue indicate lower and bars in dark blue higher values as in the base case. While many more input parameters have been assessed within the sensitivity analysis, only the most significant parameters are shown in the following figures.

The Tornado diagram for scenario 1 of the electricity only roll-out scenarios (Figure 16) shows that much higher values for smart meter hardware and PLC/GPRS communication module costs as well as smaller reductions in consumption by consumers with indirect feedback would significantly reduce the NPV. However, changing only one of these parameters to its pessimistic value would still provide a positive NPV. Only the occurrence of the pessimistic values of several of the most significant input parameter at the same time, such as a combination of significantly higher smart metering procurement costs and smaller consumption reductions than assumed in the base case, could result in a negative NPV for the most beneficial electricity (only) roll-out scenario. In other words, scenario 1 of the electricity only roll-out scenarios is quite robust to changes of the input parameters.

Other input parameters with a significant impact on the CBA results identified in the sensitivity analysis are the various cost items for the IT infrastructure, the social discount rate and the PLC/GPRS concentrator costs. Significant items on the benefits side are the percentage of manual meter readings that can be avoided with smart metering, the costs of paper bills (with and without smart metering) in comparison to electronic bills and the consumption reduction of customers provided with direct feedback.

The results of the sensitivity analysis for scenario 1 of the joint roll-out scenarios identifies the same input parameters as for electricity as the most influential ones on the CBA results. However, given the much lower (positive) NPV value for a joint roll-out, changes to some of the key input parameters can likely result in a negative NPV. Within the sensitivity analysis already 5 input parameters could be identified where more pessimistic cost and benefit values will produce overall net costs from a smart metering roll-out for Slovenia. The negative NPV can particularly be significant when higher values for smart meter hardware and PLC/GPRS communication module costs and smaller consumption reductions do occur. Uncertainty on the actual development of these input parameters can particularly be significant, given the relatively long time period required for all joint roll-out scenarios before discounted costs are outweighed by discounted benefits.

The sensitivity analysis also, furthermore, confirms the earlier observation that the joint roll-out results are to a large extent driven by the electricity results; none of the gas input parameters can be found in the 20 most influential input parameters. Even applying the pessimistic values of the three most influential gas input parameters would not cause the NPV of scenario 1 to turn negative.

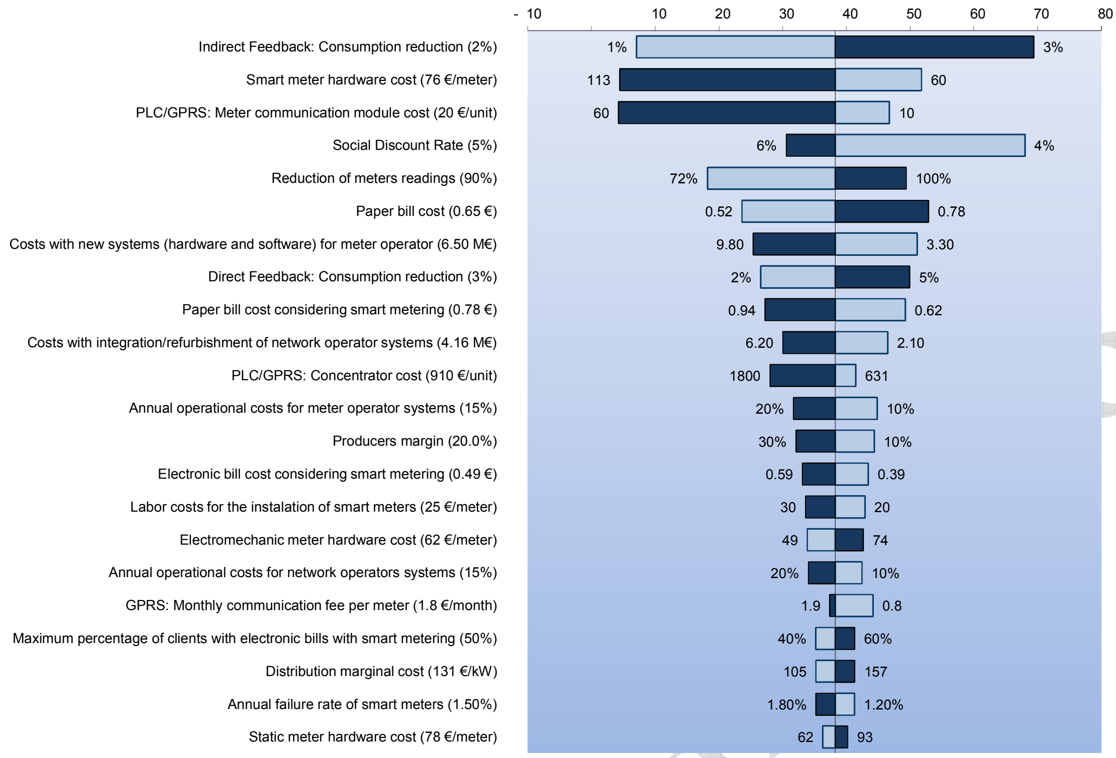

Figure 16: Sensitivity analysis for scenario 1 (electricity only)

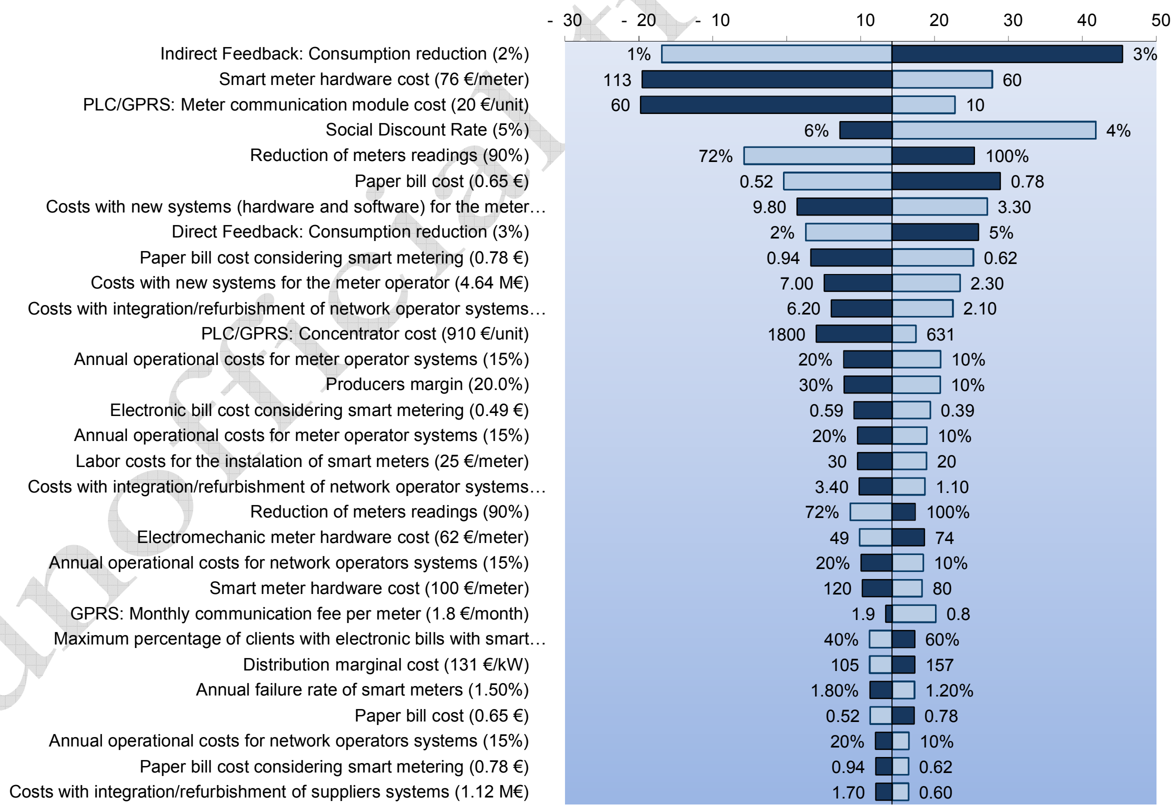

Figure 17: Sensitivity analysis for scenario 1 (joint electricity and gas roll-out)

To further assess the impact of (random) changes of the input parameters on the CBA results, also a Monte Carlo Simulation has been conducted. Within such assessment the impact of random changes of all input parameters on the NPV, according to a probability density function, is simulated. Figure 18 shows that the probability of a negative NPV in scenario 1 (of the electricity only scenarios) – providing a NPV of around € 38 million in the base case – is less than 20% (summing up the probabilities of all negative NPVs). It furthermore confirms that the significant net benefits calculated within the CBA model for a roll-out of smart electricity meters in scenario 1 are relatively robust to changes of key input parameters. The same calculations for scenario 1 of the joint electricity and gas roll-out scenarios provide a probability of around 50% for a negative NPV.

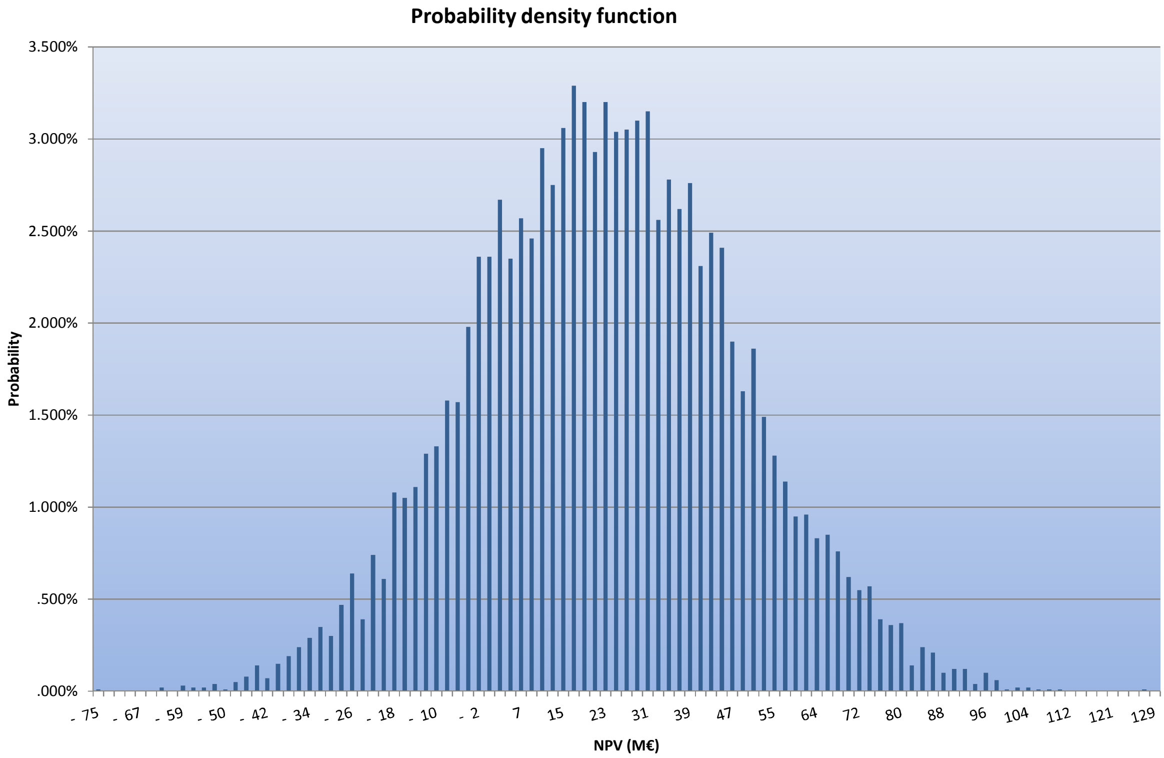

Figure 18: Monte Carlo Simulation for scenario 1 (electricity only)

8.6 Qualitative assessment of additional costs and benefits

Ideally all direct and indirect costs and benefits of smart metering arising to different stakeholders should be monetized and included within the CBA. However, as pointed out in section 8.1, not all possible costs and benefits of smart metering could be assessed within the framework of a CBA. For some cost-benefit items, this is related to a lack of reliable Slovenian specific data, for other cost-benefit items this is related to the general difficulty to precisely quantify the impact of smart metering on these parameters. Many of the potential cost-benefit items, which are difficult to quantify, have only a negligible impact, so it is not worthwhile to include them in this assessment. For other cost-benefit items the individual impact may be small, but when several of such smaller items are considered, their impact may be more relevant. Accounting for such additional costs and benefits may particularly be important for scenarios, whose NPV is close to zero.

To make an informed decision on a roll-out of smart metering, we suggest taking in particular the following additional parameters into account. We expect all of the below cost-benefit items to provide an equal impact in all roll-out scenarios, in the sense that additional benefits (costs) would in general further increase discounted benefits (costs) by the same amount. However, since faster roll-outs tend to generate larger benefits – as we have seen in the previous subchapters – we expect also the impact of the below items to be larger in faster roll-out scenarios. Naturally impacts will also be larger for scenarios with higher smart meter penetration targets.

Call centre costs reductions (electricity and gas)

The number of queries and complaints related with estimated bills will be reduced with the introduction of smart meters resulting in less call centre costs for suppliers and less opportunity costs related with the voluntary readings. However, the introduction of multi-tariffs or more detailed billing may increase the volume and the complexity of the calls in the first years. It can be expected that consumers will adapt to new bills and tariffs and that call centre costs will be reduced in the medium to longer term.

Reduced generation capacity investments (electricity)

The reduction of consumption and the shift of consumption from peak to off-peak are expected to reduce future investments in generation peak capacity as well as investment in power reserves.

Reduced investment in transmission and distribution capacity (gas)[103]

The reduction of consumption is expected to reduce future investment in gas transport and distribution capacities.

Asset management cost reductions (electricity and gas)

The implementation of smart metering provides network operators with more accurate real-time information on the current state of the electricity system and more accurate prediction of electricity/gas flows within the system. This may contribute to improved network and maintenance planning as well as to a reduction on the costs with (transformers) maintenance and failure (replacement).

Process optimization (electricity and gas)

The integrating of smart meters (and smart metering data) into the IT infrastructure of network operators (and suppliers) can also help to optimize processes and reduce operational costs (process optimization). Smart metering data can be more easily processed and evaluated, and meter-to-bill operations can be significantly improved.

[103] Please note that for electricity benefits from reduced investment in transmission and distribution capacity are already included within the CBA.

Competition (electricity and gas)

Smart metering may facilitate customer switching procedures as smart meters can be easily read at any time on request. Automation and simplification of data exchange through smart metering should speed up the process for changing suppliers and simplify the action required from the customer to make the change. Incumbent suppliers may therefore lose customers and market shares (in their home territory) while new suppliers may be able to increase their customer base and revenues. Reductions in peak demand may also result in lower wholesale prices since it would reduce the need for (expensive) peak-load generation.

Provision of new services (electricity and gas)

Smart metering enables suppliers (and other stakeholders) to offer a new set of tariffs and services arising from detailed information on individual end-user's consumption patterns. While consumers may directly benefit from the provision of these new tariff products and services, suppliers and other third parties may be able to generate additional revenues and gain market shares.

More accurate invoicing (electricity and gas)

Consumers and suppliers may also benefit from more accurate (and frequent) meter reading and invoices, resulting in higher customer satisfaction and retention and a reduced risk of payment default.

Reduced purchase costs (electricity and gas)

Smart metering may allow suppliers to reduce their energy purchasing costs through improved load profiling and forecasting.

Macroeconomic effects (electricity and gas)

A large scale investment in smart metering may provide an economic stimulus on the gross domestic product and employment, considering that significant financial and personal resources would be required for a nation-wide roll-out. Remote operations enabled by smart metering may, on the other hand, reduce employment on the side of the network operator.

8.7 Summary

From the above results for the different roll-out scenarios within the CBA framework and the qualitative consideration of additional cost-benefit parameters we can conclude the following:

A mandatory roll-out of smart electricity meters can generate significant net benefits for Slovenia. Such net benefits will be larger when a fast roll-out (such as an 80% deployment target up to 2020 or a 100% target in 2025) is conducted and when a high percentage of PLC/GPRS or PLC/WiMAX can be applied (e.g. 95%). Discounted costs will particularly be high at the beginning of a smart metering roll-out, whereas discounted benefits will only pay off in the longer term. It will therefore take at least one investment cycle until discounted costs are outweighed by discounted benefits. It could furthermore be shown within the sensitivity analysis as well as within a stochastic Monte Carlo Simulation that these results are quite robust to changes in the assumptions of key input parameters.

A joint mandatory roll-out for electricity and gas can – in some roll-out scenarios – provide net benefits in the longer term. A break even between discounted costs and benefits will, however, only be achieved after 25 years, which may be considered too long-term when uncertainty on future developments is considered. In particular, since even the most beneficial roll-out scenario (an 80% until 2020) is quite sensitive to the values of key input parameters. Furthermore, given the much smaller number of gas meters, positive NPVs estimated for some joint roll-out scenarios may partly if not largely been driven by the positive electricity results as could be shown, when compared to a gas only scenario (which is associated with large and significant net costs).

A natural roll-out can neither be recommended for electricity nor for gas unless it is conducted on a voluntary basis and costs are not cross-subsidised by other stakeholders not benefitting from smart metering.

A large scale implementation of smart metering has, however, also significant impacts on data exchange and privacy which we will discuss in the following chapter 9. Furthermore, an efficient and cost-reflective allocation of costs among the different stakeholders will be crucial for a successful deployment of smart metering; we will further analyse this issue in chapter 10.

9 POTENTIAL BARRIERS FOR SMART METERING DEPLOYMENT

9.1 Data Exchange and Privacy

Experience gathered in countries that have already rolled out smart metering as well as experience gathered in pilot projects shows that the deployment of smart metering will face many barriers. Despite observed benefits of smart metering, market participants will not in all cases adopt smart metering voluntarily or willingly. Moreover, if they do aim to, their efforts may be hampered by existing and new barriers and obstacles. Apart from legal, regulatory, and technical barriers, consumer resistance may present a serious obstacle to the deployment of smart metering.

Consumers may not perceive smart metering as positive, driven primarily by the fear that security and privacy of data gathered and processed by smart metering cannot be guaranteed, and hence unauthorized participants might have access to private, e.g. personal, data and information with the possibility for their misuse and abuse; they may be even against the authorized collection, procession and usage of the data. Examples of groups of consumers heavily opposing smart metering deployment due to the nature, amount and level of detail of personal data gathered due to data privacy issues can, for instance, be found in the United States, or in the Netherlands.

The case of consumers opposing smart metering deployment may be highly relevant. The increasing amount of more granular, digital and interactive data collected as well as compiled detailed information possibly also allows very detailed insights and conclusions on usage profile, lifestyle and daily routines of households or individuals; for instance, when someone is at home, or in extreme cases where typical demand profiles of single appliances can identify what someone is doing, with possible encroachments on their privacy and dignity. Many people may have concerns regarding the availability of such detailed data for the energy supplier or network operator. Additionally, the real-time transmission of this data from the consumer’s site to the supplier's or network operator's back-end systems through the WAN (Wide Area Network) creates some vulnerability to unauthorized access, which did not earlier exist when this kind of data was simply not generated.

The timely acknowledgement of concerns may be crucial in preventing issues endangering the success of smart metering deployment and in creating the necessary public acceptance. In the Netherlands, for instance, privacy concerns led to a serious delay in the roll-out scheme, when in April 2009 the Dutch Senate rejected a proposal for mandatory smart metering deployment. In its renewed proposal for smart metering deployment, the government was forced to lessen the requirement for mandatory smart metering installation, and to allow consumers to decide against smart metering. The revised legal framework from 2010 stipulated only a voluntary roll-out with various options for consumers to protect their data. Besides having a smart meter, which is fully integrated into smart metering systems, consumers are now allowed to keep the traditional meter, to have a smart meter where no data is transmitted automatically, or to limit the automatic transmission to supplier changes, relocation, annual billing and bi-monthly reading.

In Austria, which had initially also decided for a mandatory roll-out of smart metering to all consumers, the opportunity for consumers to reject an installation of a smart meter has recently been given. Furthermore, provisions have been implemented that, while consumption levels for electricity and gas can be measured by the smart meters every ¼ hour or every hour respectively, only the daily consumption levels per customer are allowed to be communicated to the DSOs – unless the customer explicitly wishes to have a more frequent metering.

The result of consumer resistance is a delay in the roll-out process and a less efficient roll-out as potentially a significant number of consumers may opt-out of smart metering, and economies of scale and density may be diminished or lost. It is hence very important to ensure efficacious protection of fundamental rights of individuals, e.g. that the provisions are implemented up-front to ensure that personal data is not accessed by unauthorized parties and that there are clear regulatory provisions on how data is gathered, processed, stored and evaluated, and who has access to which data for legitimate purposes. In order to protect the data against unauthorized access, adequate organizational, technical[104] and procedural measures for data/information security (e.g., access rights, encryption, digital signatures and proper audits) need to be taken[105] as a part of a wider concept of data protection, which also includes other fundamental principles of lawfulness (accordance with the statute) and fairness, proportionality, accuracy, etc. Data encryption is of particular importance when PLC technology is used to transmit data from the consumer's site to a data concentrator, as potentially every user connected to the same power line is able to intercept the communication between the meter and data concentrator.

Personal data should be, in general, protected by privacy laws. Within the European legislation general data privacy requirements are set by *Directives 95/46/EC* and *2002/58/EC* as well as *Regulation (EC) No 45/2001*.[106] However, special attention should be given to smart metering as the amount of personal data collected (and the potential harm, which could be caused with it) is much greater than before. Privacy standards and access rights should be in place before a smart metering roll-out is started. In particular, it will be important to specify exactly which data can be accessed and processed or used for which purpose or multiple purposes as well as by whom, and whether this is only granted by explicit and valid customer (revocable) consent. The importance of control of the metering data by the customer (i.e., what data with what frequency is requested by whom), and the choice of the customer

[104] Use of ISO/IEC 27000 standards, Privacy Enhancing Technologies (PETs), etc.

[105] See, e.g., Task Force Smart Grid Expert Group 2 (2011): Regulatory Recommendation for Data Safety, Data Handling and Data Protection Report - Issued February 16, 2011 http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/expert_group2.pdf

[106] *Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data*, *Directive 2002/58/EC of the European Parliament and of the Council of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector* (Directive on privacy and electronic communications), and *Regulation (EC) No 45/2001 of the European Parliament and of the Council of 18 December 2000 on the protection of individuals with regard to the processing of personal data by the Community institutions and bodies and on the free movement of such data.*

which party, i.e. data recipient, has access to it, has also been stressed by ERGEG in their *Final Guidelines of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas*.

Since the level of information that can be inferred from smart metering data (e.g., the occupancy of a property or the use of specific household appliances) does depend on the time intervals for which data is provided, it will also be important to specify for which time intervals real-time data can be collected and provided to third parties.[107] For some applications of smart meter data, such as system balancing, demand reduction and distribution network operation and planning, instant communication of meter data to the DSO or other market participants may also not be required. In other cases where personal data is collected, processed and stored, it may be provided anonymously in such a way that the individual is no longer identifiable, i.e. aggregated or de-identified. Another option would be to store short-term time interval data (where possible) only locally at the smart meter, and only communicate metering data for a longer time intervals as is, for example, currently done in the UK.

Data protection issues are also particularly addressed in the *Recommendations of the European Commission on preparations for the roll-out of smart metering systems*.[108] According to these Recommendations, data protection and security can be achieved through two major instruments. Firstly, secure data communication (i.e. encryption of data transmission) should be in place, ensuring data integrity and that data are not accessible for unauthorized parties. This includes that network operators take the appropriate technical and organisational measures to ensure the protection of personal data by incorporating data protection by design and by default settings.[109] Secondly, a clear and functional legal framework should be enforced, setting out explicit rules on data access and handling, including their disclosure and transmission to various third parties (e.g. energy suppliers, service and communications providers), as well as responsibilities to safeguard data protection and security.

The European Commission, furthermore, recommends to limit data collection by so called data controllers to those clearly and properly defined legitimate purposes for which data are processed, to limit the time for which data can be kept, and to keep personal data in a form which enables the identification of data subjects no longer than necessary for the purposes for which the personal data are processed.

Further recommendations on data protection in the context of smart metering have been provided by the Article 29 Data Protection Working Party: *Opinion on smart metering*.[110] It stresses the importance

[107] See, for example, McKenna, Richardson, Thomson (2012): Smart meter data: Balancing consumer privacy concerns with legitimate applications, Energy Policy, Volume 41, February 2012, pp. 807–814.

[108] See also: *Executive summary of the Opinion of the European Data Protection Supervisor on the Commission Recommendation on preparations for the roll-out of smart metering systems*

[109] For Privacy by Design Concept – also in terms of minimising the amount of (personal) data processed, and including customer information access to their meter reading information and enablement, see, e.g., in more detail: Information and Privacy Commissioner, Ontario, Canada: Privacy by Design: Achieving the Gold Standard in Data Protection for the Smart Grid, Toronto, June 2010 (http://ipc.on.ca/English/Resources/Presentations-and-Speeches/Presentations-and-Speeches-Summary/?id=966; 2.8.2013).

[110] Article 29 Data Protection Working Party (2011): *Opinion 12/2011 on smart metering* as of April 4, 2011

of a minimisation of flows of personal data. Moreover, the *Opinion* contains several useful recommendations regarding rights of access, data security as well as regarding the disclosure and transmission of data to third parties (including the independent vetting or monitoring of its compliance) and information rights of the (properly informed) consumers.[111]

Some of these European data protection provisions have already been transposed into Slovenian legislation, such as the *Personal Data Protection Act* (*PDPA-1*)[112]

It specifies the fundamental principles for collection and processing of personal data and determines the rights, responsibilities and measures to prevent unlawful encroachments on the privacy. Furthermore, data collecting and processing of personal data does require the statute or (valid) personal consent of the respective individual in writing or otherwise appropriate (*PDPA-1,* Article 1 (1)): "Personal data may only be processed if the processing of personal data and the personal data being processed are provided by the statute, or if the personal consent of the individual has been given for the processing of certain personal data."[113] The *Personal Data Protection Act* also regulates – *inter alia* - the following rights of individuals (such as consumers):

(i) to be properly informed in advance about the data processing, personal data types and sets as well as about the purposes of the processing, if and when their consent is required (Article 19);

(ii) to get on-demand insight into the filing system and information on her/his personal data (being processed or not), including their copying, etc.[114]; and

(iii) to supplement, correct, block and erase personal data as well as to object (restrict or prevent) their further processing and use for the non-primary purpose.[115]

We strongly recommend to properly regulate privacy issues related to smart metering in a clear, functional and comprehensive legal framework document, including but not limited to provisions on per-

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[111] It also suggests not-too-long retention periods for data and clear procedures for the processing for crime prevention and investigation.

[112] Personal Data Protection Act/ PDPA-1; Official Gazette RS; No. 86/2004 (*Zakon o varstvu osebnih podatkov - ZVOP-1)*

[113] In Article 8 (2) it is also stated: "The purpose of processing personal data must be provided by the statute, and in cases of processing on the basis of personal consent of the individual, the individual must be informed in advance in writing or in another appropriate manner of the purpose of processing of personal data." These provisions of article 8 refer to both, i.e. private and public sector. For more detailed legal grounds for private sector see also article 10.

[114] Art. 30; procedure for information is prescribed in art. 31. For the transcription, copying and written certificates and information pursuant to this right the data controller may charge the individual only material costs according to a pre-specified tariff. Rules prescribing a pricing for these costs are prescribed in *Rules on the charging of expenses concerning the execution of the individual's right to acquaint himself with his own personal data* (OG RS, nos. 85/2007 and 5/2012). See also articles 21 (storage of data and their retention) and 22 (supply of data to data recipients and responsibilities of data controllers).

[115] Articles 32 and 33.

sonal data ownership and access, data processing and exchange as well as data security and responsibilities of designated data controllers and processors. This task should be performed on the basis of the practical details of the chosen smart metering service model (see also chapter 4) and the final decision on the scope of a smart metering roll-out within a thorough Privacy Impact Assessment. Required changes, if needed, and more detailed organisational, procedural and technical rules regarding smart metering specific privacy issues may either be implemented by special law, or within the currently discussed amendments to the new *Energy Act (EZ-1),*[116] as well as with the implementing regulations and general acts[117] of AGEN-RS.

9.2 Data Exchange and Competition

In order to achieve well-functioning retail markets, as well as the establishment and development of smart metering services, effective unbundling requirements between the distribution and supply business of vertically integrated utilities need to be in place. Effective unbundling requires the DSO to treat an affiliated supply business unit in the same way as any other supplier, in particular as regards the handling of information.[118] Since the DSO is in charge of the (smart) metering processes and of the connection of customers to the grid, it manages a lot of data that are crucial for the provision of competitive supply services and additional smart metering services. A DSO affiliated to the retail supply unit of a vertically integrated utility has strong incentives to discriminate other suppliers that compete with the affiliated retail supply unit, for example, by:

- delaying the provision of customer data to a new supplier (customer switching)
- providing other suppliers with less or lower quality data in less usable data formats
- only providing the affiliated supplier with commercially advantageous information that allows him to directly approach customers with special offers.

With the introduction of smart metering and smart grids the role of the DSO as the central data hub is expected to increase even further in the future. To establish competitive retail markets, it is, therefore, of crucial importance that appropriate rules and procedures are in place to guarantee that the DSO (or any associated entity assigned with the task of central data hub, see also chapter 4) provides the same level of information to all market participants without advantages for the supply unit of the vertically integrated utility the DSO is a part of.

Besides the general unbundling requirements specified in the EU Directives, it has proven quite successful throughout Europe to describe the specific tasks of DSO(s) and supplier(s) on the electricity/gas retail market and to precisely define the procedures, timeframes and extent for the data to be

[116] See also section 2.2.

[117] Under the condition the proper legal ground is given by the law.

[118] Vertically integrated utilities have furthermore strong incentives to shift costs from its units or subsidiaries operating in competitive market segments to its regulated distribution business unit or subsidiary in order to gain a competitive advantage for its operations on the retail market. This also applies for the provision of competitive smart metering services by the supply unit affiliated to the DSO.

exchanged between the supplier and the DSO (and other market participants). This is particularly relevant for those processes such as smart metering services that involve both the DSO and the supplier (or other market participants). Such clearly defined retail market processes would ensure that all market players can exchange critical information efficiently and swiftly in a non-discriminatory manner. A definition of such process and role descriptions would be, however, beyond the scope of this project.[119]

[119] The development of such process descriptions should done together with the different stakeholders (network operators, suppliers…) preferably be led (and the final version approved) by the AGEN-RS. While there are no EU-wide standards for metering processes, with process specifics and timescales varying from country to country depending on the respective national legislation, most are directly or indirectly based on the generic process definitions from ebIX (www.ebix.org).
Very detailed process and role descriptions have for example been developed for electricity retail market processes in Germany (only available in German): GPKE – Geschäftsprozesse zur Kundenbelieferung mit Elektrizität (Processes regarding the delivery of electricity to end-users), WiM – Wechselprozesse im Messwesen (Switching processes regarding Metering). Detailed descriptions for customer switching as well as for balancing and settlement have also been defined for Denmark (see for example the website of Energinet.dk (the Danish TSO): http://www.energinet.dk/EN/El/Forskrifter/Markedsforskrifter/Sider/default.aspx)

10 APPROACHES TO COST ALLOCATION

The full-scale roll-out of smart metering requires significant investments in the beginning as a whole new communication and metering infrastructure needs to be set up. These costs are only amortized over years in which the new system is used. To ensure that relevant market parties commit themselves to the investments initially needed, a clear legal and regulatory framework is crucial, showing commitment to the smart metering roll-out by governmental and regulatory authorities. Without offering certainty for investors, that their costs will be recovered, a smart metering roll-out will be deterred and will lead to inefficient results. Successful smart metering deployment is thus depending on the decision making institutions and their choice of legal and regulatory framework.

Besides definitions of roles and responsibilities of market participants (see chapters 0, 4 and 9), the roll-out scheme (see chapters 5 and 8) and monitoring of its implementation, also a transparent, predictable and reliable cost recovery scheme – reflecting actually incurred costs and benefits – is a key requirement for a successful roll-out. It is essential that costs and benefits are identified, assessed and allocated correctly to the different market participants. In chapter 8, we have provided an indication of the expected benefits and costs for the different stakeholders, which we calculated within the CBA. In case of a mandatory roll-out, it is furthermore important that incentives for a cost efficient procurement, installation and operation of the smart metering infrastructure are provided by the regulatory framework.

10.1 Recovery of Costs of Smart Metering by Different Stakeholders

The roll-out of smart meters should be done according to the costs-by-cause principle. There are several options of how those costs can be allocated to different stakeholders, i.e. which costs should be recovered by whom. Therefore, costs and benefits need to be identified, assessed and also allocated correctly to the different market participants. In general, those groups that profit from a roll-out should also bear the according investment and operating costs of smart metering. Reflecting the distribution of smart metering benefits among different groups of stakeholders, benefits for each stakeholder group should be offset against its costs in order to calculate the net benefits (or costs) for each stakeholder. The recovery of smart metering costs can be addressed by different cost allocation options which we discuss in the following sections.

Since the metering business will remain part of the DSOs[120] in Slovenia, the investment costs as well as operating costs for the smart metering infrastructure will be incurred by the DSOs in the first place. One option would be, therefore, to leave the investment costs completely with the DSO. Apart from offering very little incentives for DSOs to invest in the metering infrastructure and thus threatening the

[120] As pointed out earlier, the use of the abbreviation "DSO" (where it applies to electricity) here and in the following does not conclude that these tasks shall be carried out by the electricity DSO only. As in the current framework (see also chapter 4), procurement, installation and operation of smart meters will be carried out by the DUs and not by DSO.

roll-out, this financing model would also contradict the cost-by-cause principle: Costs would be fully recovered by the network operator, whereas energy savings as a major benefit occur on the consumer's side. Not passing on any costs of the smart metering infrastructure to other stakeholders – as, for example, to the end-users through increased network or metering charges – would also require that the benefits arising to the DSO do outweigh its costs. Otherwise, the DSO would constantly make a financial loss from the smart metering investment, which would either require subsidies by the government or cross-subsidies from other sources; if not this would ultimately result in the insolvency of the DSO. As we have seen in chapter 8, smart metering costs do significantly outweigh the benefits for the DSO. In other words, the DSOs are facing net costs, unless the regulatory framework does include provisions that enable the DSOs to pass on some of the costs to other stakeholders.

Since benefits from smart metering arise to a wide range of stakeholders (not only the network operator), another option for the financing of the necessary smart metering investments would imply introducing a specific charge to be paid by all users of the smart metering service infrastructure (i.e. TSOs, power producers, energy suppliers, smart metering service providers and customers) to the DSOs according to their benefits. Since it is difficult to exactly identify and quantify the benefits arising to individual stakeholders – which will also not be constant over time – one option would be to charge the different stakeholders for the provision of smart metering information. These information charges could be structured according to the approximate benefits of smart metering expected for different groups of stakeholders. It is however not advisable to follow this approach. Most of the potential benefits of smart metering arise to consumers, which benefit directly from the installation of the smart meter as well as from the provision of smart metering services provided to consumers by other stakeholders. All other market players face some initial investments due to required IT-systems, adjustment of processes, etc. before they can inhibit some of the benefits of the smart metering infrastructure. Also, an explicit payment for the use of data acquired by smart meters by third parties may lead to less public acceptance due to privacy concerns. Most importantly, however, the level of benefits generated from smart metering is directly linked to the scope of smart metering services provided to consumers, which themselves are directly linked to the costs of the provision of smart metering services. Charging for the provision of smart metering information will likely reduce the amount of benefits generated for consumers. We therefore recommend that DSOs provide smart metering information free of charge to other stakeholders (unless maybe this information relates to the provision of purely commercial smart market services).[121]

Thus, the most appropriate and easiest to implement option for the financing of smart metering roll-out investments would be a monetary transfer between the customers that benefit most of smart metering, and the DSOs that bear the costs in the first place. Passing on efficient costs to the consumer can be justified in case the consumer benefits resulting from a smart metering deployment are higher than the associated costs for the consumer, which is indeed the case for the scenarios we have analysed within the CBA as we have seen in chapter 8.

[121] See also the separation between smart grids and smart markets recommended by the German regulatory authority, which has been further described in footnote 29.

As the metering business will remain part of the regulated distribution network operators, the transfer can be incorporated in the existing network price control. In fact, many countries governments opted for such a recovery of smart metering costs of network operators from regulated (network or metering) charges rather than direct subsidies. If the (additional) investments for smart meters and the smart metering infrastructure would be fully incorporated in the allowed revenues of the DSOs, these additional costs would also be fully reflected in the regulated distribution network tariffs. In this case, all smart metering costs would be fully recovered by end-users. However, the benefits that do arise to the network operator need somehow to be included into the cost calculation. We therefore recommend that only those costs are recovered by network users that exceed the benefits for the network operator carrying out the investment.

The challenge is to identify the net costs: While the approach for defining costs of the installation and operation of a smart metering infrastructure is relatively clear and straight-forward, benefits for the network operator are much more difficult to reliably quantify. As discussed in chapter 0 (and in chapter 8), main benefits of DSOs from smart metering are cost savings from remote meter reading and from reduced technical and non-technical losses as well as more efficient network operations. When considering the potential benefits for the DSO, it is especially difficult to precisely monetise some impacts from smart metering on network operations. This applies in particular for the following parameters:[122]

- Better operability of the network
- Better access to data and possibility of profiling and aggregation through better information
- Improved balancing through information
- Enhanced system security through possibilities of remote control and efficient communication
- Improved continuity of supply by measuring interruptions
- Faster fault location
- Control of reactive power by easier detection of such consumers
- Optimisation of processes, savings of operational costs, improved investment and maintenance policy

A full evaluation of the economic benefits of smart metering – as conducted within this CBA for Slovenia – can only provide an indication on the expected costs and benefits for different stakeholders. While the CBA takes into account practical experience from pilot projects in Slovenia and international experience from countries that have already progressed with a roll-out of smart metering as well as information and feedback provided by AGEN-RS, DSOs, suppliers and other stakeholders (such as manufacturers) throughout this project, it is still an evaluation of the expected costs and benefits for different stakeholders. The exact costs and benefits arising to DSOs and customers will however depend on the specific details of the implementation of smart metering and in particular on the practical details of the smart metering service model discussed in chapter 4. It will be the task of AGEN-RS to

[122] See also ERGEG (2011): Final Guideline of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas

determine the net benefits for the DSOs and to ensure that only efficient costs are passed through and recovered by end-users within the regulatory framework. The extent to which the allowed revenues and tariffs reflect the underlying costs for the provision of smart metering is also a decisive factor for investments (if a roll-out is not made mandatory, such as in case of a natural roll-out).

10.2 Treatment of Costs and Benefits in the Regulatory Framework

While it is crucial to determine if and to which extent the investment and operating costs should be passed on to end-users through the allowed revenue, it is also necessary to define how these costs will be recovered and possibly accommodated in the tariff regulation. When specifying the regulatory cost recovery framework for smart metering, we recommend taking the following criteria into account.

To reduce the financial risk for DSOs, in order to guarantee the necessary stability and predictability for the investors, so that they are able to confidently plan for the future, the general regulatory framework should be kept fairly constant over time. This is particularly important for the DSO, who needs to be assured that its investments in the network and the metering assets will not be threatened by unexpected changes in the regulatory environment. Specific details of the framework may be further developed and adjusted with the development of smart metering and in case of significant technical progress (e.g. as regards the provision of new smart metering services and the development of smart grids).

It is also essential that the regulatory framework is clearly understood by all market participants. Excessively sophisticated approaches may set very precise incentives but may appear as a "black box" to companies and customers. Under such circumstances, they may not be able to respond adequately to the corresponding signals provided by the framework. Transparency also has the advantage of promoting accountability for the actions, by the DSO, suppliers and the providers of smart metering services. It helps to avoid disputes and legal battles and improves the general acceptance of stakeholders, most importantly of consumers. The regulatory framework should, furthermore, be designed in such a way that it is practical to implement. Avoiding overly complex procedures also goes hand in hand with the administrative burden for all affected market participants (in particular the DSO). This involves consideration of the specific characteristics of the electricity (and gas) sector of Slovenia.[123]

Investors will require a transparent, predictable and reliable cost recovery scheme – that may be incorporated in the existing regulatory revenue setting methodology – before they commit themselves to the necessary smart metering investments. They will only do so if the framework offers enough certainty that the investment costs will adequately be recovered. It is, therefore, necessary that all legal and regulatory provisions are defined and communicated to the different stakeholders before the start of

[123] In addition – as already pointed out in the previous chapter – a non-discriminatory framework for the exchange of metering data between the different stakeholders is the key for the successful implementation of smart metering and the development of smart metering services. The (wider) regulatory framework should therefore also include precise definitions of the procedures, timeframes and extent for data to be exchanged between the different market participants.

the roll-out. Furthermore, provisions in the legal and regulatory framework should show commitment to the roll-out by governmental and regulatory authorities and explaining clearly how the investment and operating costs will be accommodated in tariff regulation. This includes also the precise definition of the roles and responsibilities of each market participant and the details of the roll-out scheme (e.g. the timeline, the relevant milestones and the functionalities of the smart meters) as well as the monitoring of the implementation of the roll-out by AGEN-RS according to the roll-out specification. Furthermore procedures need to be in place on what regulatory actions are to be taken if a market participant does not comply with the provisions of the smart metering roll-out.

Besides the question of which costs should be recovered by whom, also the question of how these costs should be treated / integrated in the regulatory framework need to be specified. This comprises a set of rules for

- the communication and cost reporting between the regulator and the network operator, e.g. reporting forms and cost allocation principles
- the efficiency assessment of the smart metering costs
- the inclusion in the tariff system (e.g. through the general network charge, a metering charge or a separate smart metering system charge)

As a first step we recommend to adjust the cost reporting mechanism to ensure that costs for smart metering are reported separately to the regulator in a transparent and accurate way.[124] It would allow the regulator to assess the real costs of the roll-out and to control for these costs. It does not necessary mean that the costs for the metering infrastructure need to be shown separately on the consumers' bill, but transparently provided to the regulator. In Austria, for example, the regulatory reporting forms that are submitted by the regulated network operators to the regulator each year include a separate sheet that explicitly lists different cost categories for the smart metering business.[125]

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[124] According to examples for the regulatory cost accounting framework and the regulatory data collection – recommended as a basis for a thorough regulatory assessment of smart metering investment (and operational) costs – are the data sheets used by the Austrian regulator E-Control for electricity and gas network operators and of the German regulator Bundesnetzagentur.
The Austrian data sheets (available in Germany only) can be found at:
http://www.e-control.at/de/marktteilnehmer/erhebungen/erhebungen-im-rahmen-der-tarifverfahren/unterlagen-netzbetreiber-strom
The German data sheets (available in Germany only) are published at:
http://www.bundesnetzagentur.de/cln_1911/DE/Service-Funktionen/Beschlusskammern/1BK-Geschaeftszeichen-Datenbank/BK8-GZ/2012/BK8-12-001/BK8-12-001_Beschluss_BKV.html?nn=269762

[125] Since 2007 Austria does also apply an activity-based costing framework which requires network operators to allocate their total operating costs on a set of 4 main (and 19 detail) processes, which describe the major tasks of all network operators. For each of the detail process, network operators, furthermore, have to specify which costs arise from (external) service agreements and which from internal provision. Such detailed data collection might increase the administrative burden for the DSOs, but would provide the regulatory authority with further indication on critical cost areas of individual network operators, in particular as regards cost comparisons of DSOs

Provisions for cost reporting should be accompanied by cost allocation guidelines, which define how specific cost items have to be allocated to different segments. As some costs cannot be directly attributed to smart metering (such as costs for employees that maintain the meters, as well as other parts of the network), rules need to be defined how they should be allocated to the metering part (e.g. by actual hours worked on meters and other network parts). As part of these guidelines, provisions shall also be included, which specify how cost reductions arising to the DSO from the implementation of smart metering shall be considered in its reported metering costs.

Different reasons may exist for regulatory authorities to be reluctant to allow higher revenues to network operators to cover smart metering: Planned costs may be perceived to be high, or political or social reasons may prevent price increases[126]. While it is important to understand that such a restrictive regulatory policy may undermine the success of the smart metering roll-out, political acceptance and social affordability of any price increase cannot be disregarded. To ensure that the scope of functionalities enabling energy savings does not suffer from tight budgets, it is crucial to reduce consumer resistance and consumer concerns. This can be done on one side by increasing consumer awareness of energy savings potentials and strengthening their confidence in the proposed reforms in metering infrastructure. On the other side, public acceptance will be more likely when there is certainty that only efficient costs are included in the tariffs.

Besides specific requirements for cost reporting and provisions for the treatment of costs from pilot projects (and R&D investments) in the area of smart metering and grids, regulatory authorities across Europe have generally (not yet) implemented specific regulatory requirements for smart metering, but rather include these costs in the general regulatory cost assessment framework and regulated tariff regime. It will, however, be key to appropriately consider these (additional) costs in the regulatory efficiency assessment of capital and operating costs before each regulatory period and where and if necessary to adjust this framework.

Transparency towards the expected costs and benefits for end-users and the allocation of costs among different stakeholders will be important in order to gain public acceptance. A prerequisite to establish cost reflective tariffs is the knowledge about actual costs and benefits arising to different market participants. An indication on the distribution of costs and benefits for different stakeholders has been provided with the discussion of the results of the CBA in chapter 8. In order to exactly define the level of net costs for the DSOs to be included in the allowed revenue and regulated tariffs (as discussed in the previous subchapter), further assessments of the efficient smart metering costs incurred by the DSOs and of the smart metering benefits of the DSOs would be required – which is outside the scope of this study.

with different levels of in- and outsourcing (costs of service agreements and of IT). For Austria such process descriptions (only available in German) can be found at: http://www.e-control.at/de/recht/marktregeln

[126] There have been multiple examples in the past where consumers and politicians have been opposed to price increases regardless of whether these increases had been driven by objective economic reasons.

Normative pricing principles require primarily economic efficiency and cost recovery. However, in practice there is a bias between cost recovery and investment incentives on one side and price increases for customers on the other. Including substantial investments into cost reflective tariffs will result in high price increases. Disregarding the fact that non-cost reflective prices cause a distortion of price signals and consumer behaviour, cost reflective higher prices may not be accepted politically and raise issues regarding social affordability. From the economic point of view, it is strongly recommended not to include any cross-subsidies for low income customer groups within the electricity and gas tariff regime, but rather to consider higher costs for end-users (that may result from a roll-out of smart metering) in the general social security regime. To facilitate the participation and support for smart metering of low income household customers, a few countries have especially implemented subsidised or free-of-charge energy efficiency programs for these customer groups.

As is currently the case in the area of gas in Slovenia, we recommend to show separate metering charges also on the bill of electricity customers, rather than to include them in the general network charges. Such metering charges (applied in many European countries) would then also include the investment and operating costs for smart metering, either only including the costs of the smart meters or also including the costs of the smart metering infrastructure. An alternative approach would be to establish a separate (additional) smart metering system charge to recover the efficient net costs of the smart metering infrastructure. Such separate (smart) metering charges would increase transparency for consumers (and other stakeholders) on the amount of smart metering costs to be recovered by consumers and may thereby increase public acceptance.

Another question is whether the efficient costs of smart metering are instantly charged to all consumers after the start of the roll-out, or whether they will only be charged to those customers at first that are already provided with smart meters and which are, therefore, already able to realise the potential smart metering benefits arising for consumers. Including smart metering costs in the general network charges would not allow for such discrimination of customers.

Benefits will also not be distributed equally among customers as they depend on individual consumer's behaviour, awareness, education, willingness and the consumers' leeway to reduce energy consumption. Furthermore, end-users with lower consumption have less energy saving potential and it can be argued that they should pay less for the metering infrastructure than customers with higher benefits. At the same time, some indirect benefits from a smart metering roll-out are equal for all consumers and cannot be assigned to specific groups – such as the overall economic benefits of reducing emissions, the enhancement of security of supply or the integration of renewables. Finally, although the benefits differ for different customer groups, the normative principle of non-discriminatory prices – supported by the requirements of EU Directive 2009/72 EC and 2009/73 EC – generally demands all consumers to be charged equally and not to discriminate within different customer groups.

10.3 International Experience

The state of smart metering in the EU differs from country to country: While countries such as Sweden and Italy have already completed a roll-out, others have only recently started with a roll-out or yet only taken a firm decision for a mandatory roll-out (e.g. France, Spain and UK) while smart metering in some countries remains voluntary (e.g. Denmark).

Italy

Italy was the first country in the EU that introduced smart metering in a large scale with the roll-out starting already in 2001. The roll-out was not mandatory in the beginning with the main driver being high commercial losses (i.e. fraud). Enel, the incumbent energy supplier with a market share of 85% in the household sector, voluntarily installed the new metering devices for its customers to reduce the non-technical losses. Saving or revenues in purchase and logistics, operations and customer support placed further benefits for Enel to deploy around 30 million meters. These meters had rather basic options for applications and were less useful for other objectives of smart metering, such as energy savings for consumers.

Based on the experiences with Enel's roll-out regarding cost recovery and consumer behaviour, the regulatory authority introduced a mandatory roll-out together with a regulatory and legal framework in 2006. The responsibility was assigned to the DSOs, and higher technical requirements for the metering devices were mandated than those initially installed by Enel. The change in the technical requirements was driven by a change of the main motivation for the smart metering roll-out: While the initial smart metering model of Enel mostly benefited DSOs and suppliers, the new country-wide model aimed at improving energy consumption and influencing consumer behaviour by time-dependent pricing. To achieve those goals and justify passing through costs to customers, metering devices needed to be able to support applications that offer benefits for customers.

The roll-out of smart metering in Italy was supported by three regulatory schemes, which provide cost recovery for the DSOs and offer further monetary incentives:

- a separate metering charge (since 2004) only for those DSOs that have invested in smart metering infrastructure
- determination of separate allowed revenues from metering charges (only if penetration rates are fulfilled)
- a monetary incentive for installing smart meters faster than targeted

Sweden

In Sweden, the roll-out of smart metering has been driven by legal requirements for monthly meter reading. Smart metering was seen as an instrument to ensure that energy costs and energy bills project the actual energy consumption in an environment of increasing prices and high per capita consumption. Within a detailed CBA in 2002 major benefits of a monthly meter reading were identified for customers due to reduced consumption and offset against the implied investment costs. As those benefits were greater with large customers, in a first phase starting 2006, monthly reading was mandated only for customers with an annual consumption of more than 8000 kWh. In 2009, smart metering was extended to all consumers. Smart metering was introduced by DSOs – the responsible party for meter reading – on a voluntary basis as the best option to fulfil this requirement in a sparsely populated country with annual reading thus far. The smart metering roll-out was not conducted by a coordinated approach, but individually executed by the network operators. Furthermore, investment costs were not recovered by consumers over network charges in the past but born by the DSOs due to the voluntary nature of the roll-out. In 2012, however, ex-ante assessments of allowed revenues have been introduced in the Swedish revenue-cap regulation and relevant and cost-efficient investments accordingly be acknowledged by the regulatory authority in the allowed revenues, subsequently resulting in increased network charges.

11 SUMMARY AND RECOMMENDATIONS

Within this project the economic benefit as well as the potential scope and framework for a roll-out of smart metering for electricity and/or gas in Slovenia have been assessed. To calculate the expected costs and benefits from a roll-out of smart metering for different stakeholders (i.e. DUs/DSOs, consumers, suppliers, TSOs, producers, government and the society as a whole) in Slovenia, an economic cost-benefit analysis (CBA) – as suggested by EU Directives 2009/72/EC and 2009/73/EC – has been applied. In addition, also qualitative evaluations on the preferred smart metering service model, on smart metering functionalities and services and on additional costs and benefits, which could only be assessed outside the CBA framework, have been conducted.

The results of these assessments have been presented and discussed within this final report, which we can summarize as follows:

Recommended smart metering service model

Among the four smart metering service models proposed by AGEN-RS, model A2 may provide the largest benefits. According to this model a new independent entity, the Service Centre for Smart Networks, shall be established as a part of the electricity DSO, carrying out the role of a metering data aggregator (SCSN). Communication between the smart meters and the metering centre of the DSOs/DUs shall take place through a joint communication infrastructure for electricity and gas.

In case of a joint roll-out of smart metering for both electricity and gas, model A2 may provide the largest benefits, since additional investment and operational costs of separate communication infrastructures may be avoided. The integration of the SCSN and the DSO within a single entity in model A2 may furthermore lead to a single point of contact model, being more transparent and understandable for market participants, but also supporting a more efficient (less costly) exchange of metering data for suppliers and other stakeholders. Model A2 may also have the advantage that it is easier and quicker to implement, since it may require smaller adjustments to the existing legal framework and since some of the existing infrastructure and resources of the electricity DSO may partly be used for the set-up of the SCSN.

If only a roll-out for electricity is decided on and the number of smart meters for other commodities (gas, district heating, water, etc.) remains low, then model B2 may be considered as the preferred option since many of the benefits of the establishment of the SCSN will only show for multi-utility smart metering services. However, data exchange would take place over separate communication infrastructures for electricity and gas. In model B2, it will also be beneficial to aggregate metering data at the level of the DSO in order to facilitate retail market competition and the provision of smart metering services for electricity. In this case, the DSO would take over some of the tasks that would be conducted by the SCSN in the other 3 models.

Recommended smart meter functionalities and smart metering services

AGEN-RS has defined a set of (basic) functionalities for electricity and gas smart meters, mandatorily required for meters complying with the recommendations of DG ENER and DG INFSO of the European Commission.[127] Further optional functionalities and associated smart metering services can provide significant additional benefits. Following standardisation efforts on European level as well as developments on the smart meter manufacturers' side, results in the observation that standard types of smart meters currently offered on the market now more or less provide most of the discussed smart meter functionalities. Main differences in the costs of smart meters are, therefore, not to be found in the listed functionalities but in the communication interfaces (GSM/GPRS or PLC) and in the number of measured phases (one phase or three phase meters). Smart meters with very distinctive / selective sets of functionalities will also come at an extra cost since smart meters currently on the market tend to be very much standardised across manufacturers and would need to be specifically calibrated by the manufacturers.

Recommendation for a smart metering roll-out

A mandatory roll-out of smart electricity meters may generate significant net benefits for Slovenia. Such net benefits will be largest when a fast roll-out (such as an 80% deployment target up to 2020) is conducted and when a high percentage of PLC/GPRS or PLC/WiMAX can be applied (e.g. 95%). Discounted costs will be particularly high at the beginning of a smart metering roll-out, whereas discounted benefits will only pay off in the longer term. It will therefore take at least one investment cycle until discounted costs are outweighed by discounted benefits. It could, furthermore, be shown within the sensitivity analysis as well as within a stochastic Monte Carlo Simulation that these results are quite robust to changes in the assumptions of key input parameters.

A joint mandatory roll-out for electricity and gas can – in some roll-out scenarios – provide net benefits in the longer term. A break even between discounted costs and benefits will however only be achieved after 25 years, which may be considered too long-term when uncertainty on future developments is considered. In particular, since even the most beneficial roll-out scenario (an 80% until 2020) is quite sensitive to the values of key input parameters. Furthermore, given the much smaller number of gas meters, positive NPVs estimated for some joint roll-out scenarios may partly if not largely been driven by the positive electricity results as could be shown, when compared to a gas only scenario (which is associated with large and significant net costs).

A natural roll-out can neither be recommended for electricity nor for gas unless it is conducted on a voluntary basis and costs are not cross-subsidised by other stakeholders not benefitting from smart metering.

The following table shows the main properties and the summary results of the two most beneficial roll-out scenarios for electricity smart meters.

[127] A joint contribution of DG ENER and DG INFSO towards the Digital Agenda, Action 73: Set of common functional requirements of the SMART METER, October 2011

	Scenario 1	Scenario 6
Percentage of PLC/GPRS	95%	95%
Percentage of GPRS	5%	5%
Roll out scheduling (start in 2015)	80% by 2020	100% by 2025
Discounted Benefits	342.84 M€	341.40 M€
Discounted Costs	-304.60 M€	-305.78 M€
Net Present Value (NPV)	38.24 M€	35.62 M€
Internal rate of return (IRR)	6.57%	6.81%
Payback period	16.0 years	16.8 years

Table 28: Properties and the summary results of the two most beneficial roll-out scenarios for electricity

In case of significant changes to model input parameters and in line with technological change and price developments, it will be recommended to reassess a smart metering roll-out for gas within another CBA sometime in the future.

Following the decision for a mandatory roll-out of smart metering, a detailed smart metering implementation plan should be specified covering the required roll-out, both in terms of time (start and end date and possible intermediate targets) and volume of meters to be distributed (i.e. the deployment target). During the preparation phase and at the beginning of the roll-out, the plan may be amended to consider any new knowledge, technological progress and unforeseen developments. The plan must include clearly defined milestones and responsibilities and should serve as the common point of reference for all involved market parties alike. Given the tight time schedule, any undue delay should be avoided.

Smart metering may, however, be implemented on a voluntary basis in particular for larger electricity and gas consumers. Even when a large scale mandatory roll-out of smart metering is not considered (yet), it will be necessary to establish a legislative and regulatory framework, which enables discrimination-free access to smart metering data, which safeguards data privacy and data protection and which provides a fair and efficient cost allocation of the smart metering investment and operational costs among the different stakeholders.

With the introduction of smart metering and smart grids also the role of the DSO as the central data hub is expected to increase even further in the future. It will therefore be very important for the development of smart metering services and of retails market competition to precisely define the tasks and responsibilities of DSO(s) / DUs / SCSN and supplier(s) in the retail market and to precisely define the procedures, timeframes and extent for the data to be exchanged. This includes that appropriate rules and procedures are in place to guarantee that the same level of information is provided to all market participants without advantages for the supply unit of the vertically integrated utility a DSO is a part of.

Recommendations for data privacy and data exchange

Consumer resistance towards smart metering relating to data privacy and data protection may present a serious obstacle to the deployment of smart metering. Before a roll-out takes place, provisions should be implemented to ensure that personal data is not accessed by unauthorized parties and that there are clear regulatory provisions on how data is gathered, processed, stored and evaluated, and who has access to which data for legitimate purposes.

Recommended measures include in particular:

- Technical and procedural measures to secure data communication (data protection by design and by default settings, e.g. access rights and encryption of data transmission)
- Monitoring and enforcement of a clear and functional legal framework setting out explicit rules on data access and handling, including their disclosure and transmission to various third parties (e.g. energy suppliers, service and communications providers), as well as responsibilities to safeguard data protection and security.

Further recommended measures include provisions to limit the type and amount of data that can be collected to clearly and properly defined purposes, to limit the time for which data can be kept, and to anonymise personal data.

Recommendation for cost allocation

Allocation of smart metering investment and operational costs will mostly take place within the regulatory network price control as the metering business will remain part of the regulated DUs/DSOs. It will be a key task for AGEN-RS to make sure that only efficient and only net costs (i.e. investment and operational costs of smart metering minus the benefits / costs savings arising to the DUs/DSOs) are passed on by the DUs/DSOs to other stakeholders (e.g. to consumers via network charges).

As a first step, we recommend adjusting the cost reporting mechanism to ensure that costs for smart metering are reported separately to the regulator in a transparent and accurate way. It would allow the regulator to assess the real costs of the roll-out and to control for these costs. It does not necessary mean that the costs for the metering infrastructure need to be shown separately on the consumers' bill, but transparently provided to the regulator. Provisions for cost reporting should be accompanied by cost allocation guidelines, which define how specific cost items have to be allocated to different segments. Transparency on the smart metering costs can furthermore be increased, when the net costs are recovered by a separate metering charge or smart metering system charge.

To facilitate the development of smart metering services we furthermore recommend that smart metering information is provided free of charge to other stakeholders.

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APPENDIX 1: COST AND BENEFIT ITEMS ASSESSED WITHIN THE CBA

Electricity Smart Metering

Item	Description
Procurement, installation and operation of meters (CB1)	Number of existing conventional meters (electronic and electromechanical) per year of installation.
	Smart meter capital costs (hardware) considering different types of electrical connection (three-phase, single-phase).
	Smart meter installation costs
	Smart meter failure rate
	Smart meter energy consumption
	Economic lifetime of smart meter
	Technical lifetime of smart meter
	Conventional meter capital costs considering different types of electrical connection (three-phase, single-phase)
	Conventional meter installation costs
	Conventional meter failure rate
	Conventional meter energy consumption
	Economic lifetime of conventional meter (electronic and electromechanical)
	Technical lifetime of conventional meter (electronic and electromechanical)
	Revisiting rate due to access problems
	Revisiting costs
	Percentage of meters indoor and outdoor
	Percentage of three-phase and single-phase meters
	Percentage of existing electronic and electromechanical meters
	Equipment price variation over time
	Client waiting time (household's opportunity costs)
Communication infrastructure (CB2)	Modem cost for different communication technologies (PLC, GPRS, ZigBee, WiMAX)
	Concentrators cost for the different communication technologies when applicable (PLC and ZigBee)
	Radio base stations costs when applicable (WiMAX)
	Operation and maintenance costs for the different communication technologies
	Communication fees when applicable (GPRS)
	Costs with head end systems (hardware and software) to manage the communication infrastructure and two-way communication with the smart meter including routers, firewalls, other servers and licenses.
	Operation and maintenance costs for the head end systems
	Investment period for the head end systems
	Number of meters per concentrator/collector
	Percentage of penetration for each communication technologies based on population density.
	Equipment price variation over time
Information systems (CB3)	Costs with hardware (server hardware and storage infrastructure)
	Costs with new information systems to manage and process all the meter data which is collected or transmitted
	Costs with updates of existing information systems to accommodate new smart metering processes and functionalities.
	Costs with a web portal to provide information to the clients as well as to other stakeholders (with client's permission)
	Operation and maintenance costs
	Project management costs
	Investment period

Item	Description
In-home displays (CB4)	IHD capital cost
	IHD energy consumption
	Client waiting time (household's opportunity costs)
Change on consumer's electricity consumption (CB5)	Different percentages of energy reduction depending on the type of feedback provided to the consumer.
	Average end user tariff (split on energy charges, transmission and distribution use of network charges, other charges, taxes or regulatory charges). Time series of average end user tariff and components.
	CO2 emissions per kWh
	CO2 prices
Meter reading costs (CB6)	Number of local (manual) meter readings per consumer
	Meter reading average costs (average time for single meter reading event and cost of meter reading)
	Percentage of additional meter readings due to access problems
	Additional meter reading average costs
	Client waiting time (household's opportunity costs)
Non-technical losses (CB7)	Percentage of theft (energy)
	Number of local operations (audits, etc.)
	Costs with local operations (audits, etc.)
	Administrative losses
Billing costs (CB8)	Present costs of paper bills
	Present costs of electronic bills
	Future costs of paper bills considering smart metering
	Future costs of electronic bills considering smart metering
	Percentage of paper bills
	Percentage of electronic bills
	Future percentage of paper bills
	Future percentage of electronic bills
	Time needed (per meter) to correct inaccurate invoices
	Specific cost to correct inaccurate invoices
Electricity shift from peak to off peak (CB9)	Average consumption in peak periods for a typical residential and small commercial client
	Average consumption in off peak periods for a typical residential and small commercial client
	Average end-user price peak period
	Average end-user price off-peak period
Local operations (CB10)	Number of reconnection/disconnection (debt management)
	Costs with reconnection/disconnection
	Percentage of debt (energy) per consumer
	Number of local operations to investigate voltage levels
	Costs with local operations to investigate voltage levels
Outage management (CB11)	Energy not delivered
	Reduction of annual outage time per household
	Value of service
Investment on transmission and distribution capacity (CB12)	Transmission and Distribution network losses
	T&D marginal cost
Technical Losses (CB13)	Transmission network losses
	Distribution network losses

Item	Description
Stranded costs (CB14)	Value of conventional meters replaced before the end of their economic lifetime
Global program implementation costs (CB15)	Annual costs with project management, logistics and procurement processes.
Marketing Cam-paigns (CB 16)	Awareness and communications campaigns for consumers related with energy efficiency.

Gas Smart Metering

Item	Description
Procurement, installation and operation of meters (CB17)	Number of existing conventional meters per year of installation.
	Smart meter capital costs
	Smart meter installation costs
	Smart meter failure rate
	Economic lifetime of the smart meter
	Technical lifetime of the smart meter
	Conventional meter capital costs
	Conventional meter installation costs
	Conventional meter failure rate
	Economic lifetime of the conventional meter
	Technical lifetime of the conventional meter
	Revisiting rate due to access problems
	Revisiting costs
	Percentage of meters indoor and outdoor
	Equipment price variation over time
	Client waiting time (household's opportunity costs)
Communication infrastructure (CB18)	Modem cost for the different communication technologies (PLC, GPRS, ZigBee, Wimax)
	Concentrators cost for the different communication technologies when applicable (PLC and ZigBee)
	Radio base stations costs when applicable (Wimax)
	Operation and maintenance costs for the different communication technologies
	Communication fees when applicable (GPRS)
	Costs with head end systems (hardware and software) to manage the communication infrastructure and two-way communication with the smart meter including routers, firewalls, other servers and licenses.
	Operation and maintenance costs for the head end systems
	Investment period for the head end systems
	Number of meters per concentrator/collector
	Percentage of penetration for each communication technologies based on population density.
	Equipment price variation over time
Information systems (CB19)	Costs with hardware (server hardware and storage infrastructure)
	Costs with new information systems (excluding MDMS) to manage and process all the meter data which is collected or transmitted
	Costs with updates of existing information systems to accommodate new smart metering processes and functionalities.
	Costs with a web portal to provide information to the clients as well as to other stakeholders (with client's permission)
	Project management costs
	Operation and maintenance costs
	Investment period
Change on consumer's gas consumption (CB20)	Different percentages of energy reduction depending on the type of feedback provided to the consumer.
	Average end user tariff (split on energy charges, transmission and distribution use of network charges, other charges, taxes or regulatory charges). Time series of average end user tariff and components.

Item	Description
Meter reading costs (CB21)	Number of local meter readings per consumer
	Meter reading average costs
	Percentage of additional meter readings due to access problems
	Additional meter reading average costs
Non-technical losses (CB22)	Percentage of theft (energy)
	Number of local operations (audits, etc.)
	Costs with local operations (audits, etc.)
	Administrative losses
Billing costs (CB23)	Present costs of paper bills
	Present costs of electronic bills
	Future costs of paper bills considering smart metering
	Future costs of electronic bills considering smart metering
	Percentage of paper bills
	Percentage of electronic bills
	Future percentage of paper bills
	Future percentage of electronic bills
	Time needed (per meter) to correct inaccurate invoices
	Specific cost to correct inaccurate invoices
Stranded costs (CB24)	Value of conventional meters replaced before the end of their economic lifetime
Global program implementation costs (CB25)	Annual costs with project management, logistics and procurement processes.
Marketing Cam-paigns (CB 26)	Awareness and communications campaigns for consumers related with energy efficiency.