Ernst & Young

„Cost-benefit analysis for the comprehensive use of smart metering“

On behalf of the Federal Ministry of Economics and Technology

EY

Building a better working world

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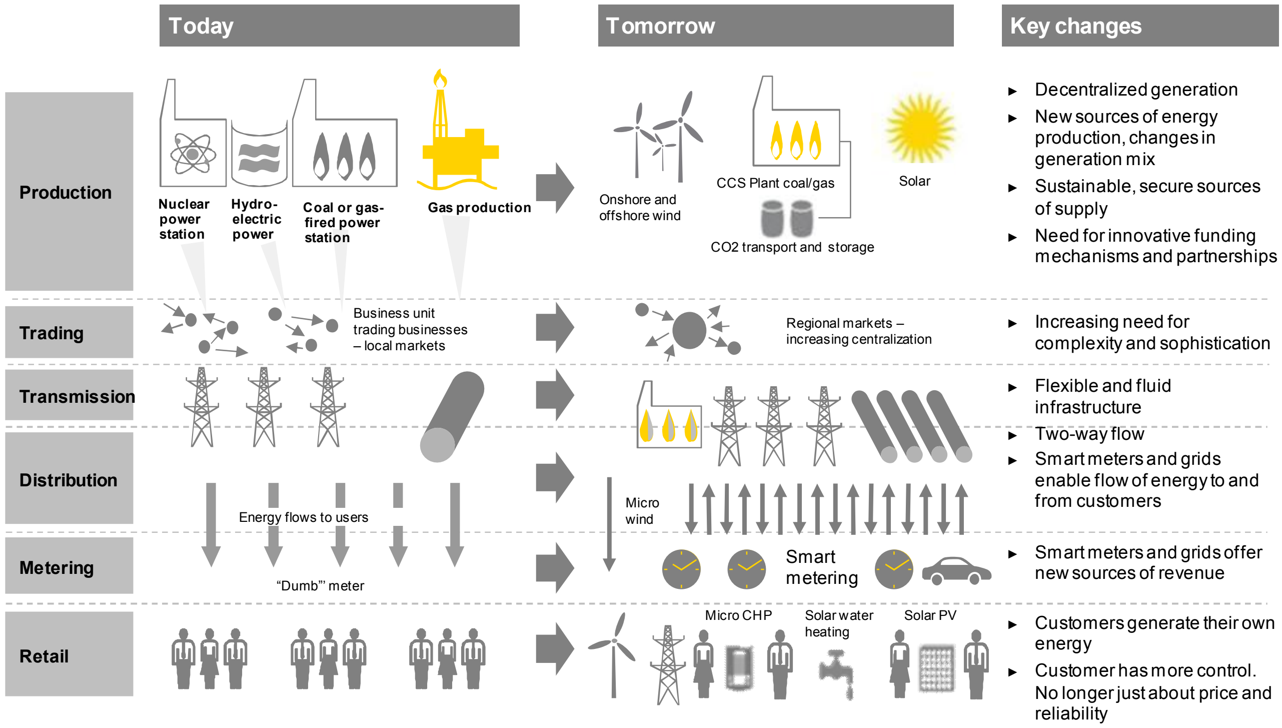
1. Introduction

The enacted turnaround in energy policy has accelerated the restructuring of grid-based energy supply in Germany, especially for electricity and gas. Clear progress is being made in shifting the entire energy supply system from a centralized to a decentralized system, and the transformation of the energy sector is taking shape (see Figure 1). While in the past energy flowed in only one direction and information about energy flows was highly limited, the decentralized energy supply system of the future is characterized by a two-way flow of information and energy. Significant changes are also taking place on the consumer side: Inactive consumers are increasingly becoming "Prosumers" who are actively helping to shape the energy supply system. Overall, these changes are especially increasing the requirements for the measurement and communication technologies used as well as data processing systems.

Figure 1: The turnaround in energy policy is accelerating the transformation of the energy sector



Source: Ernst & Young

One of the biggest challenges facing the decentralized energy supply system of the future is to manage power flows in such a way that energy supply is secured. In the future, electricity supply could become more flexible through active feed-in management and an increasing usage of demand-side management measures. Both could be realized either within the regulated grid business or the competitive retail market. Smart metering systems could play an important role here. Depending on their technical features, they could provide the necessary information about energy consumption to end consumers, network operators and producers. Smart metering systems could also be used as an enabler for modern smart grids and could help to create incentives for consumers to improve energy efficiency.

However, the introduction and especially the nationwide roll-out of smart meters will also entail substantial costs, technical challenges and risks. Aspects which need special attention are ensuring interoperability, data protection and data security requirements. The foundations for this have been laid in Germany with the BSI Protection Profile and the accompanying Technical Guideline.

Furthermore, a wide variety of roll-out strategies and approaches are possible, as demonstrated by other EU member states. In this context, the scope of a regulated (mandatory) and a market-driven roll-out is of major significance. The strategy at hand defines the scope of the installation requirements and the cost distribution for the roll-out of smart meters.

1.1 Background

The legal basis for the introduction of smart meters is the overhaul of the German Energy Industry Act (EnWG) in summer 2011, which led to the implementation of the Third Internal Market Package. Part of the Third Internal Market Package is the EU Directive 2009/72/EC (electricity). Without specifying any detailed technical distinctions (between intelligent meters and smart metering systems), the directive provides for the introduction of smart meters to assist the active participation of consumers in the electricity supply market. It stipulates that 80% of consumers shall be equipped with smart meters by 2020. However, member states are also allowed to make the introduction dependent on an overall economic assessment: "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 consumer or which form of intelligent metering is economically reasonable and cost-effective and which timeframe is feasible for their distribution."[1,2]

In implementing the EU Directive, the Energy Industry Act stipulates in § 21i (1), No. 8 EnWG that "subsequent to an adequate economic assessment as defined by § 21c (2) that meets the requirements of Directive 2009/72/EC and 2009/73/EC, the installation of smart metering systems as defined by § 21d and § 21e and measuring systems as defined by § 21f shall only be provided for under certain conditions and in certain cases and, in other cases, metering operators shall be obliged to offer such smart metering and measuring systems, and a timetable and requirements for the roll-out of smart metering systems as defined by § 21d and § 21e shall be provided for." The German legislator has therefore laid down the procedure for an economic assessment (cost-benefit analysis) as well as a timetable for and details of the roll-out of smart metering systems and intelligent meters.

In the context of the implementation of the Directive, the Federal Ministry for Economics and Technology (Bundesministerium für Wirtschaft und Technologie, BMWi) engaged Ernst & Young GmbH Wirtschaftsprüfungsgesellschaft to evaluate the nationwide introduction of smart meters on an economic basis. Accordingly, this report examines the nationwide roll-out in accordance with the law in the context of an economic cost-benefit analysis (CBA). This report has two objectives that result from the requirements of the EU on one hand, and the legislation enacted by the EnWG on the other:

1. The report can serve to consider the requirements of the EU Commission. These requirements state that the implementation of smart meters can depend on an economic assessment. "Subject to that assessment, Member States or any competent authority they designate shall prepare a timetable with a target of up to 10 years for the implementation of intelligent metering systems. Where roll-out of smart meters is assessed positively, at least 80% of consumers shall be equipped with intelligent metering systems by 2020."[3]
2. The report can serve to comply with the legal requirements of § 21c EnWG, whereby further installation requirements not included in § 21c are only permitted "… if an economic assessment by the BMWi examines all long-term, macroeconomic and individual costs and benefits, and orders a statutory regulation as provided for in § 21i (1), No. 8."[4]

Furthermore, this report evaluates general parameters to promote the nationwide equipment of households as well as other end consumers, such as commercial end users, with smart meters. In addition, it presents measures to improve the cost-benefit ratio. In this context, this report also considers the potential inclusion of the gas sector in the smart meter roll-out.

[1] EU Directive 2009/72/EC of the European Parliament and the Council of 13 July 2009 concerning the common rules for the internal electricity market and to replace EU Directive 2003/54/EG.
[2] The directive 2009/73/EC for gas does not define a specific roll-out target, contrary to the directive for electricity.
[3] EU Directive 2009/72/EC and 2009/73/EC of 13 July 2009, Annex I, Point 2, respectively.
[4] Refer to § 21c (2) EnWG.

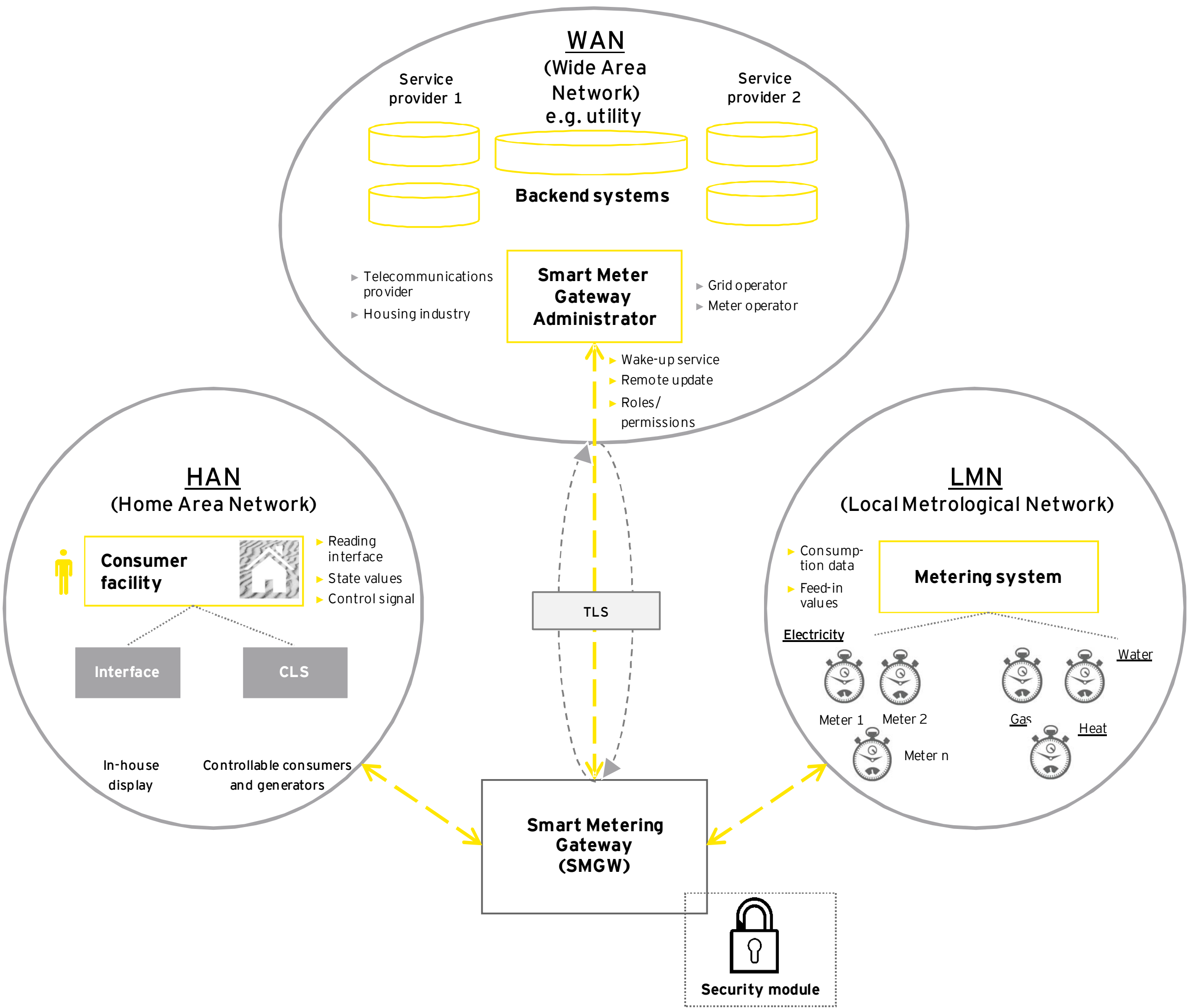
1.2 Smart metering systems and intelligent meters

The different technical characteristics and features of smart metering systems and intelligent meters allow efficient and tailored deployment for a variety of user groups. Therefore, the economic assessment of a roll-out must distinguish between smart metering systems and intelligent meters.[5]

Smart metering systems

Under § 21c EnWG, all end consumers fulfilling the stated mandatory criteria must be equipped with a smart metering system in the future.[6] This implies that only smart metering systems that not only meet the calibration regulations but also fulfill the requirements of the BSI Protection Profile can be implemented. By combining a meter with a communication unit, the Smart Meter Gateway (SMGW), and with a security module, the meter turns into a smart metering system. While the actual measurement still takes place in the measuring system, the new characteristic is the requirement to integrate the meter into a communication network. Figure 2 shows the resulting system architecture of such smart metering systems.

Figure 2: System architecture of smart metering systems according to the BSI Protection Profile



Source: Ernst & Young in conformity with BSI

[5] These and other important terms are briefly defined in Annex I.
[6] The mandatory installation requirements as provided in § 21c EnWG cover new buildings, renovations and bulk consumers (electricity consumption of > 6,000 kWh/a).

Protection Profiles for SMGW and the security module were published in combination with the Technical Guideline in March 2013. The EU Commission received the respective draft Regulation in accordance with § 21i (2) No. 8 and 9 EnWG for notification purposes. BSI's focus is on privacy, data security and the guarantee of interoperability, while the Technical Guidelines substantiate the respective requirements.

It is not possible to establish any specific requirements for the meters themselves, due to European laws. They only need to satisfy the requirements of the Measurement Instruments Directive (MID)[7] and to be safely integrated into a smart metering system that is compliant with the BSI Protection Profile.

Intelligent meters as defined by § 21c (5) EnWG

§ 21c (5) EnWG states that, in addition to the mandatory criteria for installations under § 21c (1) EnWG, intelligent meters can be installed "which reflect actual energy consumption and actual average usage time, and which can be safely integrated into a metering system which fulfills the requirements of § 21d and § 21e."[8] This implies that those intelligent meters are not initially integrated into the external communication network. However, the meters must have the ability to be upgraded through integration with a communication network that complies with the BSI Protection Profile.

Intelligent meters can offer a cost-efficient option for potential energy savings and an increase in energy efficiency, for example for end consumers who consume less than 6,000 kWh/a of electricity and therefore are not obliged by law to install a smart metering system. The integration of an intelligent meter with an external (in-house) display makes consumers aware of their electricity consumption and therefore gives an incentive to save electricity. At the moment § 21c (5) EnWG does not include the requirement for an external display. However, § 21i EnWG opens up the possibility of establishing technical equipment requirements as well as roll-out requirements in such a direction.

1.3 Approach

This report follows the recommendations of the EU Commission of 9 March 2012 for preparing for the introduction of smart metering systems (2012/148/EU). The following main steps have been conducted:

- Examination and description of assets and technologies (meters, communication systems, IT-systems), elements and objectives
- Mapping assets into functionalities
- Determination of the scenarios to be examined
- Mapping functionalities into benefits (impact analysis)
- Monetization of the benefits with respect to market players
- Identification and quantification of costs
- Comparison of costs and benefits

Scenarios under examination

This report examines three basic scenarios and two additional variations for a possible roll-out of smart metering systems and intelligent meters in Germany (s. Fig. 3). As a first step, the two scenarios are described which are required by the EU:

- The "EU Scenario," reflecting the EU requirements to provide smart metering systems for at least 80% of all end consumers by 2020.

[7] Directive 2004/22/EC of the European Parliament and the European Council of 31 March 2004 about measurement devices.
[8] Refer to § 21c(5) EnWG.

- The "Continuity Scenario" ("Business-as-usual") reflects the current legal and regulatory situation assuming no changes in the legal and regulatory situation.[9]
- Additionally, the Continuity Scenario is extended by § 21c (5) EnWG as an additional variation ("Continuity Scenario Plus")

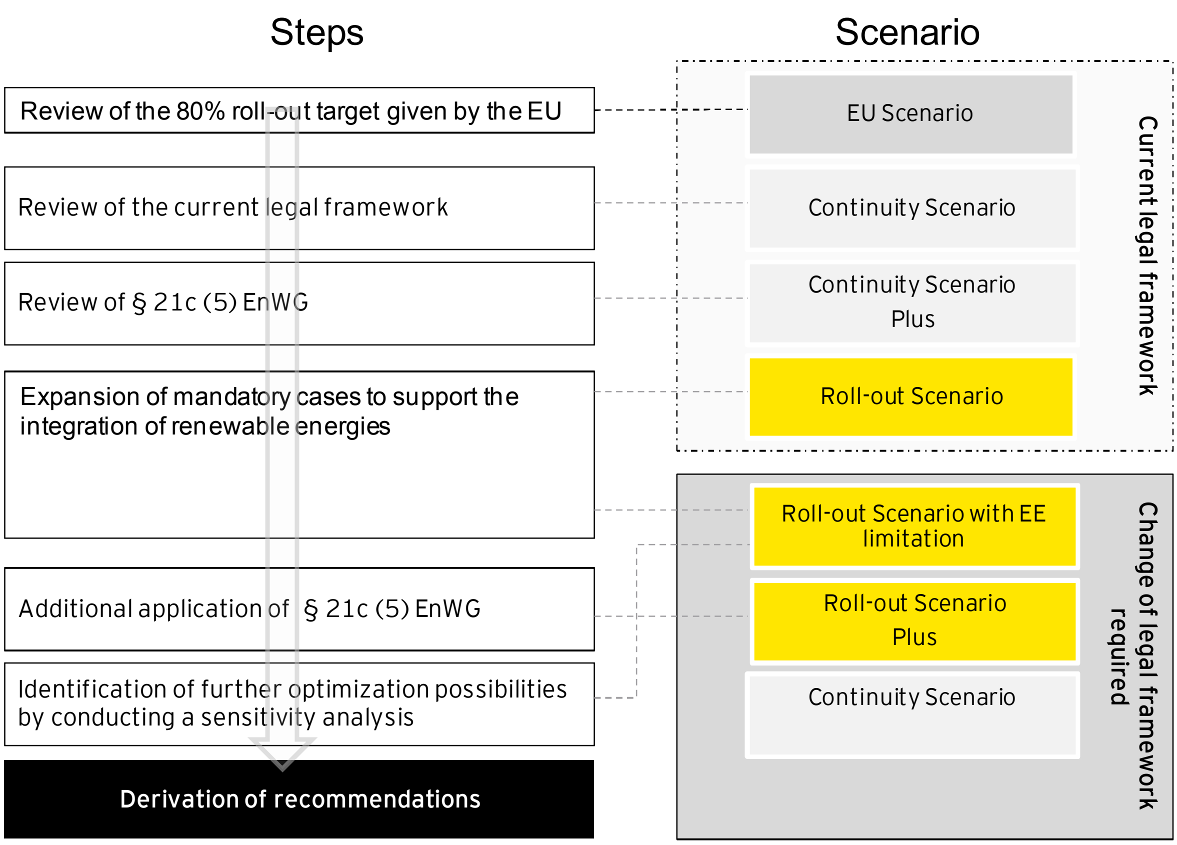
On this basis, a further scenario was examined:

- The "Roll-out Scenario" focuses on the integration of renewable energies, which represents a recommended roll-out strategy for Germany with respect to cost-benefit aspects, as well as the extended variation of the Roll-Out Scenario containing § 21c(5) EnWG ("Roll-out Scenario Plus").

For each scenario, a gross approach is applied whereby costs and benefits are determined separately and compared to a so-called baseline scenario. This baseline scenario does not contain intelligent meters or smart metering systems. The current legislation is virtually suspended.

The cost-benefit analyses are complemented by sensitivity analyses to (i) demonstrate the robustness of the results and (ii) to identify measures which can help to improve the cost-benefit-ratio of a roll-out (optimization possibilities). These sensitivity analyses were also applied to the EU Scenario as well as the Continuity Scenario in order to support and validate the above mentioned recommendations of the roll-out scenario.

Figure 3: Procedure and scenarios under examination



Source: Ernst & Young

[9] For optimizing calculations the Continuity Scenario is extended by legal changes later in this analysis in order to examine the possibility of renewable energy limitations and their impacts.

Scenario quantification

To assess and quantify the scenarios, a range of functionalities of smart metering systems are presented and analyzed from the perspectives of various market players (end customers, generators, network operators, meter operators, etc.). Based on the functional requirements of smart metering systems (direct provision of consumption data, update of the measuring data every 15 minutes, support of progressive tariff systems, etc.) the essential impacts and consequences for each market role were examined. The analyses are based on the results and experiences of pilot projects (especially in Germany), international experience, studies and own studies based on market surveys and an extensive data reconciliation which have been conducted in the context of this report.[10]

On the basis of this impact analysis, costs and benefits have been quantified and monetized. The costs have been determined and evaluated according to the EU recommendations. Additionally, a qualitative assessment of further external effects such as CO_2 savings or social consequences which have to be expected when introducing smart metering systems/intelligent meters was conducted.

Scenario assessment

The roll-out of smart metering systems and intelligent meters pursues several, partly contradicting objectives. The final assessment of the scenarios is aligned to these objectives. The following objectives in particular need to be weighed with and against each other:

- The cost-benefit analysis emphasizes the economic efficiency of a roll-out:
  - The economic cost-benefit assessment should be positive overall. The roll-out and the installation of intelligent meters and smart metering systems should not jeopardize the economic efficiency of energy supply by minimizing the additional costs of the roll-out and the introduction of smart metering systems. In this context, indirect effects also have to be considered, such as reducing the expansion of the conventional generation capacity and of the grid. These effects can influence the economic result of a roll-out of intelligent meters and smart metering systems significantly. Indirect effects have more complex interdependencies and often not fully proven in practice.[11]
  - End consumers must be protected; i.e. the costs of rolling out intelligent meters and smart metering systems should be sustainable and economically reasonable (differentiated by various consumer groups). This implies that the individual end consumer should be able to amortize his/her costs under useful conditions through electricity savings, load-shifting and utilizing value-added services. Otherwise the CBA is negative for a sector/consumer group, even if the overall economic cost-benefit analysis paints a different picture.
  - The roll-out of smart metering systems and intelligent meters must be economically attractive for the industries involved (e.g. metering operators and equipment producers) by guaranteeing an appropriate amount of investment security and the ability to achieve economies of scale.

  These economic questions are assessed using a variety of criteria:

  - The ratio of long-term total costs to total benefits – on the basis of net present value.
  - Total investments along with the question of the overall burden to the energy supply system.
  - The allocation of costs and benefits to the different market players. Here, the parties that benefit the most from the roll-out should bear the costs of it (principle of causation).
  - The ability to charge costs to end customers – differentiated among different groups (users of smart metering systems, users of intelligent meters, non-users) and consumption classes in order to identify a consumer's resilience (reasonableness).

[10] For details compare Annex III.
[11] Indirect effects should only in significant cases be taken into account to avoid that the results of the CBA are too much affected by these indirect effects.

  - Additionally, cash flows must be discounted over time. Nevertheless, the results must also be interpreted because cash flow uncertainties increase with the planning horizon. With respect to a roll-out, short- and medium-term payments (capital expenditures) are regarded as more secure than planned long-term reductions in operating costs.

However, the other objectives which are not quantified are also of high importance. Environmental impact and sustainability as well as security of energy supply are vital for the success of the turnaround in energy policy. Intelligent meters and smart metering systems can contribute to the transition of energy markets. The following objectives must also be considered:

- Environmental impact and sustainability of the energy supply system:
  - Reduce energy consumption and more efficient use of available resources: smart metering systems and intelligent meters should economically contribute to increasing and promoting energy efficiency.
  - Facilitate the integration of renewable energies and decentralized generation into the energy supply system.
- Increased security of energy supply through an improved integration of renewable energies and load management, more efficient use of existing generation, transport and distribution capacity as well as through improved grid monitoring. This implies that smart metering systems are used for grid efficiency purposes, wherever possible, in order to
  - Avoid double investments in smart metering systems and in smart grid technologies.
  - Avoid double investments in communication technologies.
  - Support the integration of renewable energies, if possible.

Finally, it needs to be assessed whether these scenarios can be put into practice. In particular, system manufacturers, meter operators and other market participants involved in a roll-out should be able to actually produce the desired quota of smart metering systems and intelligent meters to be rolled out, to install them and to promptly incorporate the resulting consequences into their processes and IT-systems.

Depending on which objectives are prioritized in the final political decisions, the assessment of these scenarios and their results differ. Thus, recommendations within this report always depend on different key aspects being used for political decisions.

2. Main scenario assumptions

The main scenario assumptions are outlined below.

Planning period

The planning periods of the European CBAs have a broad range of between 15 and 50 years. The average is about 20 years. The EU generally recommends selecting an adequate planning period covering the economic useful life of the capital goods concerned and the mid- to long-term effects. For infrastructure projects, the planning period should be at least 20 years.[12]

In this report, the planning period covers the period until a pre-defined roll-out quota is reached and all affected end consumers are provided with their first intelligent meter or smart metering system and the economic useful life of the equipment has expired.

The starting point for the CBA is 2012 because, at the beginning of our engagement, data for many important parameters was only available up to 2011.

One key purpose of this CBA is the fulfillment and review of the EU requirements and therefore the achievement of an 80% roll-out target after 10 years. The 80% roll-out target must therefore be reached by 2022, after which the economic useful life of the intelligent meters/smart metering systems expires. Based on a depreciation period of 8 to 13 years, an average depreciation period of 10 years starting from the achievement of the 80% roll-out target in 2022 is assumed, so that this report takes into account a period until 2032.

The limitation of the planning period to 2032 should ensure that robust and reliable forecasts for the parameters can be provided up to the end of the planning period, and that the results of the CBA are not exclusively dominated by long-term and therefore uncertain effects.

Mandatory installations in accordance with § 21c (1) EnWG

§ 21c EnWG states that it is mandatory in some cases to install smart metering systems as soon as it is technically possible. Those mandatory installations as defined in § 21c (1) EnWG affect the following:

- End consumers having an electricity consumption greater than 6,000 kWh/a.
- All new, i.e. PV systems put into operation after 4 August 2011[13] under the EEG (Renewable Energy Act), as well as all CHP systems installed after 4 August 2011 under the KWKG (Combined Heat and Power Act)[14], which have a connection power of more than 7 kW.
- All new buildings and apartments which have been comprehensively renovated.

Installation variations

For mandatory installations, there are two variations to consider:

- Generally, smart metering systems as defined by § 21d and § 21e EnWG must be installed in all mandatory cases set out in § 21c (1) by 2022. This especially means that the installed intelligent meter must be integrated directly into a communication network through a SMGW.

[12] See recommendation of the EU Directorates-General Regional Policy, and Urban and Rural Development, Guide to Cost Benefit Analysis of Investment Projects, July 2008, p. 36f.

[13] Amended EnWG came into force.

[14] New systems have been installed after the law entered into force at 4 August 2011. In the context of the CBA, the valuation date was 1 January 2012 due to modeling reasons as the valuation was carried out on an annual basis. There is no substantial effect on the results of the CBA as the new systems which were therefore less considered are a not significant in number and lie within the fuzziness of a model.

- § 21e (5) EnWG allows, under certain circumstances[15], that "meters which do not fulfill the requirements of (2) and (4), … can be installed by 31 December 2014 and used for up to eight years…". These meters – which are not BSI Protection Profile-compliant – will be installed in up to 50% of the examined scenarios in 2014. In all other cases, smart metering systems that meet the requirements of § 21e (2) and (4) EnWG will be installed.

Mandatory installations in the scenarios

Some of the scenarios differ in terms of their definition of mandatory cases (see Table 1). Old mandatory cases must be equipped with smart metering systems by 2018. Thereafter, only newly installed facilities and new customers fulfilling the criteria of mandatory cases will be equipped with a smart metering system.

[15] „… 1. the usage is not connected to disproportionate risks and 2. as long as the written consent of the connection user for the installation or usage of a meter system exists. The connection user must grant the written consent in the knowledge that the meter system is not in accordance with (2) and (4). The connection user can revoke his/her consent. As long as the requirements of sentence 1 are fulfilled, the obligations according to § 21c (1) and (5) do not exist. Further details can be determined by the regulation as provided for in § 21i (1) No. 11.

Table 1: Mandatory installations by scenario

	Type of facility[1]	EU Scenario	Continuity Scenario	Continuity Scenario Plus	Roll-out Scenario	Roll-out Scenario Plus
New buildings and renovations	-	Mandatory installation for all households, regardless of further criteria	Yes[2]	Yes[2]	Yes[2]	Yes[2]
> 6,000 kWh	-					
<= 6,000 kWh	-		No	IM[4] after replacement[5]	No	IM[4] after replacement[5]
EEG > 7 kW and CHP > 7 kW_{el}	New[3]	Around 80% of the customers in each single group are covered by the roll-out – however, only for consumption metering (not feed-in metering)	Yes[2]	Yes[2]	Yes[2]	Yes[2]
	Old		No	IM[4] after replacement[5]		
EEG <= 7 kW and > 0.25 kW as well as CHP <= 7 kW_{el} and > 0,25 kW_{el}	New[3]					
	Old					
EEG <= 0.25 kW and CHP <= 0.25 kW_{el}	-				No	IM[4] after replacement[5]
Controllable energy applications according to § 14a EnWG					Yes[2]	Yes[2]

Source: Ernst & Young

[1] Type of facility refers to EEG and CHP facilities; differentiated according to the year of initial operation.
[2] All existing mandatory installations must be equipped with a smart metering system by 2018. After 2018, new mandatory installations must be equipped with a smart metering system.
[3] Installed after EnWG entered into force at 4 August 2011. In our model and calculations the meters installed after 1 January 2012 are defined as new.
[4] IM = intelligent meters = § 21c (5) EnWG – meter including in-house communication system with an external display.
[5] The replacement of meters which are older than 16 years in 2014 should be allowed to take place within a transitional period - for example by 2022 – to avoid a "bow wave" of replacements and to allow the meter operator to optimize the replacement process. Thereby, the minimum of 1/16 of meters - older than 16 years - must be changed to obtain a minimum exchange rate. Further details on opportunities for recalibration, for example of digital meters, must be defined.

The impact of smart metering systems and intelligent meters

Smart metering systems contain a variety of functions which can directly result in benefits depending on the different market players. The following essential functions and impacts are considered and examined within this cost-benefit analysis (see table 2):

Table 2: Overview about functions and impacts of smart metering systems

Group of functions	Functions	Examples of impacts and consequences	Case of application BSI Protection Profile (examples)
Provision of information	Monitoring	Improvement of grid monitoring	Transmission of data to external customers
	Monitoring	Transfer of price information as incentive for energy savings and peak load shifting	Provision of data for the end consumer
	Data services	Better forecasts of energy consumptions and feed-in	Transmission of data to external customers
	Load management	Improvement of load forecasts	Request of actual feed-in of the power generation units
	Tariffs	Transfer of price information as incentive for energy savings and peak load shifting	Provision of data for the end consumer
Condition monitoring	Grid management*	Improved grid operation, increased supply security	Regular grid operating data delivery
	Administration	Improved meter management	Administration and configuration, alerting and notification of SMGW administrator
Remote reading	Meter reading	Improvement of reading rotation	Regular delivery of tariffed measured values
	Meter reading	Improvement of special payrolls (e.g. change of supplier)	Receipt of measured values, spontaneous meter reading
(Remote) control	Feed-in management (regulation of Generation facilities)*	Regulation of renewable energy and CHP facilities	Communication between external market players and CLS
	Load management*	Shut down of energy generation facilities or energy consumers	Communication between external market players and CLS
	Load management*	Reducing power consumption	Time-, load-, or event-driven tariffs
	Activation and deactivation of customers	Lock out/ -in of customers	
Communication	Value added services	Use of gateways as communication channel for value added services, for example security services	Communication between external market players and CLS

Source: Ernst & Young

* Functions with increased requirements regarding remote communication infrastructure

The various potential impacts have very different actual economic effects. Substantial impacts are based on:

- Grid benefits and
- The potential for electricity savings and load shifting (energy efficiency).

The grid benefits of smart metering systems are defined by the functions of grid management, load management, feed-in management as well as grid aspects of the monitoring function. Functions with time-sensitive applications result in higher requirements for the TC infrastructure.

The discussion regarding the benefits of intelligent meters and smart metering systems is often focussed on to electricity saving and load shifting by end consumers. The overall potential of consumption savings and load shifting has been already examined in various studies which have shown huge differences with respect to the approach and assumptions. The possible consumption savings ranged from 0% to 15% of total consumption.[16]

[16] See for example Intelliekon report p. 24ff.

Table 3: Potential electricity savings and electricity cost savings through smart metering systems

Consumption classes	Potential savings in %	Potential load shifting in %	Cost savings in € p.a. and meter (rounded values)	
			Average	Maximum
< 2,000 kWh/a	-0.5	0.25 - 5	2.50	4.50
2,000 - 3,000 kWh/a	-1.0	0.50 - 10	10	17
3,000 - 4,000 kWh/a	-1.5	0.75 - 15	20	35
4,000 - 6,000 kWh/a	-2.0	1 - 20	39	66
> 6,000 kWh/a	-2.5	1.25 - 25	75	130

Source: Ernst & Young based on the pilot projects, experiences of other countries and studies

TC infrastructure

The main requirement for time-sensitive applications is the integration of smart metering systems into the communication infrastructure which is able to send and receive cyclic control signals within a maximum of 15 minutes.[17]

The cost-benefit analysis assumes a mixture of different communication technologies which should represent a typical mixture for Germany. Such a mixture focusing on GPRS/UMTS/LTE should be technically realizable for every meter operator. It is hardly feasible and realizable to present a solution which concentrates solely on one single communication technology, due to the heterogeneity and large number of meter operators.[18] Additionally, alternative TC infrastructures were examined in sensitivity analyses.

All communication technologies offer different capacities for time-sensitive applications (see Table 4). PLC/BPL is assumed to have less capacity for time-sensitive applications. However, although BPL does provide enough capacity, it is rarely used at the moment. For narrowband PLC, new technological developments are currently being tested, but still have to prove themselves with respect to their stability and capacity when in service.

Table 4: Assumptions about mixture and availability of communication infrastructures

Communication technology	Shares in %	Capacity for time-sensitive applications in %
GPRS/UMTS/LTE	80%	90%
DSL	5%	100%
PLC/BPL	20%	20%
All-glass fiber	5%	100%

Source: Ernst & Young

In total, it is assumed that the communication coverage is 110%. On the one hand, alternative communication technologies can be used in the event that one technology defaults. On the other hand, some of the smart metering systems can be expected to be connected via two communication channels in order to create a separate channel for the network operator's time-sensitive applications.

[17] See technical directive 03109-1 of BSI. In order for the requirement to become mandatory, this recommendation would need to be legally established within the MessZV (Metering Access Regulation).
[18] This also became clear during company interviews which were conducted in the context of this study, resulting in a heterogeneous picture about facts, opinions and plans regarding the communication infrastructure of smart metering systems.

Limiting renewable energy plants

A potential benefit of smart metering systems is the support or implementation of active feed-in management, i.e. the limitation of decentralized electricity generation facilities - especially of renewable energies. The current regulatory framework obliges grid operators to prioritize electricity feed-in from renewable energies and even to extend their grid in the event that congestion could arise when new renewable energy plants (EEG plants[19]) are connected to the grid. The grid operator is only permitted to limit electricity feed-in from EEG plants during congestion in special cases.

If the feed-in of EEG plants is reduced, the compensation is regulated according to § 12 EEG. Electricity providers must be compensated for 95% of lost sales plus additional expenses minus saved expenses. If their lost sales exceed 1% of that year's sales, they must be compensated for 100% of the amount that exceeds 1%.

The CLS port (Controllable Local Systems) of the SMGW can be used to reduce the feed-in capacity by remote control. The optimal roll-out scenario assumes that a maximum of 5% of the yearly amount of energy from renewable energy plants in the low voltage grid (for each plant) can be controlled via the infrastructure of smart metering systems in order to stabilize the grid and to reduce the investment needs for new grids. In order to increase these benefits, the EEG would need to be amended accordingly.

The compensation mechanism remains in place, while a sensitivity analysis examines the impact on the economic efficiency of potentially halving the compensation.

Procurement of system components

All scenarios assume a procurement organization that is able to realize economies of scale in the procurement of components for smart metering systems (meters, gateways, communication modules and facilities). If the amount of orders doubles, the investment costs decrease by between 10 and 15% with increasing purchase order quantities – depending on the respective product. This can be achieved by co-operations if an individual meter operator does not have the required purchasing power. Each company is able to realize the respective economies of scale by combining the demand for products. This can be done via purchasing co-operations or by engaging a service provider that organizes the procurement for a large number of meter operators.

This assumption is essential for the result of the CBA (see also chapter 3.6). The expected costs as well as the (regulated) fees will not be achievable without realizing these economies of scale. Therefore, the roll-out and the economic result would be at risk.

[19] Plants producing electricity based on renewable energies, especially wind, photovoltaic and biomass, that are subsidized by the Renewable Energy Act ("Erneuerbaren Energien Gesetz" = EEG).

3. Results

The following section describes and evaluates the results as well as specific assumptions of each scenario. Table 5 features a summary of all scenarios.

The quantitative assessment of the scenarios is based on the following criteria:

- Net present value: discounted cash flows [20] incurred from the roll-out of intelligent meters and the smart metering systems for the period from 2012 to 2032; specifically the investment (CAPEX) and operating costs (OPEX) of intelligent meters and smart metering systems:
  - Capital expenditure related to the roll-out of intelligent meters and the smart metering systems expected to be incurred during the period from 2012 to 2032 is discounted. This includes meters, SMGW, communication facilities, in-house displays and IT-systems.
  - OPEX is discounted for the period from 2012 to 2032 assuming that the costs incurred are payable in the same year. OPEX includes electricity consumption of the meters, communication costs, costs for meter reading and billing, calibration costs, maintenance and repairs, replacement of damaged meters, sunk costs for previously installed conventional meters and IT maintenance. OPEX is calculated in two ways: one including and one excluding cost savings that would be achieved by the use of smart metering systems as opposed to the use of conventional meters (e.g., meter reading).
- Costs of the smart metering system/intelligent meter: this amount represents the yearly costs for a consumer using an intelligent meter or smart metering system starting in the year of installation. CAPEX is distributed over 13 years starting from the initial calibration and includes a one-off recalibration term of five years. OPEX includes all items mentioned above, such as electricity consumption of the meters and billing. Cost savings on the use of conventional meters are not included. Consequently, all costs incurred by building up a new metering infrastructure are accounted for in this item, including the cost for the continuation of conventional metering operations.
- General system charge: the general system charge includes all costs incurred for building up a new metering system infrastructure as well as for operating the new infrastructure from 2014 onwards. This fee will be invoiced as a separate component of the general fee for meter operation, meter reading and billing (domestic and commercial consumers with standard load profile).[21] To this end, a system charge of €22 per year to be paid in addition to the current fee for meter operations, meter reading and billing is calculated during the period from 2014 to 2022. The system charge includes cost savings from the use of smart metering systems as opposed to the use of conventional meters.

The roll-out can be financed either by charging only the users of smart metering systems and intelligent meters or by charging all end consumers. Table 5 shows both extremes: either users of smart metering systems and intelligent meters (costs per smart metering system/intelligent meter) have to bear all costs or the costs are spread over all end consumers in the form of a general system charge. The derivation of a financing model for the recommended Roll-out Scenario Plus in section 4.4 includes financing alternatives with partial cost allocation to both smart metering users and all end consumers. The general system charge borne by all end consumers equipped with a smart metering system or an intelligent meter is included in the fees for the smart metering system/intelligent meter.

[20] Cash flows of commercial stakeholders are discounted at 5.0% p.a., cash flows of end consumers and of the company are discounted at 3.1% p.a. – according to the EU General Directorate Regional Policy, *Guide to Cost Benefit Analysis of Investment Projects*, July 2008.

[21] The roll-out of smart metering system is assumed to begin 2014 in all scenarios.

Table 5: Summary of scenarios

	NPV[1] current law [€b]	NPV with renewables limitation [€b]	NPV with renewables limitation and halving of EEG compensation payments [€b]	CAPEX / OPEX until 2022 (incl. cost savings) [€b][2]	Cost per intelligent meter / smart metering system until 2022 [€ p.a.][3]	General system charge [€ p.a.][4] until 2022
EU Scenario	-0.1	-	-	8.5 / 12.3 (5.9)	89	29
Continuity Scenario	-0.6	0.9	1.1	3.7 / 5.2 (3.1)	109	14
Continuity Scenario Plus	-1.0	0.5	0.7	6.8 / 6.3 (3.3)	57[5]	18
Roll-out Scenario	-1.1	1.6	2.0	3.9 / 5.5 (3.3)	107	15
Roll-out Scenario Plus	-	1.5	1.9	7.0 / 6.7 (3.3)	58[5]	21

Source: Ernst & Young

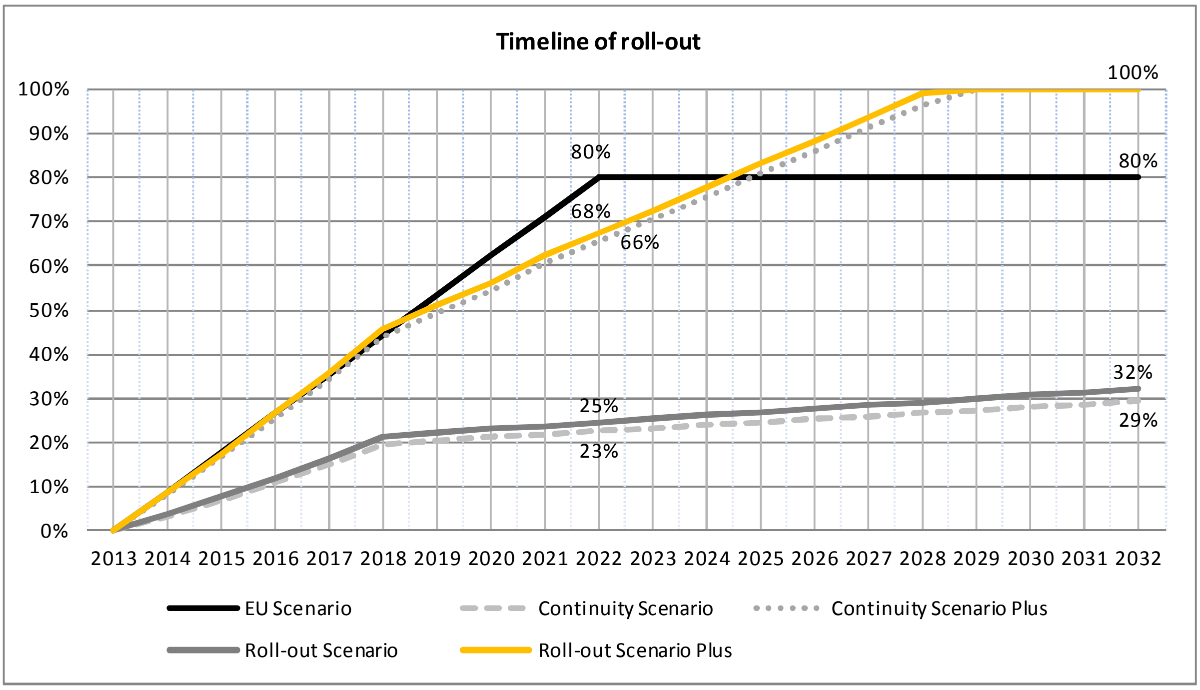
[1] NPV = net present value.
[2] The scenarios account for an initial installation of households in cases of mandatory installation until 2022. Investments after 2022 relate to either intelligent meters, new investments with smart metering systems or reinvestments. Values in parentheses include OPEX savings due to the use of smart metering systems/intelligent meters as opposed to conventional meters until 2022, which are accounted for in the derivation of the additional general expense loading
[3] Costs per smart metering system/intelligent meter effective from installation for each customer. Costs are distributed over 13 years (8+5). All costs incurred from the buildup of a new metering infrastructure are accounted for in this item, including the cost for the continuation of conventional metering operations
[4] This fee is payable by each end consumer from 2014 onwards as an additional charge to the current fee of €22 p.a. The fees include cost savings due to the use of smart metering systems/intelligent meters as opposed to conventional meters.
[5] Mixed calculation of intelligent meters and smart metering systems.

Roll-out quotas

The different scenarios result in considerably different roll-out quotas during the period under assessment. While the Continuity Scenario results in a roll-out quota of only 23% by 2022 the Roll-out Scenario yields a 25% share by 2022. The application of § 21c (5) EnWG lifts the roll-out quota to 68%; however, 43% of these are intelligent meters. The roll-out quota for smart metering systems is identical to that of the Roll-out Scenario.

The strong initial increase of roll-out quotas in the Continuity and Roll-out Scenarios as well as in their respective variations applying § 21c (5) EnWG until 2018 is a result of the completion of past mandatory installations.

Figure 4: Roll-out 2013 - 2032



Source: Ernst & Young

3.1 EU Scenario

The EU Scenario assumes that at least 80% of all metering points must be equipped with a smart metering system within a period of 10 years.

Further assumptions

The EU Scenario assumes an area-wide roll-out of smart metering systems. Supplemental regulatory and legal provisions are required to achieve the target roll-out quota of 80% by 2022. The scenario assumes an installation obligation for every end consumer as the target roll-out quota of 80% by 2022 will not be realized without an installation obligation. This installation obligation generally applies to all end consumers – regardless of power consumption or other criteria – and requires mandatory installation of smart metering systems as defined by § 21d and §21e EnWG.

The installation of smart metering systems is carried out proportionally over the roll-out term. Approximately 9% of all existing meters are replaced each year. The EU Scenario assumes – similarly to the Continuity and Roll-out Scenarios – that, from January 2015 onwards, only smart metering systems including a SMGW and necessary communication systems will be installed. In 2014, 50% of the metering systems being installed in accordance with § 21e will still not conform with the BSI Protection Profile.

After 2022, only smart metering systems will be replaced after 13 years (8 years calibration period plus 5 years recalibration) and additional smart metering systems will be installed at 80% of the new metering points (e.g., in new buildings). Therefore, the roll-out quota will constantly remain at 80% during the time period from 2022 to 2032.

As the EU Scenario envisages the measurement of consumption and possibly feed-in information only, the regulation of renewable energy plants is not included.

Results and assessment

The EU Scenario provides a negative net present value of €-0.1b for the period from 2012 to 2032 (see Table 5). Installing 38.5 million smart metering systems by 2022 requires a total CAPEX of €8.5b in the period from 2014 to 2022.

To cover the total costs (CAPEX + OPEX) of €20.8b (€8.5b CAPEX and €12.3b OPEX) during the period from 2014 to 2022 each end consumer equipped with a smart metering system would have to pay €89 annually. As the average yearly cost savings for residential consumers with low annual consumption will be significantly lower, this cost share of €89 for the mandatory installation seems unreasonably high (see table 3). The roll-out volume would require the installation of approximately 4.3 million smart metering systems per year, which equals 20,000 installations a day. This scenario creates economies of scale but bears significant risks at the same time:

1. It is not certain that the manufacturers of system components have sufficient capacities.
2. Significant personnel shortages at installation companies and meter operators due to the fact that the installation of smart metering systems is more time consuming than the installation of a meter – although smart metering systems are standardized to the fullest extent possible. Furthermore the installation requires specialized and trained personnel.
3. The setup of IT systems and adaption of business processes requires preliminary lead time before the data of smart metering systems can be processed reliably in large amounts.

Financing via a system charge

The introduction of a system charge should be considered as an alternative way of financing. This charge is paid in addition to the general fees for meter reading, meter operation, and billing (currently €22 p.a.). Beginning with the roll-out of smart metering systems in 2014, the system charge must be paid by all consumers, even if they do not use smart metering systems.

The system charge is comparable to tariffs of basic suppliers (Grundversorger). The situation of basic meter operators is comparable that of basic suppliers who incur higher costs in the case of basic supply than a competitive electricity supplier. The responsible meter operator cannot evade the obligation to install the smart metering systems and must set up IT systems, business processes, etc. to be able to:

- equip 100% of the customers in his area with smart metering systems and carry out the related metering point operations,
- sustain the operation of legacy systems for conventional meters as long as not all customers have switched to smart metering systems.

Therefore, the meter operators incur additional costs that it will not recover directly after the beginning of the roll-out. Only the (large-scale) discontinuation of conventional meter operation will result in efficiency gains for the meter operators.

In addition, smart metering systems generate benefits for all end consumers by making a significant contribution to the optimization of the energy supply system. This includes lowering CO_2 emissions, a reduced need for expansion of generation capacity and grids as well as increasing the security of supply. These effects provide a benefit for the whole system and all parties involved, e.g., even end customers that do not use smart metering systems.[22]

Due to the two reasons stated above, it is worthwhile to consider a system charge as an alternative way of financing the roll-out.

Taking into account the cost reduction for meter operators occasioned by the roll-out of smart meters (e.g., metering, management and maintenance of meters/metering systems), the charge decreases to €29 p.a. This charge would have to be paid by all customers in addition to the current fees for meter reading, operation and billing (approximately €22).

Customers with low energy consumption will not be able to offset the total charge (€29 + €22 = €51 p.a.) by using smart metering systems, regardless of any energy saving efforts or load shifting. Additionally, as the majority of customers will only be equipped with smart metering systems several years from now, a

[22] For a detailed explanation, refer to chapter 4.4.

large number of customers would pay the higher charge for a couple of years without being able to realize appropriate energy savings.

Moreover, the high capital expenditures of € 8.5b by 2022 present a significant financing risk.

With regard to Germany, EU Scenario is not economically viable, not compliant with the turnaround in energy policy and not realizable

For Germany the EU Scenario – i.e., a mandatory roll-out where at least 80% of metering points are equipped with smart metering systems by 2022 – is:

- not beneficial for the economy due to a negative net present value,
- results in disproportionally high costs for the majority of customers,
- presents the meter operators with a considerable challenge due to the high roll-out quota envisioned by 2022 with new and hardly tested metering systems,
- presents a significant financing risk because of the high level of investment required,
- represents a non-sustainable approach for smart energy supply systems, as it focuses on measuring consumption only and excludes primary benefits, like the integration of renewable energy plants. As a result, small consumer groups are charged on a level that exceeds any individual benefits they may have from using smart metering systems.

3.2 Continuity Scenario

In the second step of the scenario calculations, we analyze the Continuity Scenario. The Continuity Scenario assesses the legislative approach with the current mandatory installation in accordance with § 21c (1) EnWG.

Results

The scenario results in a net present value of €-0.6b for the period from 2012 to 2032. A total of 10.9 million smart metering systems are rolled out by 2022, resulting in a roll-out quota of 23%.

The Continuity Scenario requires investments of €3.7b by 2022, which is only 40% of the investments envisaged in the EU Scenario. Ongoing operating costs result in additional costs of €5.2b compared to conventional meters. Taking into account efficiency gains, the additional costs are reduced to €3.1b. The total costs could be financed by an annual fee of €109 to be paid by every user of smart metering systems. Alternatively, an additional system charge of €14 could be levied if one reckons in the costs savings achieved in comparison to conventional meters.

Compared to the EU Scenario, implementing the Continuity Scenario until 2022 is more beneficial (€+2.5b net present value).

Assessment

By 2022, the Continuity Scenario would be notably more beneficial compared to the EU Scenario. Additionally, the financing risks are significantly lower and it is a more suitable approach that aims to implement a smart energy supply system based on renewable energies (energy policy change).

For customers with an annual consumption of more than 6,000 kWh and operators of EEG plants with a connecting power of more than 7kW, the annual charge of €109 is economically viable. The former group can realize savings of between €75 and €130 p.a. The latter group benefits from guaranteed feed-in tariffs and – due to the fluctuating feed-in of electricity – also makes a disproportionally large contribution to the adaptation needs of the energy supply system and the resulting costs.

For new and renovated buildings, the economic burden comes to bear differently. As smaller houses and apartments are also covered by the mandatory installation, customers with low energy consumption levels are also affected by higher costs. For these customer groups, the total charge of €109 p.a. cannot be offset, regardless of energy saving measures and load shifting.

As in the EU Scenario, a system charge imposed on all consumers under consideration. This system charge would result in costs of €14 p.a. in addition to the current fees for meter reading, meter operation and billing if cost savings compared to conventional meters are included. The total charge resulting from the current fees for meter reading, meter operation and billing and the additional system charge therefore amounts to €36 p.a. per metering point. From the small consumer's standpoint, the system charge of €14 ought to be rejected, as the general public would then be financing the installation of smart metering systems for a small group of people.

Continuity Scenario is realizable but the potentials are not fully exploited

For Germany, the Continuity Scenario, where 23% of metering points will be equipped with smart metering systems by 2022 under the current regulatory framework:

- is economically unfavorable in the current situation due to the negative net present value,
- is beneficial compared to the EU Scenario envisaged by 2022,
- is unfavorable compared to the EU Scenario in the long term under the assumptions made,
- results in costs that are economically viable for mandatory installations but renders the installation of smart metering systems inefficient for some cases involving new and renovated buildings,
- can be implemented relatively easily due to moderate roll-out quotas.

To identify possibilities to improve the macroeconomic efficiency, the following chapter examines a variation of the Continuity Scenario with the application of § 21c (5) EnWG.

3.3 Continuity Scenario Plus

Paragraph 21c (5) EnWG combined with Paragraph 21i no. 8 EnWG enabled regulatory authorities to roll out forward-looking intelligent meters in addition to mandatory installations of smart metering systems. These intelligent meters must offer the possibility of integration into a BSI Protection Profile-compliant communication system. The application of paragraph 21c (5) EnWG will be discussed in the Continuity Scenario Plus.

Further Assumptions

The installation of intelligent meters - instead of or in addition to the installation of smart metering systems - is a further option for all metering points if mandatory installations according to paragraph 21c (1) EnWG are not required. The installation of intelligent meters would be done when a mandatory meter exchange at the replacement interval takes place. The exchange is assumed to be performed at regular intervals and no later than one calibration period without re-calibration (16 years for Ferraris meters). However, at present, a large portion of the installed conventional meters is already older than 16 years. To prevent a huge demand for exchange of meters at the beginning of the roll-out in 2014, an extension of the exchange period to 2022 is recommended. This would enable the meter operator to optimize the costs of the roll-out. On the other hand however, to achieve the planned scale effects and energy savings, the conventional meters should not all be replaced at the end of the roll-out period. Therefore, it is also recommended that at least 1/16 of all existing meters installed before 1999 should be equipped with intelligent meters each year.

In addition to the legal minimum requirements, the underlying intelligent meters would be equipped with an in-house communication system with an external display in the apartment of the end-user.[23] This feature allows the end-user to analyze energy consumption, identify devices with high electricity consumption and thus optimize consumer behavior and realize energy efficiency potential.

The potential to save energy by means of an intelligent meter is not at par with smart metering systems due to the lack of real-time information about the load and time-of-use tariffs.

[23] To use such intelligent meters, special requirements have to be fulfilled. Please refer to chapter 4.2.

The subsequent upgrade of intelligent meters to smart metering systems, i.e., the integration into a communication system, has not been discussed in this study.

Findings

At €-1.0b for the period from 2012 to 2032, the scenario's net present value is €0.4b lower than that of the Continuity Scenario. Overall, almost 32 million smart metering systems and intelligent meters will be rolled out by 2022. Of these, 10.9 million will be smart metering systems and 20.7 million intelligent meters. This equals a roll-out quota of 66%.

The Continuity Scenario with intelligent meters requires investments of €6.8b by 2022. This is €3.1b more than the Continuity Scenario. Ongoing operating costs amount to €6.3b. When cost savings are included in comparison to the baseline scenario, costs are reduced to €3.3b. Total costs can be covered by an annual fee of €57 paid by every end user of a smart metering system or intelligent meter. A system charge would have to cover €20 p.a. if cost savings in comparison to the conventional meter operation are taken into consideration. The system charge must be paid by every end-consumer in addition to the charge for meter operation, metering and billing starting in 2014, the beginning of the roll-out.

Evaluation of installing intelligent meters according to paragraph 21c (5) EnWG

The installation of intelligent meters according to paragraph 21c (5) EnWG is an inexpensive alternative, which can be considered as an entry-level model for the smart metering systems of the future. The underlying alternative properly informs end consumers on an external display within their apartments about the actual electricity consumption and costs frequently enough to enable them to regulate their own electricity consumption. Such a metering alternative allows providers to access customer groups for an installation, for which the relatively expensive integration into a communication system is initially not worthwhile.

An external display unit in the apartment of the end consumer is a comfortable prerequisite for realizing energy savings and load shifting. This sensitizes the end-users to their electricity consumption and electricity bill. As customers are provided with all the information about their consumer behavior through an in-house display, electricity savings and load shifting are possible. However, intelligent meters cannot provide load-specific incentives for tariffs or real time information about the grid load.

Intelligent meters can be transformed into smart metering systems in conformity with the BSI Protection Profile by means of a secure connection with a Smart Meter Gateway. Upgrading an intelligent meter via a SMGW provides a platform on which other meter operators and service providers can participate with their products and services. This is guaranteed by the standards of the BSI Protection Profile and the Technical Guidelines.

Grid efficiency and the majority of process improvements in meter reading and billing cannot be realized when using this metering alternative. Consequently, they were not included in the benefit assessment of the cost-benefit-analysis.

Operation of intelligent meters is subject to particular requirements: Intelligent meters are an upgradeable measuring system in accordance with § 21c (5) EnWG. Combined with a Smart Meter Gateway, they can be securely integrated into any communication system. In this report, intelligent meters are able to visualize the actual energy consumption and the actual use-of-time on an external display within the apartment of the end consumer. As long as the meter has not been upgraded with a SMGW to a smart metering system, the MID does not allow the specification of any particular data protection and privacy requirements for the transmission of data by the measuring system. Therefore, no obligation to install an external display should be implemented. Instead, introducing an obligation to install a display should be driven by the market. However, in this case general data security and privacy requirements such as the encrypted transfer of data must be fulfilled. Additionally, in accordance with § 21e (5) EnWG, installation of a display should require "written approval of the end consumer to install and to utilize a metering system, being aware of the fact that the system does not fulfill the requirements of section 2 and 4."[24]

[24] § 21e (5) EnWG.

Benefits for the financing of the roll-out

The Continuity Scenario Plus assumes that the possibilities arising under § 21i (1) no.8 EnWG are used and that § 21c (5) EnWG enters into force. This will result in an installation of intelligent meters or smart metering systems at 66% of all metering points by 2022. For this scenario it should be noted that:

- in overall economic terms, this alternative is currently not favorable given the circumstances as well as the current legal and regulatory framework,
- by means of price differentiation for intelligent meters and smart metering systems, a pricing based on costs actually incurred could be introduced, which would reflect the different costs and benefits of the two systems,
- the scenario would lead to costs that are economically bearable for the majority of the end-users concerned but on the other hand still includes cases in which the installation of smart metering systems is not worthwhile, as is the case for construction activities or renovations,
- it can be practically implemented with the given roll-out quotas, as the installation of intelligent meters is significantly easier than the roll-out of smart metering systems.

As the scenarios analyzed up to this point are not favorable in overall economic terms, additional alternative scenarios in line with the EU recommendation were examined.

3.4 Roll-out Scenario

The current legal framework gives rise to an obligation to install smart metering systems only for new EEG and CHP plants, i.e., facilities that were commissioned after the commencement of the EnWG on 4 August 2011 and that have a connection power of at least 7 kW. Since both older and/or smaller facilities in principle have the same effect on the power supply system as newer facilities, the Roll-out Scenario provides for mandatory installations for old EEG/CHP plants as well as those with a power input lower than 7 kW down to a negligibility limit of 250 Watt.

The Roll-out Scenario was first assessed within the current legal framework. In a subsequent step, the effects of an amendment of the EEG were considered and quantified.

Further assumptions

The integration of renewable energy poses a considerable challenge for the power supply system in Germany. The increasing amount of fluctuating power from wind and solar energy sources that is fed into the system significantly increases the need for an extension of both the electric transmission and distribution networks. However, if demand and supply of electricity were better balanced, this extension need could be reduced. Smart metering systems can help reduce the need for an extension, because they:

- allow for load management schemes that contribute to a better reconciliation of demand and supply of electric power,
- allow for a remotely controlled feed-in of power from renewable energy facilities via the CLS interface.

In order to allow for a large-scale limitation of renewable energy facilities, the current legal framework must change. It is assumed that the current regulations of the EEG concerning compensation payments for reduced feed-in capacity will be maintained.

Additional mandatory installations

In the Roll-out Scenario, the mandatory installations in accordance with § 21c EnWG are supplemented with further applications. These comprise EEG and CHP facilities that were commissioned before 4 August 2011 and facilities with a connection power of more than 0.25 kW.[25]

On the one hand, the expansion of mandatory installations can be ascribed to potential grid loads of the aforementioned generating and consuming facilities. On the other hand, it can be ascribed to the possibility to control and use these facilities, taking into consideration the expansion and use of the grids. The expansion of mandatory installations focuses on the majority of EEG/CHP facilities connected to the low-tension grid. Therefore, the roll-out mainly relates to metering points that can easily be equipped with smart metering systems with minimal additional costs and maximum benefit.

Generally, old facilities have the same effects on energy and grid efficiency as new facilities and should therefore be equipped with smart metering systems as well. However, additional installation costs may occur, e.g., when inverters are replaced. Given the favorable income situation of the operators of the generation facilities, this appears reasonable.

The expansion of mandatory installations on facilities with capacities of less than 7 kW is based on the number of these facilities, which, when aggregated, can have a significant impact on energy and grid efficiency.

For very small facilities - defined as facilities with a maximum connection power below 250 Watt - exceptions from this obligation could be made, due to the disproportionate costs that integration into a smart metering system would bring with it.

Findings – additional mandatory installations in the current legal framework

The result of the Roll-out Scenario under the current legal framework is negative with a net present value of €-1.1b. Overall, investments of €3.9bn would be necessary by 2022 to realize a roll-out quota of 25% and installation of 12 million smart metering systems.

Under the current legal framework, the potential of smart metering systems to the steer and regulate EEG facilities cannot be realized.

The remaining applications of smart metering systems and the resulting benefits thereof are not enough to achieve an overall economic advantage for the roll-out of smart metering systems.

Neither the EU Scenario with a general and non-specific mandatory installation, nor the Continuity Scenario or the Roll-out Scenario with their focus on applications with the highest benefits, lead to a positive net present value.

Therefore we examined how a change of the EEG would affect the scenario outcomes.

Consideration of a 5% limitation of EEG plants to avoid a grid expansion

Limiting each EEG plant by up to 5% of their annual energy output during times of grid congestions or voltage fluctuations would lead to a significant increase in the net present value by €2.7b to €1.6b. Only through active feed-in management, the scenario considered here would result in a significantly positive net present value. This highlights the importance of a grid-efficient roll-out and emphasizes that the high potential of smart metering systems depends not only on consumption measurement but also on the intelligent use as an important element of smart grid. This is already partially integrated in the current legal framework of the EnWG 2011.

The significant benefit is a result of the reduction of the grid expansion – particularly within the distribution grid. Reference projects in (rural) distribution grids show that up to 100% more capacity from renewable energy facilities can be connected if it is possible to limit up to 5% of the annual energy capacity by the feed-in of EEG plants as needed.[26] In this context, the scenario analysis was based on the less optimistic assumption and a reduction of no more than 50% of the development needs of the distribution grid.

Using the grid efficiency of smart metering systems offers further significant advantages. The almost complete coverage of grid relevant metering points quickly leads to a minimum penetration of 15% with

[25] The legislator still has to define the final negligibility limit.
[26] Source: Data reconciliation and market survey underlying this report; see Appendix III.

smart metering systems, especially in grid critical areas, which is necessary for a meaningful measurement of grid condition data.

The costs per smart metering system are about €107 p.a. from the time of the initial installation, so that considerable effort is needed on the consumers' side to make such an investment beneficial. A system charge per consumer of €15 plus the average charge for measurement, meter operation and billing of €22 p.a. (including cost savings) result in costs that are too high for the majority of end consumers.

Only changes to the EEG ensure economic advantages

Focusing on those metering points at which the largest benefit with smart metering systems can be gained leads to a positive economic impact on the net present value of €1.6b in the period from 2012 to 2032. However, this requires a change in the legal framework of the EEG enabling the above mentioned active feed-in management (5% limitation).

With the extension of mandatory installations to the generation- and consumer facility, the integration of renewable energies in the energy supply system will be facilitated and the financial impact can be limited, thereby increasing the value of the energy policy reform.

A roll-out quota of 25% leads to relatively high costs per smart metering system for many consumers compared to the full roll-out. In this alternative, a system fee is not recommended as the majority of end consumers cannot benefit directly from the installation of smart metering systems and the installation would be co-financed by a small group of consumers.

3.5 Roll-out Scenario Plus

The application of § 21c (5) EnWG is one possibility to reduce the costs of smart metering systems for users in the course of the roll-out. The increase in the total roll-out quota together with intelligent meters would result in further economies of scale and would allow for mixed calculations.

Findings and assessment

In the Roll-out Scenario, the application of § 21c (5) EnWG would result in a slight reduction in the net present value by €0.1b to €1.5b. However, this alternative provides several advantages.

For the end consumers, the Roll-out Scenario Plus allows for tailored solutions with regard to the installation of smart meters:

- Smart metering systems would be mandatory for metering points that can contribute to grid efficiency.
- Metering points that only contribute marginally to energy efficiency when viewed in isolation would gradually be equipped with cheaper intelligent meters. These could be upgraded easily to smart metering systems at a later point in time. Customers who do not attach importance to external communication links could be offered the installation of an intelligent meter as a cheaper alternative.

With approximately 4 million meters annually, the number of intelligent meters or smart metering systems to be installed by 2018 is as high as in the EU scenario. However, compared to the EU scenario, intelligent meters would account for more than half of the total smart meters to be installed. Therefore, installation and integration processes are easier than in the EU scenario, where only smart metering systems are rolled out. Intelligent meters do not require external communication links. The respective processes are also frequently used and tested.

The Roll-out Scenario Plus would result in a modernization of the entire metering infrastructure in Germany. By 2029, a complete roll-out with smart metering systems and intelligent meters could be achieved. This would contribute significantly to the energy policy reform (especially with regard to the integration of renewable energies and the improvement of energy efficiency).

The financing of the roll-out would be another advantage, with costs per smart meter reduced to €58 p.a. The parallel roll-out of smart metering systems and intelligent meters would result in a mixed price that would be profitable for a much larger number of customers.

Considering the cost reduction in comparison to the use of conventional meters, the system charge would amount to €21 p.a. If § 21c (5) EnWG were to apply, the system charge would have to be evaluated differently from the mandatory installation of smart metering systems. In the end, all end consumers would benefit from the application of § 21c (5) EnWG due to the installation of intelligent meters in the course of regular replacement intervals. Also, macroeconomic benefits would be higher than in the basic Roll-out Scenario, as the need to expand generation capacity and grids is further reduced.

By combining the three benefit parameters of smart metering systems, intelligent meters and macroeconomic benefits, a financing model can be derived that results in a fair allocation of roll-out cost (refer to chapter 4.4).

Roll-out Scenario Plus is recommended

From an economic point of view, Roll-out Scenario Plus is recommended. It also provides a number of additional advantages:

- A positive net present value of €1.5b in the period from 2012 to 2032.
- By using a mixed calculation which includes intelligent meters, smart metering systems and a system charge, a sustainable financing model that justly allocates roll-out cost can be achieved. In this way, fees can be tailored to the customers' needs and willingness to pay (for details, refer to chapter 4.4).
- Tailor-made solutions could be implemented for each application.
- No group of people gains an unfair advantage as all end consumers benefit directly from the roll-out.
- The accelerated roll-out increases economies of scale and provides market participants (device manufacturers, meter operators, etc.) with higher planning reliability while reducing investment risks.
- Intelligent meters create a platform for the subsequent usage of SMGWs in every building. This platform can then be used by metering operators or other service providers to sell services and products.
- With an average of 4 million smart metering systems and intelligent meters p.a. by 2018, the roll-out is ambitious. However, it is still achievable as more than half of the smart meters are intelligent meters.

Below, we assess the robustness of the recommendation and possible improvements using a sensitivity analysis and discuss selected question related to the roll-out.

3.6 Sensitivity analysis and discussion of selected question

Several further questions regarding the roll-out of smart meters were examined within the report. In addition, sensitivity analyses were performed for each input parameter in order to examine the robustness of the results and recommendations. Table 6 summarizes the main impacts. A separate examination of the impacts was carried out. The roll-out plus scenario was based on the continuation of the EEG compensation payments. In order to achieve a better evaluation of sensitivities, the EU, Continuity, and Roll-out Scenarios were included in some places in the sensitivity analyses.

Table 6: Summary of the sensitivity analyses

Assumption	Additional net present value – Roll-out Scenario Plus [€b]
Doubling of actual energy savings at an average of 3.6% p.a.	+5.7
No energy savings	-5.7
Increase in real energy prices by 1% p.a. instead of constant prices in real terms	+1.2
Tariff spread: 20% reduction in the off-peak energy rate vs. peak energy rate instead of 10%	+2.0
Optimization of grid efficiency	+2.9
Shortfall of grid efficiency	-2.9
Halving the EEG compensation payment while reducing the feed in of EEG plants	+0.4
Extension of mandatory installations according to Paragraph 14a EnWG including heat pumps, electric vehicles	0,0
Extension of the deadline to complete existing mandatory installations to 2022 instead of 2018	-0.7
Periodic replacement after 24 years (16 years calibration period plus recalibration) instead of after 16 years	-0.6
Shortfall of economies of scale in procurement	-2.2
Focus of the MSB role and the function of the Smart Meter Gateway Administrator up to max. 70 corporations	+0.7
Focus of MSB role and the function of the Smart Meter Gateway Admin-istrator up to max. 10 corporations	+1.2

Source: Ernst & Young

Below, the implications are examined in detail.

Energy savings

The amount of the actual energy savings impacts the results of the scenario calculations considerably (see Table 7).

Apart from the direct effects – particularly the reduction of energy costs for end costumers – indirect effects and interdependencies arise i.e., grid extension costs. Increasing energy savings in areas with an elevated input of renewable energies can give rise to additional grid extension costs under certain circumstances. The (renewable) power generated must be distributed and transmitted instead of using it locally.

Table 7: Sensitivities energy savings

Net present value 2012 to 2032 [€b]	Min[1] (0%)	Average[2] (1.8%)	Max[3] (3.6%)
EU Scenario[4]	-5.9	-0.1	6.1
Continuity Scenario	-3.2	0.9	5.0
Roll-out Scenario	-2.6	1.6	5.9
Roll-out Scenario Plus[5]	-4.2	1.5	7.2

Source: Ernst & Young

[1] 0% energy savings in all consumption classes.
[2] 0.5% at < 2,000 kWh/a; 1% at 2,000 - 3,000 kWh/a; 1.5% at 3,000 - 4,000 kWh/a; 2% at 4,000 - 6,000 kWh/a; 2.5% at > 6,000 kWh/a; average of 1.8%.
[3] 1% at < 2,000 kWh/a; 2% at 2,000 - 3,000 kWh/a; 3% at 3,000 - 4,000 kWh/a; 4% at 4,000 - 6,000 kWh/a; 5% at > 6,000 kWh/a; average of 3.6%.
[4] Without reducing EEG-plants.
[5] The energy savings potential within the Roll-out Scenario Plus decreases to 1.2% in the average case and 2.4% in the maximum case due to lower energy savings with intelligent meters compared to smart metering systems.

From a macroeconomic point of view, the roll-out of smart meters without energy conservation is not favorable in all cases. The risk of macroeconomic damages in the Roll-Out Scenario is low, while in the EU Scenario the risk is high. Based on an optimistic assumption, all scenarios seem to be beneficial. The recommended Roll-out Scenario Plus is the best alternative to achieve macroeconomic benefits due to energy conservation. By equipping end customers with custom-made smart metering systems or intelligent meters by 2029, energy saving opportunities will be exploited efficiently.

The economic feasibility of the introduction of smart metering systems/intelligent meters will depend on the realized energy savings, which is of great importance. A multitude of studies and pilot projects provide a good indication of the actual realizable energy savings. However, the range of the results show that further analysis of this topic under realistic everyday conditions is necessary. It is therefore advisable to perform a nationwide study by no later than the start of the roll-out.

With the assumed average energy savings potential of 1.8% or 1.2% p.a.[27] for this important CBA assumption, it is comparable to other international CBAs. Other studies have not focused on the fact that the different end consumer groups realistically have different power savings potentials. This will have a significant impact on the results of the CBA and the roll-out strategy.

We recommend running a nation-wide information- and awareness campaign in connection with the reform of the energy policy to ensure the expected average power saving of 1.8% (1.2%).

Electricity price

In the scenario calculations, a real constant electricity price was assumed coupled with an inflation rate of 2% p.a. during the period under review in order to prevent price effects from influencing the results. A real increase in end consumer prices for households and commercial consumers of 1% p.a. leads to an increase in the net present value of €1.2b. An increase in the real electricity price heightens in particular the benefits end consumers can obtain by means of energy savings and load shifting.

An additional benefit could be obtained by splitting tariffs further. A 20% decrease in prices in off-peak times compared to peak times – instead the assumed 10% as in the basic scenario – results in an additional net present value of €2.0b.

A further tariff split can be achieved by means of:

- securing an obligation from energy suppliers to offer such tariffs and /or
- systematically reforming the grid charges.

[27] Due to the fact that potential energy savings from utilizing an intelligent meter are less than from a smart metering system within the Roll-out Scenario Plus, the actual potential of energy savings is only 1.2% p.a.

Within the current regulatory framework, grid charges for customers with a standard load profile for every used kWh are identical. A more flexible model for developing grid charges could be useful for a tariff split. A significant tariff split can only be achieved by also including other charge components, since only 20% of the total charges are grid charges.

Grid efficiency

The quantification of grid efficiency is subject to great uncertainty due to missing conclusive analysis and lacking experience. In this report, we have included some extreme alternatives (see. Table 8), but not as a basis for the CBA.

Table 8: Sensitivities grid efficiency

Net present value 2012 to 2032 [€b]	Min[1]	Average[2]	Max[3]
EU Scenario[4]	-0.5	-0.1	0.3
Continuity Scenario	-0.6	0.9	2.3
Roll-out Scenario	-1.1	1.6	4.4
Roll-out Scenario Plus	-1.4	1.5	4.4

Source: Ernst & Young

[1] The introduction of smart metering systems has no influence on the grid operation and the grid expansion.
[2] Max. savings at transmission: grid planning: 0%; load management: 1%; EEG-plants limitation: 1%. Max. savings at distribution: load management: 5%; EEGplants limitation: 20%; grid planning: 2.5%; Reduction of electricity demand: 5% (city), countryside: 5% grid expansion; grid operation: 5%.
[3] Max. savings at transmission: grid planning: 0.5%; load management: 2%; EEG-plants limitation: 2%. Max. savings at distribution: load management: 10%; EEGplants limitation: 40%; grid planning: 5%; Reduction of electricity demand: 10% (city), countryside: 10% grid expansion; grid operation: 10%.
[4] Without reducing feed-in from EEGplants.

The grid efficiency of smart metering systems depends on:

- using grid and consumption information in the context of grid planning.
- using grid condition data for grid management. In the process, information on voltage and reactive and active power will be recorded by means of a smart metering system and communicated to the grid operator.
- using consumption and grid condition data in the context of a grid driven load management.
- controlling generation and consumption facilities by means of smart metering systems.
- limiting EEG generation facilities in the context of the feed-in management by means of a smart metering system.

The roll-out is negative in all scenarios if there is a lack of grid efficiency. The grid efficiency of smart metering systems is an essential precondition for the roll-out to be economically beneficial. As described above, a key requirement is to allow improved feed-in management at EEG plants through the change of EEG.

Due to a lack of conclusive general experience in this area, the assumptions with regard to the grid efficiency of smart metering systems are conservative. As with potential power savings, the theoretically available benefit of grid efficiency first has to be demonstrated under different real practical conditions. The practical development of the grid efficiency of smart metering systems and "Smart Grids" is currently only at an early stage. Therefore, the possible effects should not be overestimated. The final benefit of smart metering systems for grid operations depends to a large extent on the relevant grid conditions and the relevant feed-in and consumption situation in a grid area. Therefore, the real value could significantly differ from the average values demonstrated in this report. A more detailed result could possibly be derived from the distribution system study in the beginning of the 2014.

Halving EEG compensation payments for the limitation of EEG plants

Additionally, halving the EEG compensation payment for the limitation of EEG plants would lead to a further increase of net present value of €0.4b. Also in this context, a change of the current EEG framework would be necessary.

Delayed mandatory installations from the past

If the roll-out is delayed, the effect on grid efficiency will be lower due to the fact that there will be a higher investment need for grids in the upcoming years. Processing the mandatory installations from the past by 2022 instead of 2018 will lead to a decrease in the net present value of €-0.7b to €+0.8b.

Optimization of the organizational structure

A consolidation of the role of meter operators and the role of Smart Meter Gateway Administrators into 70 (large) meter operators would lead, in the case of the Roll-Out Scenario, to an increase in the net present value of about €0.7b. A consolidation into 10 (large) meter operators would lead to a further increase of €0.5b (see Table 9).

A lower number of companies in the roles of the meter operator and Smart Meter Gateway Administrators could lead to economies of scale with regard to development costs (particularly IT).

Furthermore, there are other advantages which are not quantified here. On the one hand, there is a simplification of market processes as the information exchange between meter operators and other market participants is concentrated on significantly fewer companies. On the other hand, there is the development of an intelligent – BSI Protection Profile-compliant – metering system infrastructure in Germany at an early development and testing stage. In this stage, high-cost learning process can be more easily absorbed by a low number of meter operators and will lead to faster learning effects compared to a learning process by each meter operator.

Table 9: Sensitivities organizational structure

Net present value 2012 to 2032 [€b]	Structure today (approx. 900 meter operators)	70 meter operators	10 meter operators
EU Scenario[1]	-0.1	0.6	1.1
Continuity Scenario	0.9	1.6	2.0
Roll-out Scenario	1.6	2.4	2.8
Roll-out Scenario Plus	1.5	2.2	2.7

Source: Ernst & Young

[1] without reducing feed-in from EEG plants.

Achieving economies of scale is essential for the success of the roll-out

Further economies of scale in procurement have not been considered, as an optimization of the procurement process is assumed in all basic scenarios. If these economies of scale cannot be realized, the net present value of the Roll-Out Scenario with a limitation on renewable energy decreases by €2.2b. Therefore, optimized procurement has an essential role for the realization of economic advantages of a roll-out with high roll-out quotas.

If a meter operator only has a few metering points, there are different opportunities for him to achieve economies of scale in procurement. He could set up co-operations with larger meter operators (e.g., larger than 500,000 metering points) or he could hire service providers who can achieve economies of scale through by bundling procurement. In order to secure the achievement of economies of scale, an adaptation of the current charging mechanism is required. The current approach provided in § 17 (7) StromNEV requires separate charges only for meter operation, measurement and billing. In deviation of the current system of acknowledgement or in contrast to the current independent determination of the charges by the regulated participant, we recommend determining an upper limit for the regulatory acceptance of charges for intelligent meters and smart metering systems. Besides the achievement of economies of scale and their consideration in the charges, this would mean that,

- transparency in calculating and displaying a system cost charge for building up a smart metering infrastructure in Germany can be guaranteed, and
- the large spectrum of meter charges can be reduced.

Expansion of mandatory installations to further consumer groups

An expansion of the mandatory installations to consumer groups that have a consumption of less than 6,000 kWh/a leads to a calculated higher net present value in economic terms but means on the other hand a too high financial burden for single consumers (groups) and defeat a market-oriented roll-out.

The highest net present value of €4.3b would be achieved if a consumer with a consumption of more than 3,000 kWh is obliged to install a smart metering system.[28] This would lead to costs of €91 p.a. per smart metering system or a system charge of €26 p.a. for each consumer. Due to the maximum savings potential of €35 p.a. for consumer groups from 3,000 to 4,000 kWh/a (see Table 3), a charge of €91 p.a. is disproportionately high.

The devices of consumers with a consumption of less than 6,000 kWh p.a. cannot be used economically for grid efficiency purposes. Therefore, it is sufficient to equip these consumer groups with intelligent meters and provide them with the opportunity to benefit from potential power savings in an economically reasonable manner.

Furthermore, the mandatory installations would defeat the market-oriented approach which provides certain advantages to these consumer groups. The grid efficiency and the energy efficiency potential are only available to a limited extent to these consumer groups. Therefore, a mandatory roll-out with smart metering systems including an expensive communication link is economically unfeasible.

These consumer groups have a penchant for new, innovative products with value-added services which put a premium on market-oriented benefits. Consumers focus on security or comfort. With a mandatory installation of smart metering systems, the incumbent meter operator would dictate the communicative integration. The space for competitive offers and innovative solutions could be limited as it is not the duty of the regulated player to design services outside the energy sector.

Changes in the mandatory installation for new and renovated buildings

The following three objectives must be considered in the evaluation of the current mandatory installations for new and renovated buildings:

1. The cost burden for consumers with low power consumption.
2. The investment security relating to the mandatory installation for manufacturers of the devices and the meter operators.
3. The value potential of modern building infrastructure for energy services and value added services.

The current mandatory installation for all new and renovated buildings also affects consumers with low electricity consumption who are obliged to install a smart metering system. Due to the fact that end consumers who consume less than 3,000 kWh/a are not able to compensate the additional costs in an amount exceeding €80 p.a. through electricity savings and load shifting, this group is significantly affected by a financial burden.

On the other hand, the number of new and renovated buildings (approximately 1 million new buildings and approximately 4 million renovated buildings between 2012 and 2022) provides a planning and investment security for manufacturers of the devices and the meter operators due the significant amount of smart

[28] At this point, the roll-out scenario with a limitation on renewable energy was considered as the effects of an expansion of mandatory installations of smart metering systems must be identified specifically. The statements would apply accordingly to the Roll-out Scenario Plus.

metering systems. This will attract investments and decrease the costs of the systems. The elimination of the mandatory installations would have a negative impact on the investment security objective.

The logic of the approach to install smart metering systems in a modern building infrastructure is obvious. It is far easier to install the smart metering systems in buildings when it is considered during the planning phase. This applies in particular to new buildings. Retrofitting is more complicated and cost intensive as shown by the first roll-outs in Germany. The same applies to the integration of value added services or special building configurations for energy efficiency: the chance of integration and development of wide markets for such modern systems is only given if installations of smart metering systems are mandatory. The current legal framework takes into account mandatory installations for new buildings and renovations.

Therefore, the mandatory installation of smart metering systems in new and renovated buildings for end consumer with a consumption of less than 6,000 kWh should only be considered in combination with a reduced financial burden for this consumer group. This would avoid a high cost burden for the consumer group concerned. It also takes into account the principle that the success of smart metering systems and intelligent meters depends not only on macroeconomic effects, but also significant user benefits on the side of the consumer. This includes the realistic chance of personally compensating the costs through energy savings and load shifting.

In our further considerations and calculations, the mandatory installation in new and renovated buildings was therefore fully maintained. The cost burden for consumers with low power consumption can be absorbed through a differentiation of charges (see chapter 4.4) and the positive effects of the mandatory installations (e.g., investment security through additional 500,000 smart metering systems p.a.) can be maintained and the reasonableness of an installation of smart metering systems for all end consumers of new and renovated buildings can be ensured.

Heat pumps, electrical vehicles and other controllable energy applications

Additionally, controllable devices according to § 14a EnWG ("Control of interruptible consumer devices in a low voltage range") can be considered for further applications of smart metering systems. This includes, for example, heat pumps, off-peak storage heating and – explicitly mentioned in § 14 EnWG - electrical vehicles. § 21i (1) No. 9 EnWG could make it mandatory to install smart metering systems in these devices by way of a regulation.

The consideration of controllable energy applications in a low voltage range, such as heat pumps, electrical vehicles etc., provides no additional benefit. The net present value in the Roll-out Scenario Plus decreases slightly (€-15m) and remains at €1.5b if the mandatory installation for consumer devices is considered. The reason is particularly the increasing communication costs which cannot be compensated by an additional benefit.

However, this approach would lead to the exclusion of electric vehicles and heat pumps in low energy buildings as material elements of a future modern energy supply system from data exchange and the possibility to be controlled. It is important to include such devices in a future decentralized energy supply system. Therefore, controllable energy applications according to § 14a EnWG should be added to the mandatory installations. In order to avoid the financial burden for smaller consumer (groups) – analogous to new buildings and renovations with less than 6.000 kWh/a – a price differentiation should be introduced (refer to chapter 4.4.).

Telecommunication infrastructure

The communication infrastructure is essential for the assessment of the scenarios. Therefore, some variations of the telecommunication infrastructure have been examined in the context of this report. The Roll-out Scenario Plus was used as basis for the examination. The central results are:

- A predominant connection of smart metering systems to PLC (including 10% BPL) with a share of 80% instead of 20% and 20% GPRS/UMTS instead of 80% (including 10% LTE) change the net present value compared to the Roll-out Scenario by €-0.6b (€0.9b).

- A 100% connection of smart metering systems to DSL connections in the Roll-out Scenario Plus leads to a net present value of €-7.8b.

- Starting at a price of less than €48 per DSL connection, the net present value will be positive compared to an assumed communication infrastructure (80% GPRS/UMTS/LTE: 20% PLC/BPL; 5% DSL; 5% fiber glass).
- The development of a separate CDMA infrastructure would lead to a significant increase in the net present value (up €2.6b) but is subject to considerable uncertainties related to the real cost for the development and operation of such a telecommunication infrastructure as well as potential costs in connection with the frequency allocation procedures. Furthermore, there are no reliable experiences in Germany.

Further sensitivity analyses have not been performed as there will be a large number of telecommunication solutions in practice. The valuation of the different solutions depends on a wide range of factors and the roll-out strategy of each meter operator:

- A full roll-out of smart metering systems will give PLC/BPL cost advantages over GPRS/UMTS/LTE.
- Radio-based telecommunication solutions are cheaper compared to wired solutions but can lead to significant additional costs depending on the local conditions.
- The development/operation of a separate communication network for smart metering systems and Smart Grids could be economically reasonable (CDMA, own DSL connection). The impacts on the competition between meter operators through the development of in-house solutions must be considered. The network must be open to all interested meter operators.

We recommend leaving the development of the telecommunication infrastructure to each meter operator, provided the minimum requirements of a telecommunication infrastructure are fulfilled. As minimum requirement, it has been mentioned in particular that control signals must be sent and received at least every 15 minutes.

If there are any further requirements with regard to the telecommunication infrastructure, for example to increase the reliability of information supply and to send and receive the control signals to improve the grid efficiency of smart metering systems, there will be the opportunity to install a separate communication connection via the Smart Metering Gateway, e.g. for the network operator.

Extension of the deadline for mandatory installations and replacement interval

The extension of the completion deadline for the current mandatory installations from 2018 to 2022 decreases the net present value by €-0.7b. In particular, the impact on the grid efficiency will be less if the period for mandatory installations of smart metering systems is extended. Each delay in the development of smart metering systems will have a negative impact on avoided investments in the grid – and therefore on the net present value of the roll-out – as a majority of investments must be made in the transmission and distribution grid in the next few years.

An extension of the usage of conventional meters to 24 years (16 years calibration period plus 8 years recalibration for Ferraris-meters) decreases the net present value by €-0.6b for the Roll-out Scenario Plus.

In this alternative, almost 90% of electricity meters will be replaced by smart metering systems by 2032, meaning that a nation-wide replacement of conventional gas meters will be done before the nation-wide replacement of electricity meters is completed. In view of this, we recommend replacing conventional power meters after 16 years, as the EnWG regards the electricity sector as the driving force.

Accomplishment as full roll-out

The Roll-out Scenario Plus is, to all extents, a full roll-out, because, in the long-term, 100% of the metering points will be equipped with a smart metering system or an intelligent meter. Factually, the assumptions of the scenario lead to a fragmented approach if the meter operators implement the roll-out one-to-one. Mandatory installations of smart metering systems and Ferraris meters during a regular replacement will be distributed locally over streets and buildings.

If the roll-out is accomplished as a full roll-out, this would yield an additional net present value of €+1.2b in the Roll-out Scenario Plus. In this case, it is assumed that the meter operator realizes a cost-optimized roll-out, e.g., by installing smart metering systems and intelligent meters street-by-street or by installing smart metering systems and intelligent meters in a building for all end consumers if one mandatory installation must be installed. Lower installation costs and lower communication costs with PLC lead to increased roll-out costs. Other effects, such as the further increase of the roll-out amount per year and the combined economies of scale, have not been included.

The accomplishment of a full roll-out should be optional to every market player. If there is an economic advantage, each company can roll out intelligent meters and smart metering systems. An obligation is not recommended as it is a macroeconomic roll-out which is hard to realize in practice and will lead to a high cost burden for each consumer group.[29]

Value added services

Value added services are another opportunity to generate benefits in a non-mandatory roll-out strategy. In the context of this report, the opportunities to provide value added services via smart metering systems were treated with caution. The potential is without doubt available, but at the moment, there are no reliable experiences in Germany or in other countries.

The benefits of the value added services have been considered in the CBA as lump sum. Studies assume that end consumers are willing to pay of €200 p.a. for the use of value added services.[30] With an assumed added value of 10% and a market penetration of 10%, each consumer could obtain an additional benefit through smart metering systems of €2 p.a. at the beginning of the roll out. The value increases to €10 p.a. for each consumer by 2032 (50% market penetration).

To improve the opportunities to provide value added services through a SMGW, we recommend:

- developing platforms through intelligent meters in all buildings until 2029, on which all value added service providers can offer their products and services via additional SMGWs,
- connecting the functions of the SMGA to the meter operator as the meter operator has viable interests in marketing and selling additional services,
- analyzing the opportunities and possibilities of providing, marketing and delivering value added services in pilot projects and a comprehensive study.

3.7 Inclusion of gas in the roll-out

The roll-out of smart metering systems is primarily driven by electricity in Germany. Generally, the roll-out is also applicable to the gas sector. Below, the treatment of the gas sector during the roll-out is examined.[31]

Legal framework

Depending on their size, gas meters must be replaced every 8 to 16 years. § 21f EnWG states that only gas meters may be installed that can be connected to a BSI Protection Profile-compliant metering system that meets the requirements of § 21d und § 21e EnWG.

Possible synergies between gas and electricity

Sharing a communication structure, minimizing costs due to simultaneous installation (as far as possible) and the simultaneous adaption of processes for gas and electricity (as far as possible) offer potential synergies especially for diversified companies. The following main alternatives come into consideration:

1. Simultaneous replacement of a gas meter with an intelligent gas meter when an intelligent meter or smart metering system for electricity is installed
2. Simultaneous installation of an intelligent gas meter when an intelligent meter or smart metering system for electricity is installed in accordance with § 21c (1) a) EnWG

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[29] See conclusion and valuation of EU Scenarios.

[30] Compare, for example, Bundesministerium für Bildung und Forschung 2012: *Study about economical potential and new business models in the sector of ambient assisted-living systems.*

[31] The usage of a shared communication infrastructure for gas and electricity was not considered in the calculations.

3. Setting up a communications link for already installed intelligent gas meters (gas meters according to § 21f EnWG) to the smart metering system for electricity

The mandatory replacement of gas meters parallel to the installation of intelligent meters or smart metering systems for electricity results in significant additional costs. These include costs already incurred for the installation of gas meters that must be replaced before the end of their planned period of use and the assignment of specially trained personnel to replace or install the gas meters.[32] Furthermore, significant additional efforts are necessary due to the specific gas-related technical requirements.

If an intelligent electricity meter is installed in a new building, the mandatory installation of a smart metering system could be extended to gas. However, additional costs for installing smart metering systems for gas could also be significant in such cases. Therefore, introducing mandatory installation of smart metering systems for gas is not recommended. Because the electricity and gas meter operators are usually different companies, a competitive approach is favorable in which the gas meter operator can take over the installation of smart metering systems for electricity.

With regard to renovations, the assessment must be more differentiated. On the one hand, cost disadvantages in connection with the replacement of the gas meter and the additional costs for customers with a low consumption must be considered. On the other hand, renovations provide the ideal opportunity for installing a large number of smart gas metering systems, which would provide the market participants with a higher degree of planning and investment certainty. Currently, approximately 50%[33] of new and existing buildings are connected to the gas grid, but the number of gas meters is lower because usually there is only one gas meter in a multi-family house with a central heating system while apartments are measured via a sub-metering system for heat. Therefore, 1 million smart gas metering systems would have to be installed annually.

The connection of already installed gas meters to the communication network of a smart electricity metering system requires some significant additional efforts and costs. A competitive approach seems to be appropriate.

Recommendations

In summary, we recommend leaving the current provisions of § 21f EnWG for gas unchanged. Additional costs for the installation and setup of a communications link for intelligent gas meters can be significant. A competitive market approach is preferable to a mandatory roll-out for the gas sector. If the installation of a meter for electricity is already mandatory in a gas-heated building, competition will be stimulated because the meter operator can realize synergies by a parallel roll-out of gas and electricity meters.

3.8 Summary: Sensitivities and possibilities for optimization

In this report, we made assumptions regarding the likely development of key drivers for the roll-out of smart metering systems. The assumptions are based on the experience of other countries, studies, the evaluation of pilot projects in Germany and discussions with market participants. Due to the sensitivity of certain parameters, further research is necessary to reliably assess the impact and effects of the introduction of smart metering systems.

The results of the sensitivity analysis point out the risk associated with a mandatory 80% roll-out (EU Scenario). If, for example, the assumed average energy saving potential of 1.8% is not realized by consumers, a macroeconomic damage of up to €5b between 2014 and 2022 could result from investments of €8.5b.

The sensitivity analysis points out further possibilities for optimization in Roll-out Scenario Plus which go beyond facilitating a limitation of feeding in renewable energies by adapting the EEG. We suggest the implementation of these measures:

[32] Also refer to the DVGW working papers G 685, G 459-1,G 459-2, G 600.
[33] BDEW, *"Heizungsstruktur in Deutschland 2011"*.

- Information campaign by the Government to make end consumers more energy conscious, thereby ensuring that at least the assumed minimum energy savings potential of 1.8% is realized
- Increase in the flexibility of grid charges[34]
- Reduction in the compensation payments to EEG plants by half (maximum of 5% of annual energy generation per facility)
- Limiting of the tasks of metering operators and SMGAs to a defined number of companies[35] and implementation of limits for the regulatory approval of fees for intelligent meters and smart metering systems to ensure the realization of economies of scale
- Inclusion of § 14a EnWG controllable energy applications in the mandatory installation of smart metering systems with cost dampening for customers with an annual consumption of less than 6,000 kWh[36]

Overall, the potential improvement results in a net present value of €5.0b and €5.4b for Roll-out Scenario Plus with 70 and 10 meter operators for electricity, respectively.

[34] Was accounted for in the calculation in the form of a tariff spread of 20% between off-peak and on-peak prices.
[35] For illustrative purposes, 70 and 10 MSB/SMGA were assumed in the calculations, respectively.
[36] Was not explicitly included in the calculations.

4. Assessment and recommendations

The following key recommendations result from the analysis of a nationwide roll-out of smart metering systems and intelligent meters in Germany. They are based on the Roll-out Scenario Plus, whose major characteristics are summarized in the following table (see Table 10).

Table 10: Characteristics of the recommended Roll-out Scenario Plus

Issue		Roll-out Scenario Plus
Object of roll-out	Smart metering systems	Metering systems which fulfill the requirements of § 21e (2) und 4 EnWG, consisting of a Smart Meter Gateway and one or more connected measuring systems
	Intelligent meter electricity	§ 21c (5) EnWG meter that can be securely integrated into a metering system according to § 21d and § 21e EnWG, and with an external display additionally
	Intelligent meter gas	§ 21f EnWG meter that can be securely integrated into a metering system according to $ 21d and § 21e EnWG
Mandatory installation	Electricity consumption > 6,000 kWh/a	Mandatory installation of smart metering systems – existing mandatory installations until 2018
	Electricity consumption < = 6,000 kWh/a	Installation of smart meters at the end of the regular replacement interval
	New buildings and renovations	Mandatory installation of smart metering systems – existing mandatory installations by 2018
	EEG <= 7 kW and > 0.25 kW and CHP < = 7 kW_{el} and > 0.25 kW_{el}	Mandatory installation of smart metering systems – existing mandatory installations by 2018
	EEG <= 0.25 kW and CHP <= 0.25 kW_{el}	Installation of smart meters at the end of the regular replacement interval
	Controllable energy applications according to § 14a EnWG (heat pumps, electric vehicles etc.)	Mandatory installation of smart metering systems – existing mandatory installations by 2018
Mandatory share	Exchange of old meters at the end of the regular interval	Conventional meters whose age equals or exceeds 16 years at the beginning o the roll-out must be replaced by smart meters or smart metering systems by 2022
		At least 1/6 of existing conventional meters whose age equals or exceeds 16 years at the beginning of the roll-out must be replaced by smart meters and smart metering systems by 2022
Other	Organization of metering operators and the function of SMGA	Based on 830 small (less than 100,000 metering points) and 70 large (more than 100,000 metering points) metering operators as well as realizing economies of scale due to optimized procurement activities
	Reduction of power feed-in of renewable energy facilities	The feed-in of renewable energy plants can be reduced by at most 5% of plant-specific annual generated power while maintaining compensation payments[37]

Source: Ernst & Young

[37] The suggested halving of compensation payments increases the net present value by +€0,4b. This effect has been excluded in the following calculations, having no influence on the direct costs and benefits of the roll-out.

4.1 Roll-out strategy under Roll-out Scenario Plus

In contrast to other EU member states, no obligation to install modern metering systems had been implemented into legislation in Germany by 2011. Instead, the metering business was liberalized and the approaches and experiences of other EU member states were analyzed.

In mid-2011, during a significant reform of the Energy Industry Act ("Energiewirtschaftsgesetz" – EnWG) a basic decision was taken to implement a secure and intelligent metering business that should take into account both the requirements of the energy turnaround ("Energiewende") as well as data security and privacy requirements. Smart metering systems should be installed only if they fulfill the BSI Protection Profile and the Technical Guidelines which have been developed since the end of 2010 by the BSI in collaboration with the most important stakeholders and institutions. Furthermore, smart metering systems have to incorporate the requirements of modern energy supply systems and not only to visualize consumption data. Therefore smart metering systems shall also enable the controlling and regulation of loads and generation plants as well transmit information about grid conditions. Due to these specific needs, smart metering systems, devices and communication links have to fulfill increasing requirements. This complex background must be taken into account by the roll-out strategy.

As further technological developments were required in order to guarantee data protection and to meet the complex demands of an intelligent energy supply system, it was not yet possible to start the nationwide roll-out of smart metering systems. Data protection requirements have been published in the "BSI[38] Protection Profile" and the Technical Guidelines. Besides this, an ordinance covering the minimal technical requirements using smart metering systems has been submitted to the EU for notification according to Directive 98/34/EU.

Without further legal measures, investors face substantial uncertainties which are detrimental for a roll-out. A key decision-making factor for market participants is the reliability of basic conditions effecting the investment, which can be ensured through an increase in mandatory installations. On the other hand, the effects resulting from this measure must be evaluated: This relates on the one hand to the financial burden on customers (or customer groups) and, on the other, to the impact on innovation and competition.

Therefore it must be examined whether customers can realistically benefit from the mandatory installation of smart metering systems on an individual level. From a microeconomic standpoint, mandatory installations should be rejected if a positive result cannot be achieved even under optimistic assumptions. This is the case for the EU Scenario. Mandatory installations of smart metering systems in Germany lead to a high financial burden for end consumers with low or average energy consumption. In addition, the EU Scenario cannot fulfill the requirements of a smart grid.

Furthermore, the roll-out strategy should leave enough room for innovation and market forces to support the development of a "smart market". This is true for the recommended roll-out strategy because the installation requirements are directed at all meter operators and not just the incumbents. As a certain market volume results from this approach, competitive metering operators can also benefit from the installation requirements.

A market-oriented roll-out that is open to competition and innovation should therefore be pursued systematically. Competition between metering operators is stimulated in various ways through mandatory installations in a limited number of specific cases. Mandatory installations provide long-term investment security for equipment manufacturers and metering operators because, in the long-run, at least all end consumers are required to switch to smart metering systems and intelligent meters. On the other hand, competitive metering operators have the opportunity to attract new customers because mandatory installations at the end of regular replacement intervals take place over a period which is long enough to make customers open to competitive offers.

Core elements of the market-oriented roll-out

The core elements of the market-oriented roll-out are as follows:

- Strengthening competitive elements:
  - The installation of smart metering systems and intelligent meters is available to all customers at attractive and guaranteed terms.

[38] Federal Office for Information Security Germany (Bundesamt für Sicherheit in der Informationstechnik, BSI)

    - Every metering operator has the opportunity to offer smart meters or smart metering systems to potential new customers.
    - Intelligent meters create a platform for the subsequent usage of SMGWs in every building. This platform can then be used by metering operators or other service providers to sell services and products.
- Increased mandatory installations of smart metering systems due to grid-related reasons:
    - The installation obligation pertaining to old EEG and CHP plants should be extended to all EEG[39] and CHP facilities and the insignificance threshold should be reduced from 7 kW to 250 W to maximize the contribution of smart metering systems to grid efficiency.
    - Inclusion of controllable energy applications according to § 14a EnWG in order to integrate these important elements of a future energy supply system into feed-in and load management systems.
- Introduction of obligation to install intelligent meters to increase energy efficiency in an economically reasonable way:
    - Mandatory installations of smart metering systems should not be further extended. Consumers with an annual consumption of less than 6,000 kWh save up to €66 per year from smart metering systems through reduced consumption and load shifting (see Table 3). A mandatory introduction entails costs of €90 per year and is thus disproportionate and inefficient.
    - Intelligent meters cost €40 per year and thus constitute a cheaper solution as compared to smart metering systems. Therefore conventional meters should be replaced by intelligent meters at the end of regular replacement intervals. As the interval duration is not yet set by law, a legislative amendment is necessary. This amendment should refer to the existing provision of § 21f EnWG in combination with calibration regulations and it should take into account that gas meters must be replaced after 16 years at the latest. That is why the regular replacement interval of electricity meters should equal the interval for Ferraris meters (16 years).
- Operation of intelligent meters is subject to particular requirements: Intelligent meters are an upgradeable measuring system in accordance with § 21c (5) EnWG. Combined with a Smart Meter Gateway, they can be securely integrated into any communication system. In this report, intelligent meters are able to visualize the actual energy consumption and the actual use-of-time on an external display within the apartment of the end consumer. As long as the meter has not been upgraded with a SMGW to a smart metering system, the MID does not allow the specification of any particular data protection and privacy requirements for the transmission of data by the measuring system. Therefore, no obligation to install an external display should be implemented. Instead, introducing an obligation to install a display should be driven by the market. However, in this case general data security and privacy requirements such as the encrypted transfer of data must be fulfilled. Additionally, in accordance with § 21e (5) EnWG, installation of a display should require "written approval of the end consumer to install and to utilize a metering system, being aware of the fact that the system does not fulfill the requirements of section 2 and 4."[40]
- By integrating an intelligent meter into a smart metering system, which is compliant with the BSI Protection Profile, an in-house communication link will be established by a Smart Meter Gateway allowing a display in the apartment of the end consumer to be connected with the metering system compliant with the BSI Protection profile. According to the BSI Protection Profile, the smart metering system must be operated by a SMGW-Admin in order to prevent the metering system and Smart Meter Gateway from being compromised. An intelligent meter must be transformed into a Protection Profile-compliant metering system if secure integration into a communication network, i.e. a connection to third parties, especially to smart grids, should be enabled.
- In addition, the market-oriented roll-out should be supported by the following measures:
    - The potential discrimination of competitive metering operators by regulated metering operators should be prevented by offsetting imbalances between the two groups (see chapter 4.4).

[39] Renewable Energy Act. (Erneuerbare-Energien-Gesetz).
[40] § 21e (5) EnWG.

- Support for pilot projects analyzing the usefulness of metering systems which are compliant with the BSI Protection Profile, and their effect on end users and grid operations to test the complexity of the system and operating conditions in smart grids and to increase the stability of the system.
- As success or failure of the roll-out heavily depend on the behavior of end consumers, information campaigns should be launched during the restructuring phase of the energy supply system ("Energiewende") to explain to end consumers the importance of smart meters and smart metering systems for the integration of renewable energies.

Taking into account different interests

The recommended roll-out strategy pursues and develops the market-oriented approach. This takes into account the different objectives of the roll-out of intelligent meters and smart metering systems (see chapter 1.3) as well as different interests.

The recommended Roll-out Scenario Plus is favorable for the overall economy. Scenario analyses reveal little risk of macroeconomic damage. However, there is additional optimization potential, which can be exploited through legislative amendments. In this context, the additional extension of controllable energy applications according to § 14a EnWG must be highlighted. Electric vehicles and low energy buildings, equipped with heat pumps, will have an increasing importance in the future energy-efficient world. Electric vehicles and heat pumps can be used for stabilizing and shaping peak loads as part of feed-in and load management.

Protection of end consumers is guaranteed because only those customers who:

- either disproportionately contribute to the costs of the energy supply system.[41]

  or

- are able to relieve the energy supply system.[42]

are obliged to install smart metering systems.

Through the inclusion of old facilities and EEG and CHP facilities with more than 0.25 kW and less than 7 kW connection power, all metering points which can disproportionately contribute to grid efficiency have to switch to smart metering systems. Metering points, which contribute little to grid efficiency, are only provided with intelligent meters to increase energy efficiency.

The additional obligation to replace conventional meters at the end of regular intervals ensures that increases in energy efficiency through energy conservation and load shifting are realized in an efficient and economically reasonable way. In the case of these facilities, (mandatory) installations of smart metering systems, which are embedded into a communication system, are inefficient.

The obligation to install intelligent meters at interval ends creates additional economies of scale: Installations prescribed by law provide a long-term growth perspective for the roll-out of intelligent meters and smart metering systems and hence offer long-term investment security.

Harmonization of useful life and calibration periods are suggested in order to enable a controlled and cost-effective replacement of meters after reaching the end of their useful life and calibration period. The useful lives of communication devices and gateways (according to Annex 1 StromNEV between 4 and 8 years), calibration period for electricity metering systems (8 + 5 years) differ from the useful life of an intelligent gas meter (currently 12 years).[43] These differences will cause significant additional costs for the meter operator during the roll-out: On the one hand, the selective replacement of devices (gateways and meters) after the end of the useful life/calibration period will result in significant additional costs (e.g. travelling costs); on the other hand a replacement of devices that are not fully depreciated before the end of their useful life/calibration period would not be economically reasonable.

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[41] Disproportional means, those customers compared to other customers in his/her sample, e.g. compared to all residential customers. Regarding the "costs of the energy supply system" a customer could be assessed isolated or as a member of a wider group having similar or identical behavior.

[42] Also in this context the definition of the footnote before is applicable.

[43] Within the calculations, a useful life of 13 years for intelligent meters and gateways was used.

Summary

The financial burden for end consumers is too high in a purely mandatory-driven roll-out. Furthermore, innovative solutions are at risk in the absence of a competitive market. On the other hand, the purely market-driven approach bears the risk that the grid efficiency of smart metering systems could be neglected. In addition, lack of investment security and little potential for economies of scale could prevent the creation of a market and thus delay or even prevent the roll-out.

The recommended market-oriented roll-out strategy mentioned above merges the advantages of both approaches in order to offset the respective disadvantages.

The recommended roll-out strategy guarantees that the hitherto step-wise roll-out can be continued and corrected after some time based on a review, if necessary. In the current transition phase from the current energy system to an intelligent energy supply system, any radical change - either in the direction of a purely mandatory roll-out or in the direction of a purely market-driven roll-out – would create too much risk for the energy sector, which is a highly sensitive area for the overall economy.

4.2 Role allocation

As part of the roll-out strategy, responsibilities with regard to intelligent meters, Smart Meter Gateways and communication systems must be assigned to different market roles. Roles should concentrate as much as possible on a company or a market role in order to not unnecessarily render market and communication processes more complicated. Lawmakers should pay special attention to provisions regarding the role of the Smart Meter Gateway Administrator to ensure smooth operation of smart metering systems. In general, every corporation can apply for these roles if they fulfill the task-specific requirements or demonstrate sufficient capability.

Smart metering systems and intelligent meters

The obligation to install intelligent meters and smart metering systems should still be fulfilled by metering operators. They are responsible for end consumers receiving smart meters or smart metering systems if the law requires the installation of these devices.

Metering point operators must inform end consumers about their obligation to install and operate smart metering systems and the costs resulting from this replacement. If the system and meeting point operator are identical, end consumers must be informed that they can accept alternative offers of competitors. This approach ensures that mandatory installations will be made whilst strengthening the competition in the market for metering point operation.

Each metering operator is also responsible for the replacement of conventional meters by an intelligent meter after 16 years.[44] In this case, the regulated metering operator has to refer the end customer to competitive offers, too.

Smart Meter Gateway

Smart Meter Gateway Administrators (SMGA) are responsible for the roll-out of Smart Meter Gateways (SMGW). The role of SMGA within one distribution grid should generally be assigned to the metering operator with the highest number of metering points (basic SMGA). This ensures the existence of an SMGA for every grid before a smart metering system is installed and operated. This facilitates operating Smart Meter Gateways in multi-family buildings, e.g. if there are multiple metering points which are integrated into a communication system via SMGW.

End consumers have the right to choose another SMGA than the basic SMGA, e.g. their metering operator. Hence, a change of the SMGA is always possible on request of the customer.

[44] Meters older than 16 years should be replaced within a transitional period, e.g. by 2022. This will prevent a wave of replacements at the beginning of the roll-out. Furthermore the metering operator has room for optimizing his replacement strategy and processes. However, at least 1/16 of the existing meters older than 16 years must be replaced annually in order to secure a minimum rate of replacement. Those details and the possibilities for recalibration must be defined by the legislator.

The Smart Meter Gateway Administrator must fulfill the following requirements, which have to be further elaborated by lawmakers:

- Privacy and data security requirements as prescribed in the BSI Protection Profile.
- Ensuring quality of grid-related functions with a special focus on system control and regular provision of information about the grid via the gateway.
- Ensuring technical operation in order to enable third parties to offer new products and services as part of "smart markets".[45]

Through the introduction of smart metering systems, more and more sensitive data about end consumers will be collected, which is of high relevance to market participants. SMGAs should be as independent as possible in order to prevent discrimination against potential competitors (aggregators, energy services providers, providers of innovative energy products, providers of value added services, etc.) and to support the development of the "smart market". To ensure these goals, alternative solutions are possible:

1. The SMGA must fulfill requirements which have to be further elaborated, e.g. certification according to ISO 27001, which specifies the requirements for information security, including IT risks, as well the requirements of the BSI Protection Profile and Technical Guidelines.
2. The SMGA must be legally unbundled from other vertical business areas of the company (especially generation, trading and retail).

Vertically integrated utilities can only act as SMGAs if they unbundle their activities, if they engage an independent third party, or if they transfer their duties to another (bigger) basic metering operator of a different (larger) distribution area ("opt out" of the basic metering operator).[46]

Suitable third parties such as telecommunication or housing companies can act as SMGAs if they work as service providers for system or meter operators or if they are metering operators themselves.

It is recommended to use certification in accordance with ISO27001 as a minimum criterion for the role of SMGA. The compulsory legal unbundling of power supply companies should be assessed in 2017 after evaluating first experience related to the roll-out.

Communication connections

In the case of mandatory installations, the metering operator is responsible for integrating the smart metering system into the communication network. The communication network connection must fulfill minimum technical requirements. The SMGW-Admin is responsible for the reliability of the communication connections and for fulfilling the technical requirements (refer to chapter 4.3).

The regulatory regime should incorporate future requirements for smart metering systems with regard to telecommunication and the SMGW-Admin. Competitive and cost-effective solutions of separate communication connections for "M2M-Services" should be possible. Based on their competencies according to § 11 MsysV-E, the Federal Network Agency can define further details by taking into account the specifications of calibration as well as the BSI Protection Profile and Technical Guidelines.

Investment security

Smart metering systems and intelligent meters require substantial investments at the beginning of the roll-out, which will be amortized over the useful life of the system. In order to provide additional investment security for companies and thus to support the roll-out, regulation should make refinancing easier for regulated metering operators (§ 17 StromNEV). Smart metering systems should be depreciated over 8-13 years (currently depreciation periods for meters equal 20-25 years in accordance with appendix 1 of the Electricity Grid Fee Ordinance (StromNEV)).

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[45] Processes and deadlines should be substantiated and set by the Federal Network Agency (BNetzA) in cooperation with market participants.

[46] A detailed concept for opting-out has to be developed by the regulator in collaboration with the market players.

Summary

The recommended role allocation ensures the operation of fundamental processes in regulated areas of the energy sector by assigning the role of general SMGA to the metering operator. In addition, competition among metering operators is further supported because every metering operator:

- Has the opportunity to make offers to end consumers for both mandatory and voluntary installations of smart metering systems.
- Is responsible for the roll-out of intelligent meters and smart metering systems.
- Is generally responsible for the installation of Smart Meter Gateways.
- Discrimination of competitive smart metering operators as compared to regulated operators is prevented.

Furthermore, the role allocation provides necessary conditions for the development and the support of the smart market because:

- The independence of the SMGA must be guaranteed to make SMGW accessible to every company without facing discrimination.
- Every interested company can offer and render its products and services in the smart market either through barrier-free access to SMGW or by acting as metering operator.

The recommended role assignment must consider the necessary conditions for both the mandatory and the market-oriented roll-out. Thus, requirements to secure grid operation and established market processes must be fulfilled in order to guarantee energy supply. On the other hand, competition in the metering market and the smart market must be supported as much as possible.

4.3 Functional requirements and technical properties

In addition to comprehensive requirements regarding privacy and data security in compliance with the BSI Protection Profile, further requirements arise regarding technical properties of the smart metering system components (communication system, IT system). These requirements result from the Technical Guideline BSI TR-03109 and the specific application of the smart metering system. At this point we are only providing initial recommendations regarding minimum requirements.

Meters

First, meters must fulfill the requirements of the measuring instrument directive (MID)[47]. This directive dates back to 2004 and it is thus questionable whether the requirements are abreast with meter technology, operating conditions of meters as part of complex smart metering systems, communication technology and requirements regarding privacy and data security.

The operation of an intelligent meter is subject to particular requirements: The intelligent meter is an upgradeable measuring system as defined by § 21c (5) EnWG. Combined with a Smart Meter Gateway, it can be securely integrated into each communication system.

In this report, intelligent meters are able to visualize the actual energy consumption and the actual use-of-time on an external display within the apartment of the end consumer. As long as the meter has not been upgraded with a SMGW to a smart metering system, the MID does not allow the specification of any particular data security and privacy requirements for the communication link of the measuring system.

Therefore it is essential in the coming years to adapt the MID from 2004 to the requirements for metering systems concerning privacy, data security, communication and as a part of an intelligent energy supply system of the future. Furthermore, the MID must conform with EU directives that have subsequently come into force (Third internal energy package, Energy Efficiency Directive), which is not the case to date. As long as the MID has not been adapted, the request from the EU Commission for “data protection by de-

[47] Directive 2004/22/EG of EU from 31st March 2004 regarding measuring instruments.

sign" cannot be fulfilled. Finally, the BSI Protection Profile and Technical Guidelines must be applicable for intelligent meters even if the metering system must apply the MID.

Therefore, in-house communication must fulfill general data security and privacy requirements such as the encrypted transfer of data. Furthermore, the communication link must be unidirectional, exclusively informing the end customer without any connection to the grid. Otherwise the intelligent meter would be compromised and no longer able to be integrated into a smart metering system which is compliant with the BSI Protection Profile. As soon as bi-directional communication or a communication link to a third party is implemented, a Smart Meter Gateway must be installed enabling such connections.

By integrating an intelligent meter into a smart metering system, which is compliant with the BSI Protection Profile, an in-house communication link will be established through a Smart Meter Gateway allowing a display in the apartment of the end consumer to be connected with the metering system compliant with the BSI Protection Profile. According to the BSI Protection Profile, the smart metering system must be operated by a SMGW-Admin in order to prevent the metering system and Smart Meter Gateway from being compromised. An intelligent meter must be transformed into a BSI Protection Profile-compliant metering system if secure integration into a communication network, i.e. a connection to third parties, especially to smart grids, should be enabled.

Communication system

There are no specific requirements regarding the communication system infrastructure because every installation will be realized in a different way. Each meter operator can choose its preferred solution.

Special requirements for time-sensitive applications are being discussed concerning reliability, cold start-up ability, data transfer rates, bandwidth and latency:

- Grid operators demand a reliability of 99.99% for critical grid-related applications with priority over other services.[48] As the majority of applications processed by smart metering systems is not time-sensitive, a comparatively low reliability of communication connections in smart metering system is sufficient. Critical applications like bigger solar or CHP facilities can be integrated into the communication system through separate connections or through a smart metering gateway.
- Accordingly, no cold start-up ability and continuous power supply for the smart metering system are necessary.
- Data transfer rates between 50-500 kbps are crucial conditions for operating smart grid applications. [49] For the purpose of meter reading and the provision of information, it should be possible to collect and transfer data every 15 minutes. Various factors have an influence on meeting these requirements. In addition to the data transfer rate, data amount and available communication connection play an important role. It is recommended to conduct pilot studies to test which requirements data transfer rates have to meet in certain scenarios. Based on current information, data transfer rates of 500 kbps are sufficient for smart metering systems.
- The bandwidth for radio technologies for smart metering applications should be less than 1 GHz, otherwise connecting devices in cellars are at risk. [50] Therefore, we recommend to utilize communication technologies with less that 1 GHz.
- BSI Technical Guidelines the following requirements related to latency: [51]
    - Transmitting a wake-up signal within 15 s.
    - Synchronization of time within 18 s.

  For critical smart grid applications, latent periods which are substantially shorter at less than 100 ms are necessary in some cases.[52] As already mentioned above, applications processed by

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[48] Eurelectric, Public Consultation on Use of Spectrum for more efficient energy production and distribution: "For critical services, for which low latency is compulsory, public carriers need to ensure a very high level of availability (>99.99%) and should give priority to these services."
[49] Ibidem.
[50] See Sörries, 2012, S.54; Eurelectric: Public Consultation on Use of Spectrum for more efficient energy production and distribution, 2012, S. 16.
[51] Time delay between sending and receiving data.

smart metering systems are not time-sensitive and thus longer latent periods are sufficient for smart metering systems. If necessary, those technical parameters could be defined by the Federal Network Agency in line with their competencies after pilot projects are conducted.[53]

Data storage and processing

Additional technical requirements for the Smart Meter Gateway result from the BSI Protection Profile and the Technical Guideline ("Technische Richtlinie"). They especially include minimal requirements for SMGWs regarding tariffs, accounting issues and grid-related data collection, which have to be performed by SMGWs according to guidelines.[54]

4.4 Funding model

Costs related to the roll-out of smart metering systems should be allocated in line with their origin. Groups which benefit from the roll-out should bear costs commensurately.

Benefit by market role

Benefits of the roll-out for specific groups are as follows:

- End consumers benefit through energy conservation (€+6.3b), load shifting (€+2.9b) and value-added services (€+1.1b).
- Energy suppliers save costs related to customer service and call center services (€+1.6b) and due to improved billing processes (€+0.9b) and claims management (€+0.4b). In addition, procurement expenses decrease due to more precise load forecasts (€+0.3b).
- Meter operators benefit from improved meter reading (€+0.6b) and improved meter management (€+0.4b). Furthermore, process improvements result from the replacement of conventional meters (€+2.4b).
- Network operators must meet lower investment demands (€+2.7b) due to improved grid planning, grid monitoring, load forecasts, possible feed-in and load management. On top of that, positive effects arise in the areas of grid management (€+0.7b) and billing processing (€+0.5b).
- Energy producers face lower investment demands (€+0.7b).[55]
- The state and society benefit from:
  - The decrease in energy consumption and the resulting decrease in CO_2 emissions (€+0.1b).
  - Increased power supply security (€+0.1b).
  - The simplified integration of renewable energies (not quantifiable).
  - The reduced grid expansion resulting in lower investments and lower ecological damage (not quantifiable).
- Operators of EEGand CHP facilities can integrate their generation capacity into the energy supply system more easily through smart metering systems (not quantifiable)

These results demonstrate that intelligent meters and smart metering systems create value through various means in three areas:

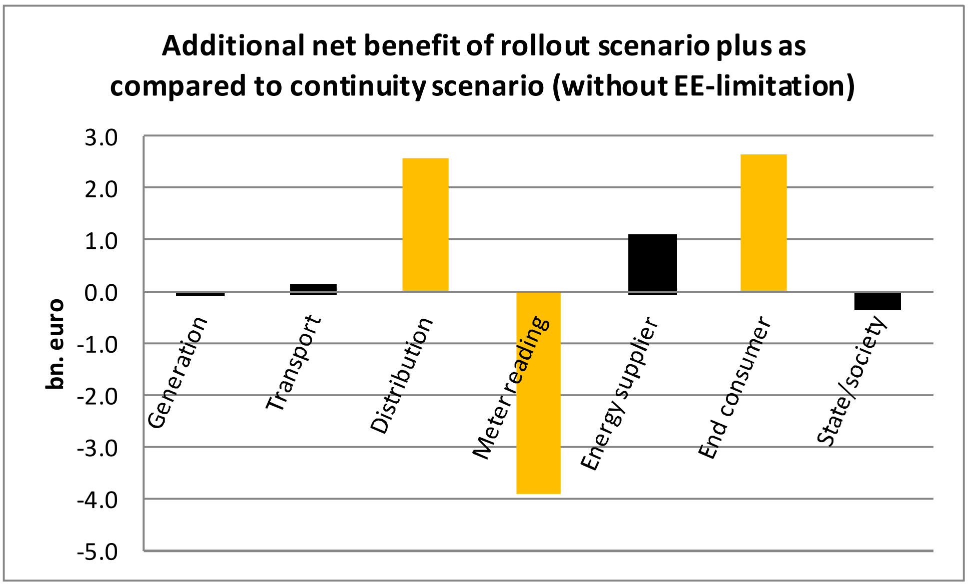
- Increase in energy efficiency (energy conservation and load shifting) through intelligent meters and smart metering systems.

[52] See Eurelectric, Public Consultation on Use of Spectrum for more efficient energy production and distribution: „"Latency: a general level between 10ms (teleprotection) and 300ms for metering and demand response, while tighter requirements are needed for mission-critical applications related to network operations (to a maximum of 2ms in some cases)."
[53] See § 11 MsysV-E.
[54] Technical Guideline BSI TR-03109-1, p.76ff.
[55] Investments of 1,6 GW in new built gas-fired power plants will be avoided between 2014 and 2032.

- Grid efficiency of smart metering systems.
- Improved business processes (meter reading, billing, load forecast) of various market participants.

If costs related to the roll-out of intelligent meters and smart metering systems are shared among market participants, costs borne by single groups must be compared to their respective benefit. Benefit is the additional benefit as compared to the current situation described in the Continuity Scenario without restrictions on renewable energy facilities.[56] Figure 5 summarizes the costs and benefits of the roll-out for the different market participants.

Figure 5: Additional net benefit by market participants



Source: Ernst & Young

According to Roll-out Scenario Plus, distributors (€+2.6b) and end consumers (€+2.6b) mainly benefit from the introduction of intelligent meters and smart metering systems as compared to the current situation. End consumers especially profit from energy conservation and load shifting. The grid efficiency of smart metering systems and the restrictions imposed on renewable energy facilities are beneficial to distributors. Costs related to the roll-out are primarily borne by meter operators (€-3.9b). The net benefit of energy suppliers is €1.1b. The state and society incur tax losses of €-0.3b.

Market roles and groups to be included in funding

The transfer of additional benefit from energy suppliers to end consumers is subject to market-driven and competitive processes and is therefore not relevant to the roll-out. It is recommended to fund the roll-out through payments by end consumers to meter operators. Hence, costs can be allocated to three groups:

- Users of smart metering systems to the extent to which they benefit from the use of smart metering systems.
- Users of intelligent meters to the extent to which they benefit from the use of intelligent meters.
- The general public and hence every end consumer due to the benefit for the overall economy resulting from the turnaround in energy policy.

The increase in mandatory installations imposes an origination-based fee on end consumers who disproportionately make use of the energy supply system. Through behavioral changes, every consumer can benefit from the installation of intelligent meters or smart metering systems.

[56] By assumption costs and benefits in the current situation are completely covered by law and regulation frameworks.

However, end consumers who do not have to install intelligent meters and smart metering systems also benefit from the roll-out through:

- Benefits to the overall economy, such as the reduction in CO_2-emissions, the increase in energy supply security or the integration of renewable energies into the energy supply system, which are not attributable to single groups of end consumers.
- Cost savings attributable to all end consumers, such as the decrease in grid charges due to improved grid management and lower investment needs into the grids.
- Lower construction activity and thus less direct disturbances through construction sites or new power lines.

Hence it is justified if all end consumers bear a certain share of the roll-out costs.

In addition, it is conceivable to impose fees on all consumers (primarily energy suppliers, grid operators, service providers), who have access to data collected by smart metering systems and create additional benefits from it. It is recommended not to introduce such a fee for several reasons:

1. Major parts of the additional net benefits provided by smart metering systems are available to end consumers with effect from the date of installation (see Figure 5).
2. All other market participants first have to invest substantial amounts in e.g. IT systems and process amendments before they can actually benefit from smart metering systems.
3. A broad public acceptance is needed for the roll-out of smart metering systems. Explicit payments for using data collected by smart metering systems could raise concerns regarding data protection, which should be avoided in the introduction phase.

This issue should be addressed, examined and evaluated as part of the roll-out review in 2017.

Funding elements

Funding elements for intelligent meters and smart metering systems are as follows:

- Fees imposed on all intelligent meter and smart metering system users with effect from the date of installation.
- Different fees for the use of intelligent meters and smart metering systems are necessary in order to allocate costs by origination.
- System charges paid by users of conventional meters – not using a smart metering system and an intelligent meter - as an additional component of their fees for meter operation, meter reading and billing with effect from the roll-out year (assumed to be 2014).

The system charge covers all costs of the metering operator which are required for establishing the systems in order to operate a smart metering infrastructure. Additionally, all additional costs of the metering operator required for keeping the old systems running in order to operate conventional meters for less end customers are covered.

Funding scenarios

The following funding scenarios were examined for the Roll-out Scenario Plus:

1. Scenario 1: Costs of smart metering systems and intelligent meters are allocated by origination (no system charge).
2. Scenario 2: Mixed calculation for smart metering systems and intelligent meters (no system charge).
3. Scenario 3: General contribution – costs completely covered by system charge.
4. Scenario 4: Mixed calculation for smart metering systems and intelligent meters with system charge.

5. Scenario 5: Costs of smart metering systems and intelligent meters are covered origination-related contribution and system charge.[57]
6. Scenario 6: Origination-related fees for smart metering systems and intelligent meters considering the reasonableness of smart metering system fees and general cost allocation via system charges.[58]

The following fees result from the different funding scenarios in Roll-out Scenario Plus (see Table 11). It is recommended to define these fees - whose amount will be set by the Federal Network Agency - as regular fees for the incumbent meter operator that will be granted to the latter according to incentive regulation.

Competitive meter operators are free to determine the fee amount and are thus not bound by incentive regulation. As fee calculation is based on assumptions and forecasts, the Federal Network Agency must regularly assess installation and operating costs of smart meters and adjust fees if necessary.

Funding provided by system charges with effect from the roll-out start is fundamentally different from fee payments of smart metering system and intelligent meter users:

1. If funding is provided via user fees, the meter operator must make up-front payments for capital expenditures and funding costs. Economies of scale are realized continuously over a longer time horizon. The meter operator receives payments as soon as it has installed the smart meter. Funding via fees directly relates to capital expenditures and operating expenses.
2. If funding is provided via system charge, end consumers partially pay for the roll-out costs up-front. Funding costs are disconnected from actually paid capital expenditures and operating costs. In addition, the meter operator realizes economies of scale by using smart meters, which are partially funded by end consumers. Therefore, efficiency gains must be considered in the system charge calculation.

[57] The system charge mainly reduced calculated fees for smart metering systems because they exhibit significantly higher macroeconomic benefits than intelligent meters due to grid efficiency.
[58] See footnote 39.

Table 11: Examined financing scenarios for Roll-out Scenario Plus

	SMS > 6,000 kWh/a and REA-/CHP-facilities > 1kW[1]	SMS <= 6,000 kWh/a and REA-/CHP-facilities <= 1 kW[1]	Intelligent meter	General charge for metering operation, meter reading and billing (of which system charge)[2]
Scenario 1	€90 p.a.		€40 p.a. aft. installation	€22 p.a. from 2014 (incl. €0 p.a.)
Scenario 2	€58 p.a.			€22 p.a. from 2014 (incl. €0 p.a.)
Scenario 3	€43 p.a. from 2014			
Scenario 4	€46 p.a.			€30 p.a. from 2014 (incl. €8 p.a.)
Scenario 5	€60 p.a.		€38 p.a.	€30 p.a. from 2014 (incl. €8 p.a.)
Scenario 6	€62 p.a.	€50 p.a.	€38 p.a.	€30 p.a. from 2014 (incl. €8 p.a.)

Source: Ernst & Young

[1] The consumption limit of 6,000 kWh/a is relevant to all competitive installations and mandatory installations subject to § 21c (1) a) EnWG. For mandatory installations subject to § 21c (1) c) EnWG, the connection power of greater or smaller than 1 kW is pivotal for charging.

[2] The system charge is paid by users of conventional meters in addition to their fees for meter operation, meter reading and billing with effect from the roll-out year (assumed to be 2014).

In total, the financing volume covers proportionate capital expenditures and operating costs of intelligent meters and smart metering systems during the years 2014-2022 (approximately €9.4b). In a roll-out funded via system charge, realized efficiency gains must be considered. The financing volume in this scenario is €8.4b.

The scenarios lead to different financial effects. The more funding is related to actual roll-out payments, the lower are additional funding costs. Therefore, funding costs must be considered in the financial model.

Including financing costs

Meter operators must make above-average investments at the beginning of the rollout. Fees for financing the roll-out are calculated using average total costs (capex and opex) uniformly distributed over the complete useful life of intelligent meters and smart metering systems. Metering operators will be underfunded. This is especially the case if the roll-out is co-financed by a general system charge and fees for intelligent meters and smart metering systems are reduced. This especially applies to scenarios 4, 5 and 6.

The inclusion of financing costs means that fees increase in some scenarios. Table 8 summarizes the fees which are necessary in the different scenarios to cover financing costs (5% per year on accumulated differences between income and expense).

Table 12: Funding scenarios considering financing costs

	SMS > 6,000 kWh/a and REA-/CHP-facilities > 1kW[1]	SMS <= 6,000 kWh/a and REA-/CHP-facilities <= 1 kW[1]	Intelligent meter	General charge for metering operation, meter reading and billing (of which system charge)[2]
Scenario 1	€90 p.a.		€40 p.a. aft. installation	€22 p.a. from 2014 (incl. €0 p.a.)
Scenario 2	€58 p.a.			€22 p.a. from 2014 (incl. €0 p.a.)
Scenario 3	€55 p.a. from 2014			
Scenario 4	€51 p.a.			€30 p.a. from 2014 (incl. €8 p.a.)
Scenario 5	€70 p.a.		€42 per	€30 p.a. from 2014 (incl. €8 p.a.)
Scenario 6	€72 p.a.	€55 p.a.	€42 p.a.	€30 p.a. from 2014 (incl. €8 p.a.)

Source: Ernst & Young

[1] The consumption limit of 6,000 kWh/a is relevant to all competitive installations and mandatory installations subject to § 21c (1) a) EnWG. For mandatory installations subject to § 21c (1) c) EnWG, the connection power of greater or smaller than 1 kW is pivotal for charging.
[2] The system charge is paid by users of conventional meters in addition to their fees for meter operation, meter reading and billing with effect from the roll-out year (assumed to be 2014).

Including financing costs, the sum of all payments in scenario 5 and 6 is positive in 2031.

Financial contribution to roll-out

The financial contribution to the roll-out in the different financing scenarios is shown in the following table:

Table 13: Financial contribution to the roll-out by group

Financing scenario / Group	Share[1] in%	1	2	3	4	5	6
Sum mandatory installations SMS	36%	56%	36%	(15%)[2]	29%	39.5%	40.0%
thereof > 6,000 kWh	24%	37%	24%	(13)[2]	19%	25,9%	26.4%
thereof EEG	4%	6%	4%	(1%)[2]	3%	4.0%	4.0%
thereof CHP	< 1%	1%	< 1%	(< 1%)[2]	< 1%	0.5%	0.5%
thereof new buildings/renovation	8%	5%	8%	(1%)[2]	7%	9.1%	9.1%
thereof <= 6,000 kWh	3%	5%	3%	(1%)[2]	2%	3.3%	2.6%
thereof intelligent meters	64%	44%	64%	(25%)[2]	52%	41.7%	41.4%
Fee of meter operator to all customers	0%	0%	0%	100.0%	20.0%	18.7%	18.6%

Source: Ernst & Young

[1] Share of respective smart meter user group (sum of intelligent meters and smart metering systems). Shares are averages over the years 2014 until 2022.
[2] Share of respective group in total metering points.

Evaluation

Considering the effects for the overall economy that are pursued with the roll-out of smart metering systems, financial contributions of all end consumers are recommended (scenarios 4 until 6). The additional fee of €8 p.a. is a manageable amount for all end consumers. In total, end consumers without intelligent meters or smart metering systems pay less than 20% of the roll-out costs. Furthermore, all end consumers have the opportunity to install intelligent meters or smart metering systems before the end of the replacement interval.

The mixed calculation with both intelligent meters and smart metering systems (scenario 4) implies a fee of €51 p.a. for every end consumer. This is very attractive for end consumers, but it bears the risk of underfunding if a disproportionate number of end consumers opt for smart metering systems instead of intelligent meters.

Therefore, a separate fee for users of intelligent meters and smart metering systems should be introduced. This ensures that costs are allocated according to origination and it supports the roll-out of smart meters. The resulting fee increase of €70 p.a. for users of smart metering systems (scenario 5) is acceptable because it will be probably offset by energy conservation and load shifting.

Although different fees for users of smart metering systems according to consumption (scenario 6) have disadvantages due to practical reasons, it is recommended to adopt this approach: The introduction of different fees reduces the costs that consumers with lower consumption have to bear, especially if they are required to install a smart metering system in the case of new buildings, renovations, and as operators of smaller EEG and CHP facilities. Additionally, fee differentiation results in a reasonable financial burden for small EEG and CHP facility operators (connecting power between 0.25 kW and 1 kW), for controllable energy applications according to § 14a EnWG, as well as for smart metering systems that are not subject to § 21c (1) a) and b) and c) EnWG.

Balancing mechanism between meter operators

Mixed funding through contributions of smart metering system users, users of intelligent meters and general fees – as envisaged in the recommended scenario 6 - raises further questions:

- How are different structures treated – especially in terms of the different share of mandatory installations in grid areas?
- How are competitive meter operators treated?
- How can "cherry picking" be prevented if competitive meter operators concentrate on conventional meters in order to receive the general system fee without installing smart metering systems?

As the number of mandatory installations can differ significantly in every grid area, basic meter operators receive different compensation in addition to the system charge of €8 p.a. for the installation of smart metering systems. However, the larger the grid area of the incumbent meter operator, the smaller the need for regional balances.

Discrimination through different fees – e.g. between urban and rural areas or between areas with high and low levels of power feed-in of renewable energy facilities – can also be prevented through mix effects in sufficiently large areas of the basic meter operator. As already mentioned above, this ensures that economies of scale, which are necessary for the roll-out, can be achieved.

A balancing mechanism in favor of competitive metering operators would need the following organization: Every basic metering operator manages a fund for "establishing a smart metering infrastructure" within the area it is responsible for. Additional general fees collected by meter operators in their area will be contributed to the fund. The fund makes payments to compensate for prices in excess of costs for smart metering systems.

The additional system charge enables the reorganization and operation of a new metering infrastructure. It must not be misused to gain extra revenues by remaining in the conventional system. Therefore, a procedure shall be introduced which allows either to cede the charge to the basic metering operator or to oblige competitive metering operators to install only intelligent meters and smart metering systems to new customers.

There are three alternative ways to treat basic and competitive meter operators which must be considered:

Scenario A – Competitive meter operator contributes to balancing mechanism

In the first scenario A, the competitive meter operator contributes equally to the financial compensation. The main objective of this scenario is to establish a nationwide smart metering infrastructure and to treat competitive and regulated metering operators equally.

The competitive meter operator introduces a system charge of €8 p.a. for every conventional meter it operates in the area of the basic meter operator. For each installed smart metering system, the competitive metering operator receives €20 p.a. from the basic metering operator.

This mechanism prevents that competitive meter operators from focusing on conventional meters and trying to get additional fees by dumping without investing in smart metering systems. Accordingly the competitive metering operator pays €8 p.a. to the fund for each conventional meter which it operates within the area of the basic metering operator.

On the other hand, the competitive metering operator receives €20 p.a. from the basic metering operator for each smart metering system which it installs within the area of the basic metering operator in order to accelerate the roll-out of smart metering systems in Germany.

The disadvantages of this scenario are first the significant administrative efforts. Secondly, the funding system could be jeopardized by an accelerated replacement of conventional meters with smart metering systems.

Scenario B – Competitive meter operator contributes partially to the balancing mechanism

A second alternative would be the partial involvement of the competitive metering operator in the balancing mechanism. Besides the establishment of an intelligent metering infrastructure, the main objective of this alternative is the improvement of competition on the metering market. The latter objective is pursued by an approach where the competitive meter operator acts as the link to the customer whereby he can bundle the installation and operation of smart metering systems of basic meter operators.

The competitive meter operator pays to the basic system operator a system charge of €8 p.a. and meter for each conventional meter operating within in the area of a basic meter operator. However, the competitive meter operator does not receive a grant from the basic meter operator because it does not have the same duties as the basic meter operator.

In order to ensure that the competitive and the basic meter operator are treated equally, the competitive meter operator can use the basic meter operator for services related to the installation and operation of smart metering systems (at regulated fees). The competitive meter operator can thus act as the "face to the customer" if the latter wants it to.

Scenario C – Competitive meter operator does not contribute to balancing mechanism

Alternatively, competitive meter operators can be obliged to install only intelligent meters and smart metering systems in order to support the roll-out. They are thus prohibited from installing new, additional conventional meters. The main goal of this scenario is to accelerate the reorganization of the metering infrastructure within Germany. No additional administrative effort for a balancing mechanism is necessary.

In this scenario, existing customers of the competitive meter operator do not have to pay a system charge to the basic meter operator. Only the basic meter operator receives an extra charge for establishing new systems.

Recommendations

Overall, financing scenario 6, which suggests contributions from both smart metering system/intelligent meter users and all end consumers, is recommended. Hence, the principles of origination-based cost allocation and reasonableness are taken into account in the best possible way. Users of smart metering systems must pay significantly higher fees than users of intelligent or conventional meters.

Financing scenario 6 is also recommended because installations remain mandatory in new buildings or as part of renovations, including a fee differentiation for customers with a threshold at 6,000 kWh/a of electricity consumption. The same differentiation should be applied for a connection power of 1 kW as well as for end customers having interruptible devices according to § 14a EnWG, which are not subject to § 21c (1) a), b) and c) EnWG.

The three scenarios do not distinguish between the fees for end customers. The regulated meter operator is only allowed to charge limited fees. The scenarios are different related to the administrative burden and how the competitive meter operator is treated.

The recommended balancing mechanism B ensures that incumbent and competitive meter operators face the same conditions when competing for end consumers. By being able to engage the basic meter operator (at regulated fees), the disadvantages of a competitive meter operator against a regulated meter operator are offset.

If the roll-out can be funded despite the fact that no system charges are paid for conventional meters operated by competitive metering operators, it is recommended to exclude competitive meter operators from the funding system and instead to oblige them to install intelligent meters and smart metering systems (scenario C). This must be examined in detail.

4.5 Legislative and regulatory amendments

The following legislative amendments are necessary to implement the recommended roll-out strategy:

- Regulations with regard to minimum technical requirements.
- Possible mandatory installations of intelligent meters in accordance with § 21c (5) EnWG.
- Introduction of additional minimum requirements for meters as defined by § 21c (5) EnWG, according to which intelligent meters have to be equipped with an external display.
- In accordance with § 21e (5) EnWG, the introduction of a transitional period for the installation of a display of at least 2 years (end of 2016), but at most until specific privacy and data protection requirements for every meter in accordance with the requirements for smart metering systems are allowed. Additionally, in accordance with § 21e (5) EnWG, the installation of a display should require “written approval of the end consumer to install and to utilize a metering system, being aware of the fact that the system does not fulfill the requirements of section 2 and 4.”
- Increase the number of mandatory installations according to § 21c EnWG, i.e. all existing EEG and CHP facilities above 7 kW and all existing and future EEG and CHP facilities above a certain insignificance threshold, if necessary.
- Including controllable energy applications according to § 14a EnWG as mandatory installations.
- Adjustment of depreciation period of intelligent meters and smart metering systems in accordance with the Network Charges Ordinance (StromNEV).
- Harmonization of useful life and calibration periods for enabling an optimized and cost-effective roll-out after the installation.
- Introduction of a system charge in the Network Charges Ordinance (StromNEV) for regulated meter operators as part of overall fees for meter operations, meter reading and billing in order to partially fund the roll-out (amount not yet determined).
- Introduction of fee limitations in the Network Charges Ordinance (StromNEV) for operation, reading and billing activities related to smart meters (amount not yet determined).

- Introduction of an obligation for load profile meter readings ("Zählerstandsgangmessung") at mandatory smart metering system installations (with the exception of new buildings and renovations) and ensuring that grid operators are allowed to request other grid efficiency information. Otherwise, the benefits of smart metering systems could not be realized (optimization of purchasing energy, process improvements, grid efficiency effects). The CBA would be negative.
- Introduction of regulation stating that Ferraris electricity meters have to be replaced after 16 years at the latest (one calibration period without re-calibration).
- Amendment to EEG in order to reduce the power feed-in of EEGfacilities by up to 5% of the annual power generation capacity, if necessary.
- Amendment to EEG in order to halve compensation payments for reduced power feed-in (up to 5% of power generation capacity).

In addition, further details of the roll-out must be substantiated. In particular, requirements on Smart Meter Gateway Administrators and telecommunication infrastructure must be defined.

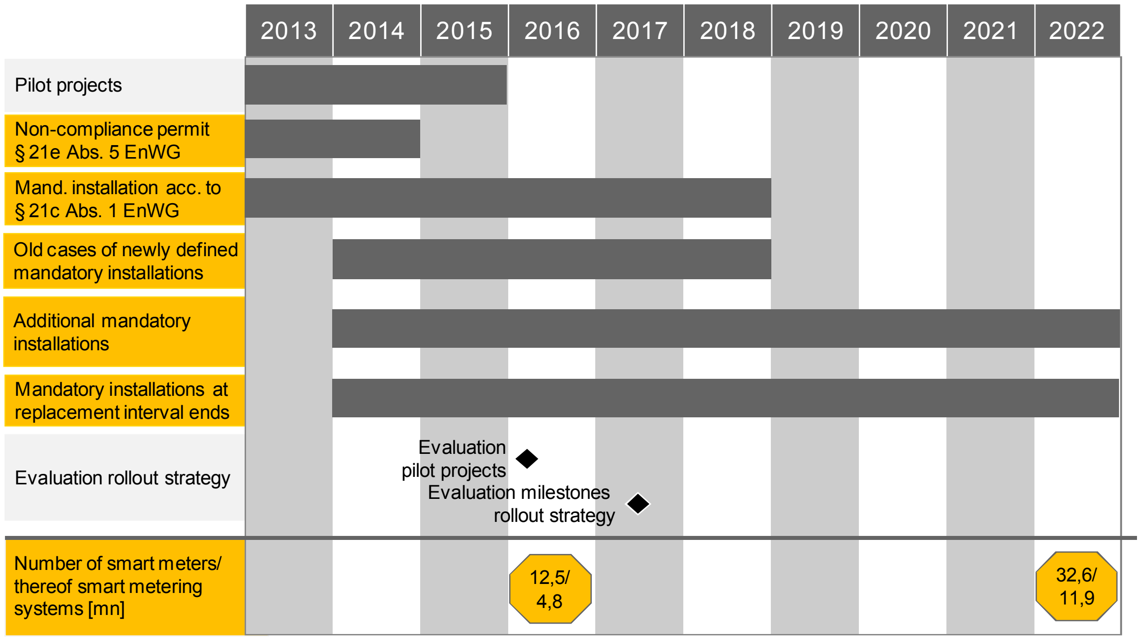
4.6 Roll-out timetable

The roll-out of smart metering systems and intelligent meters in Germany should happen after the necessary legal (especially adaptation of the EEG) and regulatory amendments. Given the current market situation it should be stretched and take place in stages:

- Non-compliance permit until the end of 2014 according to § 21e (5) EnWG.
- Existing mandatory installations according to § 21c ("Altfälle") must be carried out by the end of 2018.
- The same applies to mandatory installations in existing EEG and CHP facilities with annual generation capacities beyond a certain minimum threshold, which still has to be set.
- Additional mandatory installations must be carried out throughout the whole roll-out period.
- Additional intelligent meters according to § 21c (5) EnWG will be installed at the end of replacement intervals after one calibration period.
- Until the end of 2016, no obligation will be introduced to install an external display within the apartments of end customers.
- Furthermore, competitive installations of smart metering systems and intelligent meters will happen throughout the roll-out period.
- The requirements of the BSI Protection Profile and Technical Guideline BSI-TR03119-1 shall be tested in pilot projects until the end of 2016.
- In 2017 the roll-out strategy should be evaluated in order to assess the overall performance and to identify potential areas of improvement.

The resulting roll-out timetable is shown in the following image.

Figure 6: Roll-out timetable – electricity



Source: Ernst & Young

It is recommended to evaluate the roll-out in 2016 or 2017. The first evaluation is based on pilot projects and test regions, the regulation of which under § 21i (1) no. 6 EnWG still has to be further defined. The second evaluation based on practical experience will be carried out at the beginning of 2017. In case of delays – e.g. because smart metering systems are not available in sufficient quantities at the beginning of 2014 – target roll-out quotas as of year-end 2016 will have to be adjusted for the evaluation in 2017. Based on these two evaluations, the roll-out strategy must be optimized and amended if necessary.

5. Abstract and conclusion

In contrast to other EU member states, no obligation to install modern metering systems had been implemented into legislation in Germany by 2011. Instead, the metering business was liberalized and the approaches and experiences of other EU member states were analyzed.

In mid-2011 during a significant reform of the Energy Industry Act ("Energiewirtschaftsgesetz" – EnWG) a basic decision was taken to implement a secure and intelligent metering business that should take into account both the requirements of the energy turnaround ("Energiewende") as well as data security and privacy requirements. Smart metering systems should be installed only if they fulfill the BSI Protection Profile and the Technical Guidelines which have been developed since the end of 2010 by the BSI in collaboration with the most important stakeholders and institutions. Furthermore, smart metering systems have to incorporate the requirements of modern energy supply systems and not only to visualize consumption data. Therefore smart metering systems shall also enable the controlling and regulation of loads and generation plants as well transmit information about grid conditions. Due to these specific needs, smart metering systems devices and communication links have to fulfill increasing requirements. This complex background must be taken into account by the roll-out strategy.

As further technological developments were required in order to guarantee data protection and to meet the complex demands of an intelligent energy supply system, it was not yet possible to start the nationwide roll-out of smart metering systems. Data protection requirements have been published in the "BSI[59] Protection Profile" and the Technical Guidelines. Besides this, an ordinance covering the minimal technical requirements using smart metering systems has been submitted to the EU for notification according to Directive 98/34/EU.

Without further legal measures investors face substantial uncertainties which are detrimental for a roll-out. A key decision-making factor for market participants is the reliability of basic conditions effecting the investment, which can be ensured through an increase in mandatory installations. On the other hand, the effects resulting from this measure must be evaluated: An increase in mandatory installations will lead to additional expenses or customers and it will have an impact on innovation and competition.

Therefore it was examined whether customers can realistically benefit from the mandatory installation of smart metering systems on an individual level. From a microeconomic standpoint, mandatory installations should be rejected if a positive result cannot be achieved even under optimistic assumptions.

EU Scenario not favorable from macro- and microeconomic perspective

The EU Scenario targeting a roll-out quota of 80% by 2022 by a general mandatory installation provides a negative net present value and is also not economically reasonable for the majority of consumer groups. Even under optimistic assumptions, the majority of end consumers cannot compensate costs related to the installation and operation of smart metering systems by energy conversation and load shifting. Furthermore, a system charge must be paid by end customers over many years without benefiting from a smart metering system. Therefore, a system charge of €29 p.a. and per customer in addition to the current charge of €21.60 p.a. was not justifiable.

Current legislation aiming at interesting use-cases for smart metering systems

In contrast to the EU Scenario, the current legislation aims for installations where smart metering systems could either relieve the energy supply system or where significant energy conversation and load shifting potential open up the opportunity for end customers to utilize those systems in an economically reasonable way. The current legislation is clearly beneficial compared to the EU Scenario until 2022. In contrast to the EU Scenario, the financial burden has to be shouldered by those end customers who benefit most from the installation of smart metering systems. Additionally, financing risks are limited and the current approach fits better into the establishment of an intelligent energy supply system based on renewable energies ("Energiewende").

[59] Federal Office for Information Security Germany (Bundesamt für Sicherheit in der Informationstechnik, BSI)

Recommended Roll-out Scenario: An evolution of current legislation

However, the potential of the existing legislation has not been fully exploited. Therefore the currently implemented roll-out strategy was enhanced. The mandatory installation of smart metering systems and intelligent meters is aimed at regulated and competitive meter operators. This provides appropriate room for innovation and competition in order to establish a smart market. Competitive meter operators as well as regulated meter operators will benefit from the mandatory installation due to the fact that the given market volume will fall to competitive market players.

The current legal framework stipulates an obligation to install smart metering systems only for new EEG and CHP plants, i.e. facilities that were put into operation after the commencement of the EnWG on 4 August 2011, and that have a connection power of at least 7 kW. Since both older and/or smaller facilities in principle have the same effect on the power supply system as newer facilities, the Roll-out Scenario also provides for mandatory installations for old EEG/CHP plants and those below a power input of 7 kW down to a negligibility limit of 250 W.

The Roll-out Scenario was first assessed with the current legal framework. In a second step, the effects of an amendment of the EEG were considered and quantified.

Only a change in the EEG will safeguard the economic advantages of a roll-out

The potential of smart metering systems with regard to controlling and regulating EEG facilities cannot be realized within the current legal framework. Energy conversation and load shifting – which have the greatest benefit, combined with other benefits – are not sufficient to achieve a positive economic cost-benefit ratio under the current legal framework. Neither the EU Scenario nor the Continuity Scenario and the Roll-out Scenario, focusing on use-cases with the greatest potential to benefit, realize a positive net present value.

The consideration of the opportunity to limit each EEG plant up to 5% of their annual energy capacity during times of grid congestion or voltage fluctuations leads to a significant increase in the net present value by €2.7b to a total of €1.6b. Only the opportunity of active feed-in management turns this scenario around and a significantly positive net present value can be achieved. This highlights the importance of a grid-efficient roll-out and illustrates that the high potential of smart metering systems depends not only on consumption measurement but also on intelligent use as an important factor within a smart grid. This is already partially integrated in the current legal framework of EnWG 2011.

The significant benefit results from the reduction of the grid expansion – in particular within the distribution grid. Reference projects in (rural) distribution grids show that up to 100% more capacity from renewable energy facilities can be connected if it is possible to limit up to 5% of the annual energy capacity by the feed-in of EEG plants if needed.[60] In this context, the scenario analysis was based on the less optimistic assumption and a reduction of a maximum of 50% of the development needs of the distribution grid.

The exhaustion of the grid efficiency of smart metering systems offers further significant advantages. The almost complete coverage of grid-relevant metering points leads to a minimum penetration of 15% with smart metering systems (especially in grid-critical areas), which is necessary for a meaningful measurement of grid condition data.

In summary, the adaptation of the EEG – in favor of an active feed-in management and hence avoiding network investments - is a condition sine qua non for an economically reasonable roll-out of smart metering systems; in the absence of such an adaptation of the EEG, the roll-out is unlikely to get off the ground.

Intelligent meter contributes economically to improving energy efficiency

Furthermore, the recommended Roll-out Scenario plus is characterized by offering different reasonable solutions for various circumstances. The Scenario focuses on the roll-out of intelligent meters beside smart metering systems. § 21c (5) EnWG provides the possibility to integrate intelligent meters into a smart metering system (by adding a smart meter gateway).

Intelligent meters combined with an external display are able to visualize the actual energy consumption and the actual use-of-time within the apartment of the end consumer descriptively. This is a prerequisite for end customers consuming less than 6,000 kWh/a to save energy and to shift loads in an economically

[60] Source: Data reconciliation and market survey in the context of this report; see Appendix III.

reasonable way. Intelligent meters enable end customers with smaller energy consumption to realize existing energy conservation potential. In this way, the roll-out contributes economically to improving energy efficiency in Germany.

Particular requirements for operating intelligent meters must be established in order to enable the latter integration into a smart metering system. Intelligent meters increase the total roll-out quota, resulting in economies of scale and the possibility of a mixed calculation. Mandatory installations added by replacing conventional meters during the regular exchange will lead to a full roll-out of intelligent meters and smart metering systems by 2029. Rolling out 31.6m intelligent meters and smart meter systems corresponding to a roll-out quota of 66% will be achieved by 2022. One third of the total sum will be smart metering systems and two third intelligent meters.

Therefore it is essential in the coming years to adapt the MID from 2004 to the requirements for metering systems concerning privacy, data security, communication and as a part of an intelligent energy supply system of the future. Furthermore, the MID must conform with EU directives that have subsequently come into force (Third internal energy package, Energy Efficiency Directive), which is not the case to date. As long as the MID has not been adapted, the request from the EU Commission for "data protection by design" cannot be fulfilled. Finally, the BSI Protection Profile and Technical Guidelines must be applicable for intelligent meters even if the metering system must apply the MID.

Roll-out Scenario Plus micro- and macro-economical favorable

On the one hand, the recommended Roll-out Scenario Plus is characterized by focusing on mandatory installations which are relevant for network efficiency and on improving energy efficiency. Those mandatory installations can also be realized by competitive meter operators. On the other, significant room for competitive initiatives is given. Extending mandatory installations for EEG and CHP facilities to existing installations and facilities with a connection power between 0.25 kW and 7 kW aims to broadly exploit network efficiency gains by integrating EEG and KWKG facilities. Integrating EEG facilities aims to reduce feeding-in electricity from renewable energies and hence to reduce investments for grid extensions. This requires an adaptation of the current EEG that enables an increased reduction of renewable energies without the need to extend the grid by the grid operator at the same time.

In addition, mandatory installations should be extended to controllable energy applications according to § 14a EnWG which are a significant element of modern energy supply systems. Especially heat pumps and electric vehicles will offer the possibility of preventing investments in the extension of networks as well as of stabilizing and optimizing an intelligent energy supply system.

The result of focusing on metering points enabling the potential benefits of smart metering systems and intelligent meters to be realized (by a differentiated approach) is a positive economic net present value of €1.5bn in the period from 2012 to 2032. This requires an adaptation of the current legislative framework, especially the EEG.[61]

Therefore, from a macro-economic perspective, the Roll-out Scenario Plus is recommended and offers several additional advantages:

- By using a mixed calculation, which includes intelligent meters, smart metering systems and a system charge, a sustainable financing model that fairly allocates roll-out costs can be achieved. In this way, fees can be tailored to the customers' needs and willingness to pay (for details, refer to chapter 4.4).
- Tailor-made solutions are possible for each application.
- No group of people is privileged as all end consumers directly benefit from the roll-out.
- The accelerated roll-out increases economies of scale and provides the market participants (device manufacturers, meter operators etc.) with higher planning reliability and decreased investment risk.
- Intelligent meters create a platform for the subsequent usage of SMGWs in every building. This platform can then be used by metering operators or other service providers to sell services and products.

[61] Within the sensitivity analyses the adaptation of the Continuity Scenario was also examined.

- With an average of 4 million meters p.a. by 2018, the roll-out is ambitious. However, it is still achievable as more than half of the smart meters are intelligent meters.

Data protection and data security requirements

With the BSI Protection Profile and the associated Technical Guideline, privacy and data security requirements are given particular consideration in Germany. The experiences in other countries have shown that this aspect requires particular attention. Otherwise, there is a risk that the roll-out could fail due to local opposition.

The fulfillment of specific data protection and data security requirements therefore has to be paid particular attention. This is achieved by the specific requirements for the independence of the Smart Meter Gateway Administrators - which should ask in a first step for a minimum certification according to ISO27001. It must be possible to establish protection profiles for metering systems that are accredited under MID in order to prevent gaps in protecting the system as explained before.

A smart grid is not viable without any WAN communication. Information provided by smart metering systems is extremely important for realizing smart grids and therefore for realizing the assumptions made within this CBA. Hence it is necessary to introduce an obligation for load profile meter readings ("Zählerstandsgangmessung") at mandatory smart metering system installations (with the exception of new buildings and renovations) and to ensure that grid operators are allowed to request other grid efficiency information. Otherwise, the benefits of smart metering systems could not be realized (optimization of purchasing energy, process improvements, grid efficiency effects). The CBA would be negative.

Funding model

The principles of cost allocation according to origin and reasonableness were taken into account through mixed funding of users of intelligent meters or smart metering systems and all end consumers. Users of smart metering systems must pay €72 p.a. (€55 p.a. in the case of mandatory installations and electricity consumption of less than 6,000 kWh/a, as well as EEG and CHP small facilities with a connecting power from 0.25 kW und 1 kW, respectively) and therefore significantly more than users of intelligent meters (€42 p.a.) or end consumers who are not yet using intelligent meters or smart metering systems (additional €8 p.a.).

With an additional system charge of €8 p.a. from beginning of the roll-out, every end consumer makes a contribution to the installation of the meter infrastructure and therefore to the turnaround in energy policy. In particular, the consumer helps ensure that renewable energies can be better integrated in the current energy supply system and that the expansion requirements for generation capacity and grid connection can be decreased. The consumer benefits directly through lower grid charges. Furthermore, the customer has the opportunity to invest in intelligent meters and smart metering systems. A meter according to § 21c (5) EnWG is a low-cost variant for consumers with a low power consumption to compensate the costs through power savings – at least partially.

At this point, no final recommendation about the compensation mechanism can be made. Three alternatives can be considered, in which the competitive meter operator is included in the compensation mechanism in different ways. Basically, the mechanism should help to drive forward the roll-out of smart metering systems and intelligent meters in Germany. It should also lay the foundations for creating a level playing field for basic and competitive meter operators as well as for minimizing the administrative burden.

Roll-out quota in the European context

Under the current legal framework, Germany wants to install 24 million intelligent meters and smart metering systems for power and gas. This scenario only comprises mandatory installations according to the current legal framework. Germany is in fifth place in Europe as far as the roll-out of intelligent meters and smart metering systems by 2020 is concerned. In the recommended Roll-Out Scenario Plus according to § 21c (5) EnWG, the amount of mandatory installations increases to 50 million for intelligent meters and smart metering systems and a further 14 million for intelligent gas meters by 2029. Therefore, Germany will climb to the top spot in Europe (see Table 14).

Table 14: Targeted number of intelligent meters rolled out in Europe

Country	Responsible for roll-out	Focus	Timeframe for nation-wide roll-out	Number of intelligent meters
Germany Roll-Out Scenario Plus	Meter operator	Electricity and gas Electricity smart metering system: ▶ New and renovated buildings, ▶ Households and small businesses with a consumption > 6,000 kWh/a ▶ EEG and CHP facilities (old and new) ▶ Controllable energy applications according to § 14a EnWG Additionally: Installation of intelligent meters which can be integrated in a BSI Protection Profile-compliant communication system during the regular replacement of meters after 16 years	2012 - 2029	Power: ~50m Gas: ~14m
France	Grid operator	Power (conceived for gas) Households and small businesses	2013-2018	Power: ~35m
Italy	Grid operator	Power and gas Households	Strom: 2001-2011 Gas: completed 2016	Power: ~32m Gas: 21m
Great Britain	Supplier	Power and gas Households and small businesses	2014 - 2019	Power: ~27m Gas: ~23m
Spain	Grid operator	Power	2010-2018	Power: ~26m
Netherlands	Grid operator	Power and gas Households and small businesses	2014-2020	Power: ~7.7m Gas: ~6.9m
Sweden	Grid operator	Power Households	2006-2009	Power: ~5.1m
Ireland	Grid operator	Power and gas Households and small businesses	2015-2019	Power: ~2.2m Gas: 0.6m

Source: Ernst & Young

Appendix:

I. Definition of terms

The basic terms in the context of intelligent meters and smart metering systems are defined as followed:

Terms	Definition
Communication component	Unit for the communication connection, normally a chip or SIM card
Communication system	Set of modules and technologies in a smart metering system which is required for the data transfer – incl. all necessary data transfer components such as antennae, data concentrators etc.
Communication technology	Wireless or by cable technology for the transfer of (measurement) data
Conventional meter	Any meter (measuring instrument) not measuring actual energy consumption and actual time of usage, such as Ferraris meters.
End consumer	Individual and corporate bodies according to § 3 No. 25 EnWG who buy energy for own consumption
Feed-in management	Feed-in management includes a temporary reduction of the feed-in-load of renewable energy, CHP, methane plants to the grid.
General fee	General fee for meter operation, measurement and billing which will be supplemented by an additional system charge.
Grid efficiency	Function and impact of smart metering systems which have a positive effect on the grid area (grid planning, grid management and grid operation)
Household consumers	End consumers according to § 3 No. 22 EnWG who use energy mostly for own consumption or for professional, agricultural or commercial purposes with a consumption less than 10,000 kWh p.a.; in the context of this report, the terms "customer," "consumer" and "end consumer" are used interchangeably.
Intelligent meter	Upgradeable meter according to § 21c (5) EnWG measuring the current energy consumption and the current usage time. An intelligent meter can be expanded by a certificated smart meter gateway to a smart metering system which is compliant with the BSI Protection Profile and therefore securely integrated in a communication system. For this, the intelligent meter needs a communication interface enabling communication compliant with the BSI Protection Profile to a certificated smart meter gateway. This interface must be operated with a SMGW. Phase 1: intelligent meter As long as the meter has not been upgraded with a SMGW to a smart metering system, the MID does not allow the specification of any particular data protection and privacy requirements for the communication link of the metering system. Therefore, in-house communication must fulfill general data security and privacy requirements such as the encrypted transfer of data. Furthermore, the communication link must be unidirectional, exclusively informing the end customer without any connection to the grid. Otherwise, the intelligent meter would be compromised and no longer able to be integrated into a smart metering system which is compliant with the BSI Protection Profile. As soon as bi-directional communication or a communication link to a third party is implemented, a Smart Meter Gateway must be installed enabling such connections. Phase 2: Upgrading to a smart metering system By integrating an intelligent meter into a smart metering system, which is compliant with the BSI Protection Profile, an in-house communication link will be established by a Smart Meter Gateway allowing a display in the apartment of the end consumer to be connected with the metering system compliant with the BSI Protection Profile. According to the BSI Protection Profile, the smart metering system must be operated by a SMGW-Admin in order to prevent the metering system and Smart Meter Gateway could be compromised. An intelligent meter must be transformed into a Protection Profile-compliant metering system if secure integration into a communication network, i.e. a connection to third parties, especially to smart grids, should be enabled.

Individual meter	Meter according to the EU Energy Efficiency Directive that measures power, gas, heat or water consumption for an end consumer
Meter	Measuring instrument.
Measuring system	Communication-integrated measuring instrument, meaning metering systems to record electrical energy that shows the current energy consumption and the current usage time (§ 21d EnWG) – applies accordingly to gas, heat and water
Modern metering system	Metering system to record electrical energy that shows the current energy consumption and the current usage time, but not fulfilling the requirements of the BSI Protection Profile and Technical Guidelines. In this report, such systems are also referred to as smart meters.
Smart market	Smart market is the area outside the grid where energy or derived services are traded on the basis of available grid capacities
Smart meter	Modern metering system.
Smart meter gateway	Devices or units responsible for collecting and processing meter data, and the communication possibilities for devices in the LMN, devices within the LAN (such as controllable local systems) for protection against attacks from the WAN and to provide the necessary cryptographical primitive (together with security modules).
Smart meter gateway administrator	Responsible organization which installs, configures, controls the gateway
Smart metering systems	Metering systems according to § 21d (1) EnWG, consisting of smart meter gateway and one or several connected meters.
System charge	Independent component of the general charge that must be paid by all end consumers from the beginning of the roll-out for establishing new systems and ongoing operation of conventional meters.
System type	Physical component (current structure) of a smart metering system, consists of a meter, SMGW and communication module in Germany.
Time-critical applications	Control signals must be sent and received within 15 minutes.

II. Glossary

Abbreviation	Definition
A	Annum (year)
BPL	Broadband power line
BSI	Bundesamt für Sicherheit in der Informationstechnik (Federal Agency for Security in Information Technology)
CAPEX	Capital expenditure
CBA	Cost-benefit analysis
CCS	Carbon capture and storage
CLS	Controllable local system
CO_2	Carbon dioxide
DSL	Digital subscriber line
EEG	Erneuerbare-Energien-Gesetz (Renewable Energy Act)
EC	European Community
EnWG	Energiewirtschaftsgesetz (Energy Industry Act)
etc.	et cetera
EU	European Union
GmbH	Gesellschaft mit beschränkter Haftung (limited liability company)
GPRS	General packet radio service
ISO	International Organization for Standardization
IT	Information technology
Kbps	Kilobits per second
kW	Kilowatt
kWh	Kilowatt hour
CHP	Combined heat and power
KWKG	Kraft-Wärme-Kopplungsgesetz (Act on Combined Heat and Power Genera-tion)
LMN	Local metrological network
LTE	Long Term Evolution
MID	Measuring Instruments Directive
m	million
NPV	Net present value
OPEX	Operational expenditure
p.a.	per annum (per year)
PC	Personal computer
PLC	Power line
PV	Photovoltaic
SIM	Subscriber identity module
SMGA	Smart meter gateway administrator

SMGW	Smart meter gateway
StromNEV	Stromnetzentgeltverordnung (Electricity Grid Fee Regulation Ordinance)
TC	Telecommunication
TLS	Transport layer security
UMTS	Universal Mobile Telecommunications System
WAN	Wide area network

III. Data reconciliation and market survey

In the context of this report we talked to the following companies and associations:

BDEW Bundesverband der Energie- und Wasserwirtschaft e.V. / e.descom Telekommunikation GmbH
BITKOM Bundesverband Informationswirtschaft, Telekommunikation und neue Medien e.V.
BRUNATA Wärmemesser GmbH & Co. KG
BSI (Bundesamt für Sicherheit in der Informationsverarbeitung)
Deutsche Telekom AG
Dr. Neuhaus Telekommunikation GmbH
DREWAG Netz GmbH
E. ON
E.ON Metering GmbH
E-Energy Begleitforschung B.A.U.M. Consult GmbH
EMH metering GmbH & Co. KG
EnBW Operations GmbH
Energieversorgung Halle Netz GmbH
ENSO NETZ GmbH
EWE NETZ GmbH
GÖRLITZ AG
Hager Electro GmbH & Co. KG
Heinz Lackmann GmbH & Co. KG
ista Deutschland GmbH
Itron Zähler & Systemtechnik GmbH
Landis+Gyr GmbH
Mainova AG
Pfalzwerke Netzgesellschaft mbH
RheinEnergie AG
Rhein-Ruhr Verteilnetz GmbH
RWE Deutschland AG / Projekt E-DEMA
SAP DEUTSCHLAND AG & CO. KG
Siemens AG
smartOPTIMO GmbH & Co. KG
SMGA
Städtische Werke Netz + Service GmbH
Stadtwerke Duisburg Netzgesellschaft mbH

Stadtwerke Düsseldorf Netz GmbH
Stadtwerke Erfurt GmbH
Stadtwerke EVA Huntelal
Stadtwerke Fellbach GmbH
Stadtwerke Mainz Netze GmbH
Stadtwerke Speyer GmbH
Stadtwerke Weilburg GmbH
Stromnetz Hamburg GmbH
SWM Infrastruktur GmbH
Syna GmbH
Theben AG
Thüga AG
Trianel GmbH
umetriq Metering Services GmbH
Utilicount GmbH & Co. KG
Vattenfall Distribution Berlin GmbH
Verband der Anbieter von Telekommunikations- und Mehrwertdiensten e.V. (VATM) / Power PLUS Communications AG
Verband kommunaler Unternehmen e.V.
Vodafone GmbH
VOLTARIS GmbH
WSW Netz GmbH

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