SOGNO

D6.5 v1.0

Recommendations to policy makers, enterprises (business model design) and other stakeholder groups for designing regulatory frameworks and incentive systems, including CSR guidelines for business models in the energy sector

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Abstract

The deliverable develops recommendations based on the SOGNO project results that concretely address Distribution System Operators, European Policy Makers and National Regulators, Consumer Organisations and Environmental Organisations but are relevant for all ICT and energy sector actors including small- and medium-sized enterprises and electricity end-users. The recommendations aim at encouraging business model innovation in the smart grid service market in a way that it brings societal, environmental and economic benefits.

Keyword list

Business model innovation, Regulatory framework analysis, economic and societal benefits of smart grid services, SOGNO recommendations

Executive Summary

SOGNO envisions an IOT platform for smart grid services to be developed as an open source solution cost-effective, seamless and secure power supply for consumers that become active players while supporting Distribution System Operators (DSOs) in their system responsibilities. The SOGNO solution enables business model innovations for both smart grid service providers and Distribution System Operators (DSOs) as service recipients, as well as infrastructural changes, which affect a large number of sectoral actors (e.g. consumers, retailers, aggregators, DSOs, Transmission System Operators, energy producers, etc.). The project has gathered knowledge on trialling innovative software solutions for DSOs in the field guided from SOGNO-specific economic, technical and societal research while the findings have frequently been validated through consultations with various stakeholder groups.

The present deliverable develops recommendations based on the SOGNO project results that concretely address DSOs, European Policy Makers and National Regulators, Consumer Organisations and Environmental Organisations but are relevant for all ICT and energy sector actors including small- and medium-sized enterprises and electricity end-users.

The recommendations presented within the Deliverable serve the following purposes:

- Contribute to the development of an innovative market environment for cloud-based smart grid services based on cutting-edge Information and Communication Technology (ICT) which is expected to encourage business model innovation, substantive knowledge gains and job creation in the European Union
- Contribute to the development of a European-wide regulatory framework which removes the barriers for DSOs to use “Software-as-a-Service”
- Encourage DSOs to try mastering the complex challenges of energy transition with the help of smart grid services
- Emphasise the importance of socially sustainable electricity supply in terms of ensuring that the benefits of using smart grid services are fairly distributed along the value chain and do not lead to increasing in electricity prices.

The recommendations are backed from an investigation regarding the effect of smart grid service deployment on DSOs’ business models under varying regulatory conditions. Under conservative assumptions regarding the benefits of smart grid service deployment, the results show the potential of smart grid service deployment to decrease total system cost and therewith network tariffs and eventually consumer electricity prices.

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1. Introduction

Service Oriented Grid for the Network of the Future (SOGNO) is a 30-month project which has started in January 2018 and is funded by the European Commission in the Work Programme Horizon 2020 under the topic 'Next generation innovative technologies enabling smart grids, storage and energy system integration with increasing share of renewables: distribution network'. SOGNO trialled the implementation of cloud-based system awareness services and autonomous self-healing services for advanced distribution network management.

1.1 Motivation and Purpose of the Deliverable 6.5

Distribution network management based on cloud-based smart grid services - as envisioned in SOGNO - is a reasonable means for Distributor System Operators (DSOs) to cope with current operational challenges that arise from volatile, bi-directional electricity flows and decreasing simultaneity of electricity consumption and production as well as extreme weather conditions. The business of DSOs and the overall energy system can benefit from DSOs conducting an active electricity distribution management approach which is about adaptive, intelligent grid operation with proactive voltage and Distributed Generation (DG) unit control, automatic fault recovery, automated reaction to unusual transient behaviour and real-time grid-monitoring driven ICT-connected measurement devices [1]. Hence, reliability and continuity of electricity supply as well as successful integration of renewable energy sources are increasingly dependent on DSOs' grid data processing capabilities.

However, current market and regulatory conditions do not comprehensively incite DSOs to establish those capabilities by utilising (cloud-based) smart grid services but partly favour investments in reinforcement or distribution network expansion for situations in which both smarter grid management and e.g. reinforcement would lead to the same goal. However, even if the evaluation of benefits of the SOGNO solution lead DSOs to perceive the advantages of smart grid service utilisation, this type of solution is different from the traditional view of grid management, and therefore it needs first to conquer the trust of DSOs to be successful. Hence, the utilisation of cloud-based smart grid services is potentially perceived as risky from the perspective of DSOs. This can be because service-induced improvements of operational performance are less certain to pay out financially than investments in the regulatory asset base are and because structural changes in the value chain for smart grid services - from software installations to existing Supervisory Control and Data Acquisition (SCADA) systems to decentralised procurement of cloud-based services via "Internet of Things" (IoT) platforms - can bear significant switching costs, particularly for large DSOs with business processes being highly integrated. Moreover, within the DSO community, it exist concerns over edge-computing cloud-based services in terms of cybersecurity, systems availability and manageability. Hence, DSOs can benefit from market conditions that allow them to flexibly test and potentially deploy advanced smart grid services - which possibly better fit their requirements than those that can be obtained via the existing SCADA system - in parallel to their existing distribution network management system without affecting its functioning and without upfront investments. For this purpose, SOGNO follows the approach of an open and modular software architecture for the deployment of advanced smart grid services.

The SOGNO platform fosters easy integration with DSOs' legacy systems and relating data exchange for improved grid operation. Additionally, it aims at seamless integration with other platforms for additional data exchange processes or services and to offer power system data to other sectors (smart cities, smart buildings, etc.). This is conducive to the development of an innovative market environment and business model innovation, as it facilitates trial-and-error learning for network operators and lowers market entry barriers for manufacturer of measurement devices and software developers while it promises overall economic, environmental and societal benefits (see Deliverable 6.4). Accordingly, this Deliverable develops recommendations to encourage alternative value chain structures for smart grid service supply and the development of corresponding business models based on the learnings from the SOGNO project.

1.2 Related Project Work and Outline of the Work Report

The recommendations presented in chapter 3, on which background information and corresponding analysis is provided in chapter 2, result from iterative feedback and information exchange processes with various stakeholder groups and related (plenary) discussions involving the whole SOGNO consortium. The foundations for the development of those were the lessons learned from the SOGNO field trials (work package 5) and the consultations of various stakeholder groups (work package 7) as well as SOGNO-specific technical (work package 1-4) and economic-/sustainability- and regulatory research (work package 6).

1.3 How to Read this Document

While the document has been written trying to make it as self-consistent as possible, to fully capture the underlying aspects behind the value chain and innovative business models presented in this paper, an overall view of the concepts developed in the SOGNO project is needed. In particular, additional Deliverable that could be helpful to grasp a comprehensive view of the innovative concepts promoted in the project are:

- D1.1 – Scenario & architectures for stable & secure grid (M12): it includes a description of power system scenarios investigated in the project, with motivations for the services presented in this deliverable for current and future distribution grids.
- D4.1 – Definition of the overall SOGNO system architecture (M10): it provides the high-level overview of the modular implementation of the IoT platforms used as a reference for the flexible integration of the SOGNO services
- D5.2 Report on the outcome of the SOGNO Field Trials and laboratory tests (M30): it provides practical guidelines from the SOGNO Field trials relating to the categories of data communications as well as planning and installation of services are summarised here
- D6.1 – Analysis of SOGNO results regarding standards and regulations (M30): it provides additional insights on SOGNO stakeholder interactions and presents the project results from the perspective of regulation and standardisation

2. The SOGNO Solution

2.1 SOGNO-trialled Value Chain Design

Conventionally, DSOs access distribution network management services through installing software to their existing Distribution Network Management (DNM) system. In SOGNO, a legacy system (SCADA) with central procurement of measurement devices and monolithic software from one vendor is contrasted with the approach of a distribution management system based on an open platform with open interfaces, so that any value chain partner (e.g. hardware and software suppliers, prosumers, flexibility traders, etc.) could be integrated. As demanded by the DSO, the platform can be either run in a cloud or on the internal servers of the DSO. That is, service-demanding DSOs are to choose between remotely-hosted (cloud-based & open) IOT-platforms and self-hosted IOT platforms via which different service modules can be provided. For instance, the SOGNO solution encompasses the following service modules:

- State Estimation (SE)
- Power Quality Evaluation (PQE)
- Load- and Generation Forecast (LGF)
- Power Control (PC)
- Fault Location Isolation and Service Restoration (FLISR)

The SOGNO-trialled approach is to provide DSOs with flexible access to distribution network management services (e.g. with system awareness services and autonomous self-healing services) via (potentially open) IOT platforms on which multiple algorithm implementers can install grid management services as modules and the DSOs can choose the modules that benefit them most, The SOGNO service modules all have particular potentials to improve DSOs' operational performance (see Deliverable 6.4).

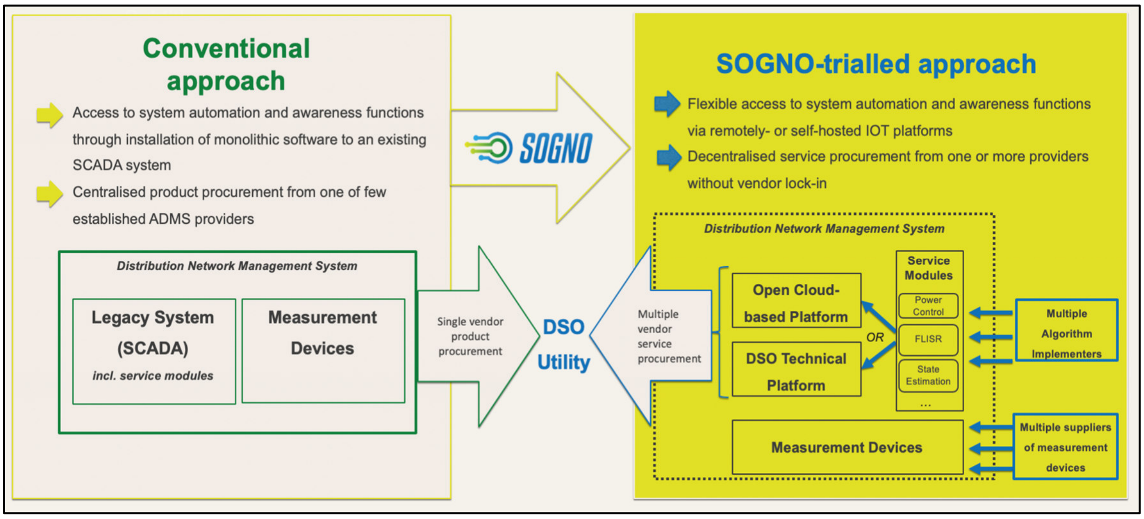

Figure 1: SOGNO-trialled business model changes

Applied in practice, the SOGNO-trialled concept enables DSOs to easily deploy and flexibly test different distribution network management services without upfront investment outlays, as the distribution network management services to be accessed are financed through periodical (e.g. monthly or yearly) payments ("Software-as-a-Service (SaaS)"). Moreover, the DSO could obtain the corresponding measurement devices from multiple manufacturers integrated in the SaaS package or separately purchased. Hence, the cost structures of DSOs switch from Capital Expenditure (CAPEX)-type outlays (relatively high one-off irregular payments) to OPEX-type payments (regular payments of the same amount). Whereas a modular and open software architecture - as trialled in SOGNO - enables DSOs to choose between software and hardware components from multiple vendors in order to obtain those that meet their requirements at highest quality, conventional procurement of so called Advanced Distribution Management Systems (ADMS, SCADA system, software, measurement devices) is made via a single supplier of the entire package (e.g. big manufacturers as Schneider or Siemens) with the DSO being 'locked-in' by one vendor. From an overall economic perspective, the arrangement of activities and resources as proposed by the SOGNO-trialled business models, is a more decentralised one.

That is, while DSOs conventionally procure software and hardware products from one single vendor, SOGNO envisages DSOs to procure software (and potentially (integrated) hardware) services from multiple vendors.

The market diffusion of the SOGNO platform and SOGNO service modules is depicted by two stages that imply different time frames, changes in mobile internet access standard and different degrees of decentralisation.

SOGNO Mark-1 solution (present and short-term future)

The SOGNO Mark-1 solution (Figure 2) concerns the present and short-term future. At this stage, DSOs use the SOGNO services to obtain additional AI-enhanced system awareness and autonomous self-healing features next to their legacy system (e.g. SCADA) which they can use in parallel. Within this rather centralized solution the SOGNO services are deployed on a centralised server in DSOs' systems. All communications are based on 4G or wire and artificial intelligence is used for some services in some IoT components to bring additional functionalities. All services can run with the Mark-1 solution, but attention should be paid to effects of latency, reliability and security.

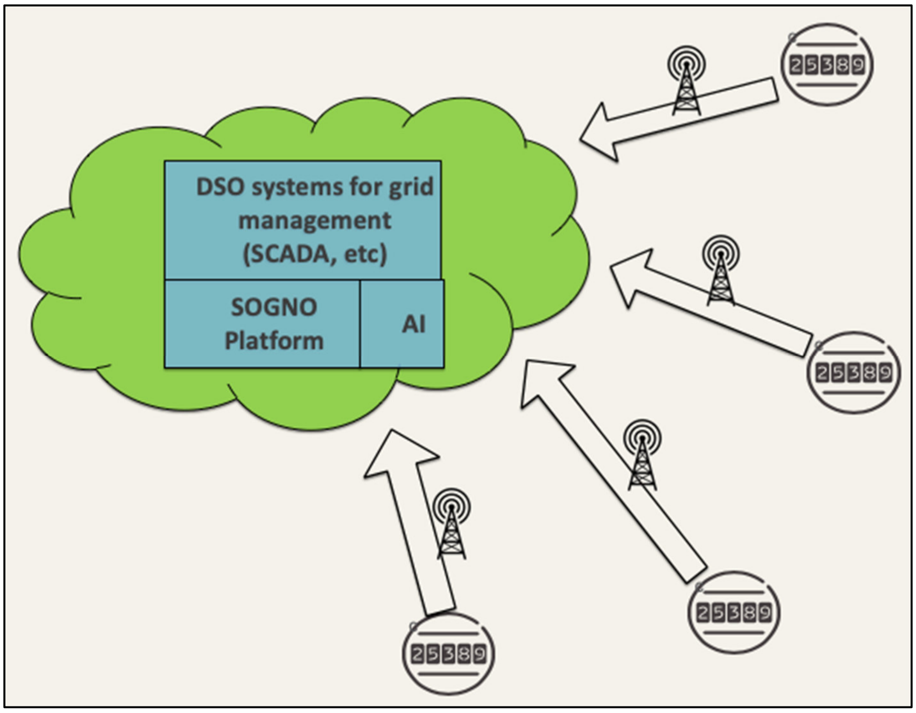

Figure 2: SOGNO Mark-1 Solution (present and short-term future)

The potential benefits of SOGNO Mark-1 solution [2–6] are:

- Operational performance improvements:
  - Better operational decision-making
  - Lower curtailment and higher shares of Renewable Energy Sources (RES)
  - Lower grid asset stress
  - Lower maintenance
  - Less overload conditions
  - Less power failures
  - Financially: Lower total system costs and lower penalties/higher rewards
- Data security: Data stored on DSO-controlled servers only
- Reduction of dependencies: DSOs building up own competencies in various areas:
  - ICT
  - Optimisation
  - Deployment of advanced measurement devices
  - Business model innovation: ability to offer the full network optimisation package (incl. Demand Side Management (DSM) and load aggregation) out of one hand
- Efficient tailoring of the services to particular DSOs requirements
- Lower upfront investment through service-oriented procurement of functionalities

SOGNO Mark-2 solution (medium or long-term future)

The SOGNO Mark-2 solution (Figure 3) concerns the medium or long-term future. At this stage, DSOs' distribution management system is considered to be entirely based on the SOGNO reference architecture with independent modules provided by different vendors. According to this decentralized solution in the edge cloud, central DSO servers are only used for supervision and visualization. With 5G being the dominant mobile internet access standard enabling high performance communications, services can exploit low latency, network slicing and increased reliability as compared to Mark-1 solution. Artificial Intelligence is fully integrated in services and IoT platform to raise DSOs' performance to a new level.

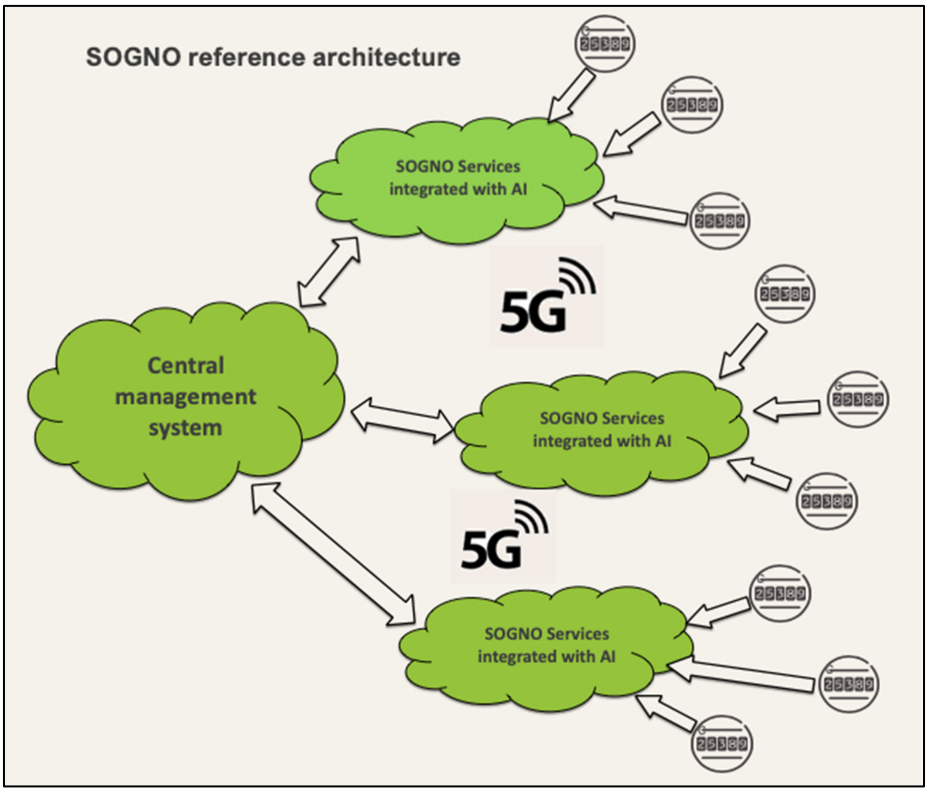

Figure 3: SOGNO Mark-2 Solution

The potential benefits of SOGNO Mark-2 solution [2–6] are:

- Further operational performance improvements as compared to Mark-1:
  - Better operational decision-making
  - Lower curtailment and higher shares of RES
  - Lower grid asset stress
  - Lower maintenance
  - Less overload conditions
  - Less power failures
  - Financially: Lower total system costs and lower penalties/higher rewards
- Facilitates following the rapid technological developments and business model innovation (DSM, Load aggregation, etc.)
- (Flexible) access to more efficient and advanced services (and often also hardware)
  - Optimization and diagnostics
  - Measurement and sensors
- IT activities (e.g. maintenance, backups, security and installations) are executed by external experts
- Less capacity restrictions
- No upfront CAPEX requirements
- Especially providing shortly large scale computing capacity needed at short notice is less expensive due to sharing it via the cloud service provider
- Techniques like substation virtualisation allow the optimisation of servers and therefore the reduction of energy-costly features

The potential risks of the SOGNO Solutions Mark-1 or Mark-2 are:

Decentralised procurement of network management services entails switching costs and (initially) higher transaction costs for DSOs. The higher the integration of DSOs' business processes into its existing SCADA system, the less likely it is they will procure network management services from alternate supplier(s). For instance, for a large DSO like ESB Networks, whose processes are already highly integrated with an existing DNM "it would be extremely unlikely (…) that it replaces over time its existing SCADA / DNM and services, with edge-computing cloud-based services from alternate supplier(s). (…) Moreover, when considering stand-alone edge-computing cloud-based services per se (e.g. SOGNO's State Estimate or FLISR), the DSO has significant trust concerns over the cloud. These concerns primarily relate to cybersecurity, systems availability and manageability. While 5G will bring advances in data communications, it won't remove the DSO concerns that exist over availability and manageability for core control systems. While ESB Networks believes that 5G will have a major role in improving the communication of data and information to field operatives hand-held mobile devices, it won't remove mis-trust concerns over cloud-based services that integrate directly with SCADA / DNM" (statement from a technical expert in ESB Networks).

The alternative value chain structure is promising, since it potentially increases public knowledge (SOGNO platform is considered an open-source one) and competition among hardware and software vendors. As a consequence, the average quality of hardware units and software services is expected to increase while also the CAPEX of DSOs can be expected to decrease with lower investment payments and lower (equity and debt) interest rates through low-risk service-oriented procurement.

A generally declining price level or higher quality level of system awareness services and autonomous self-healing services entails lower overall costs for DSOs to maintain network operations. Additionally, the purposive deployment of innovative system awareness services and autonomous self-healing services itself increases the reliability and continuity of supply. Hence, the DSOs potentially gain financial benefits which can be partially transferred to the end-users as there are less network charges necessary to be collected from them to finance DSOs' allowed revenues (based on CAPEX, depreciation, non-controllable OPEX and quality-based bonusses or penalties). Whereas Deliverable 6.4 outlines in more detail how the SOGNO business models including SOGNO service deployment itself specifically effect economic-, DSO-business-related, social-, and environmental parameters, the next section analyses the SOGNO solution against the background of existing regulations to derive recommendations (chapter three).

2.2 Regulatory Framework and Analysis

Most commonly, regulatory frameworks allow DSOs to obtain "a maximum total allowed revenue (TAR) in return for […] (electricity distribution) services in one year, with the TAR in one year being equal to the TAR in the previous period corrected for (i) a requirement on improved efficiency performance, (ii) change in overall price level (inflation), and (iii) optional compensation schemes for adverse developments in demand. […] (The TAR) in the starting year is dependent on the total regulat(…)[ory] asset base (RAB), the weighted average cost of capital and the operational expenditures [7]." Parts of the OPEX are non-controllable (e.g. usage of higher-level grid) and fully compensated while other parts are controllable (e.g. maintenance) and only compensated when not considered as inefficient by the regulator. Inefficient OPEX directly reduce DSOs' income. In this way, regulators determine DSOs' revenue streams to allow DSOs to cover non-controllable OPEX and controllable but efficient (as compared to certain benchmarks) as well as CAPEX including the returns to shareholders and depreciation of assets [8]. Figure 4 generally conceptualises DSOs' business models [7]. Although regulatory frameworks vary from country to country, they usually bridge DSOs' overarching operational goal attainment (cost-efficiency, reliability and continuity of supply as well as minimal RES curtailment) and DSOs' economic success. In two-thirds of all European countries, DSOs are rewarded or penalised by the regulators according to their operational performance in terms of continuity of supply [9]. Hence, DSOs' business success depends on the volume of compensated CAPEX, the share of compensated expenditures in relation to total expenditures, its operational (cost-) efficiency and its measured quality of supply.

The TAR is funded via network tariffs (e.g. connection charges, use-of-system charges) that constitute a share of the electricity price and are collected through clients' final electricity bills (see figure 8, taken from [10]). Network tariffs are based on the costs incurred by DSOs for the operation, maintenance and expansion of the networks. The fee system determines how the allowed revenues are distributed among the user groups and shall ensure that these costs are passed on to network users in a non-discriminatory and, as far as possible, appropriate manner [11]. The main cost driver is the simultaneous annual maximum load of the network, as this is most relevant for grid dimensioning [11]. In both Germany and Ireland, network tariffs account for around 25% of the average electricity price [10,12]. In recent years, the trend of increasing electricity prices was driven by increasing network tariffs that were granted by the regulators because the challenges (e.g. volatile, bi-directional electricity flows and decreasing simultaneity of electricity consumption and production) DSOs have to master were considered to justify higher network operation costs.

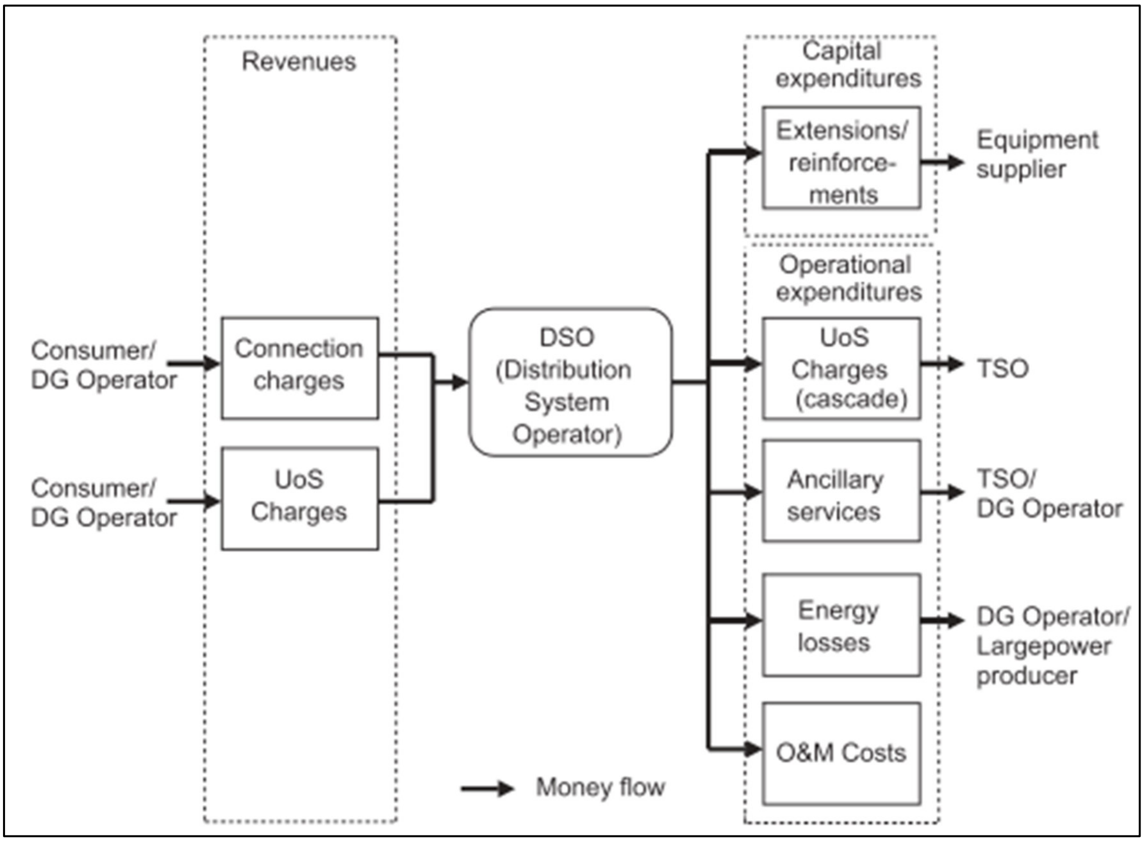

Figure 4: Conceptual representation of DSOs' business model (taken from [7]**)**

The present deliverable analyses effects of both the SOGNO Mark-1 and Mark-2 solutions on a DSO's business model respectively considering whether regulatory changes are implemented that allow DSOs' to offset the cost of smart grid services in order to identify societally beneficial scenarios. In this regard, we analyse the outcome in a total of 5 scenarios (see Table 1). That is, we respectively compare a Baseline model without any smart grid services being purchased by the DSO with models for which we expect the financial outcome of grid operation to change according to the stage (Mark-1 or Mark-2) of the SOGNO solution being implemented and according to the regulatory changes being potentially made.

Table 1: Models

Baseline	SOGNO Mark-1 solution (present and short-term future)		SOGNO Mark-2 solution (medium or long-term future)	
	no regulatory changes	the cost for purchasing cloud-based smart grid services are compensated by the regulator	no regulatory changes	the cost for purchasing cloud-based smart grid services are compensated by the regulator

We respectively calculated the models for a total of 5 scenarios. The scenarios imply changes in the models as delineated in Table 2.

Table 2: Scenarios

Scenarios	Properties
Basic	• Operational performance improvement through smart grid service utilisation → while reference System Average Duration Index (SAIDI) is 4, SAIDI is expected to rise from 7 in the Baseline model to 5 when Mark-1 solution is implemented to 3 when Mark-2 solution is implemented • Annual costs for purchasing smart grid services of 10,000 € in any than the Baseline model • No changes in other OPEX categories
Less CAPEX	• All assumptions from the Basic model plus: • Smart grid services substitute investments in RAB in a way that 1 € of OPEX incurring from smart grid service procurement substitutes an investment of 100 € in the RAB
Inefficient Baseline	• OPEX in the Baseline model are considered as being partly inefficient and compensated to only 90% • Cost cuts and cost-efficiency improvement over time o Implementation of Mark-1 solution leads to a cost cut in OPEX (excl. smart grid services) by 5% as compared to the Baseline model and these expenditures to be compensated to 95% o Implementation of Mark-2 solution leads to a cost cut in OPEX (excl. smart grid services) by 10% as compared to the Baseline model and these expenditures to be compensated to 100% • No SAIDI improvement • No changes in CAPEX as compared to the Basic scenario
Risky Cloud	• All assumptions from the Basic model plus: • Higher cost of capital (8%) as compared to other scenarios (5%) as smart grid service utilisation is assumed to imply higher risk from an investor's perspective
Less TOTEX	• All assumptions from the Basic model plus: • Smart grid service utilisation substitutes investments in regulatory asset base to the same extent as in the "Less CAPEX" scenario • Smart grid service utilisation leads to cost cuts to the same extent as in the "Inefficient Baseline" scenario while the OPEX are all considered as efficient and hence to be compensated to 100%

In our analysis, we consider the business of a DSO over a five-year regulation period (see Table 3). The DSO in our model is assumed to serve 80.000 clients with an assumed consumption of 2,000 KWh each. The initial regulatory asset base is suggested to amount 100,000,000 € with an average lifetime of asset of 45 years over which the assets are assumed to be linearly depreciated. We assumed the regulatory authority to compensate the DSO 100% of its total planned investments in the regulatory asset base which are assumed to amount 11,632,000 €

($CAPEX_0$). The relation of the total RAB and net investments in the regulation period are estimated based on the "Decision on DSO Distribution Revenue for 2016 to 2020" from the Commission for Energy Regulation, Ireland [12].

The rate of return which corresponds to the regulatorily granted Weighted Average Cost of Capital (WACC) is suggested to amount 5%. The annuity of capital requirement (compensated CAPEX per annum over 5-year (T) regulation period) is given by

$$CAPEX\ annuity_t = CAPEX_0 * \frac{(1+WACC)^T * WACC}{(1+WACC)^T - 1} \quad [12–14] \qquad (1)$$

That is, for the underlying Basic Scenario, the annuity of capital requirement amounts

$$11{,}632{,}000 * (1.05^5 * 0.05) / (1.05^5 - 1) = 2{,}686{,}698.85\ € \qquad (2)$$

while the annual net investments (excl. shareholder return) in the regulatory asset base (for e.g. physical grid extension or reinforcements) amount 2,558,760.81 €.

Besides compensated CAPEX, DSO's allowed revenues are composed of compensated OPEX - the OPEX considered as efficient by the regulator -, depreciation allowed on the CAPEX, and a quality of supply incentivisation element. The quality element is calculated based on the applicable quality regulation in Germany [15]. That is, the quality element is a calculated according to the formula containing three factors which are multiplied. The estimated value of lost load, the number of clients served and the difference between reference SAIDI lost and actual SAIDI in a given year. Hence, the quality element turns into positive reward when the actual SAIDI is greater than the reference SAIDI but incurs penalty costs for the DSO when the actual SAIDI is lower than the reference SAIDI. Smart grid service utilisation when Mark-1 or Mark-2 solution are implemented are assumed to cost an annual service fee of 10,000 € which are reported separately in our calculation scheme (Table 3). When we consider the solutions as being accompanied by regulatory changes which lead to the DSO being compensated for the procurement costs of the smart grid services, the service fee of 10,000 € per annum covered by the revenues while it otherwise decreases DSO's annual cash flow correspondingly. In addition, we assume that DSO's OPEX incurred a total of 826,000 € for ancillary services, energy losses and other operating and maintenance costs. When the OPEX are considered as efficient by the regulator, (e.g. as modelled in the Basic scenario) they are compensated to 100%.

For the evaluation of the models, we basically consider two relevant parameters. First the Net Present Value (NPV) of DSOs' allowed revenues which is also used in the Ireland context to express the advantageousness of DSO compensation [12]. Second, the annual network tariffs as they - funded via clients' electricity bills - are associated with the social benefits of grid investment and optimisation [12]. Without considering any differences in taxation schemes, debt capital structure and debt capital interest rate, the Net Present Value of DSOs' allowed revenues can be expressed as follows :

$$Net\ Present\ Value\ of\ DSOs'allowed\ revenue = \sum_{t=0}^{t=T} \frac{Net\ Cash\ Flow_t = (Allowed\ revenues_t - Net\ investment\ in\ RAB_t - OPEX_t)}{(1+WACC)^t} \quad [12–14] \qquad (3)$$

As shown in Figure 5, a change from the Baseline to Mark-1 solution and a change from Mark-1 solution to Mark 2 solution promise the NPV of the modelled DSO's allowed revenues to increase, respectively. Obviously, when the cost of smart grid services (here: 10,000 € per annum) are compensated, the NPV is respectively higher. We conclude that an electricity grid investment project is always higher more beneficial when the DSO implements the more sophisticated solution for the smart grid services while at the same time service costs are compensated by the regulator. In our analysis, not the absolute numbers of the NPV's and network tariffs calculated (the calculation of the models in the "Basic" scenario is exemplarily given in Table 3) but the relation between the NPV's in the different models and scenarios matters. It can be observed that the NPV is always lowest when the use of smart grid services according to the Mark-1 or Mark-2 solution is considered as risky from an investor's perspective (which we simply modelled through a higher discount rate). Hence, in DSOs' decision-making processes, there is a trade-off between reaching improvements of operational performance and corresponding financial gains associated with the implementation of the Mark-1 or Mark-2 solutions and avoiding any risk that is perceived to potentially go along with decentralised (cloud-based) smart grid service procurement.

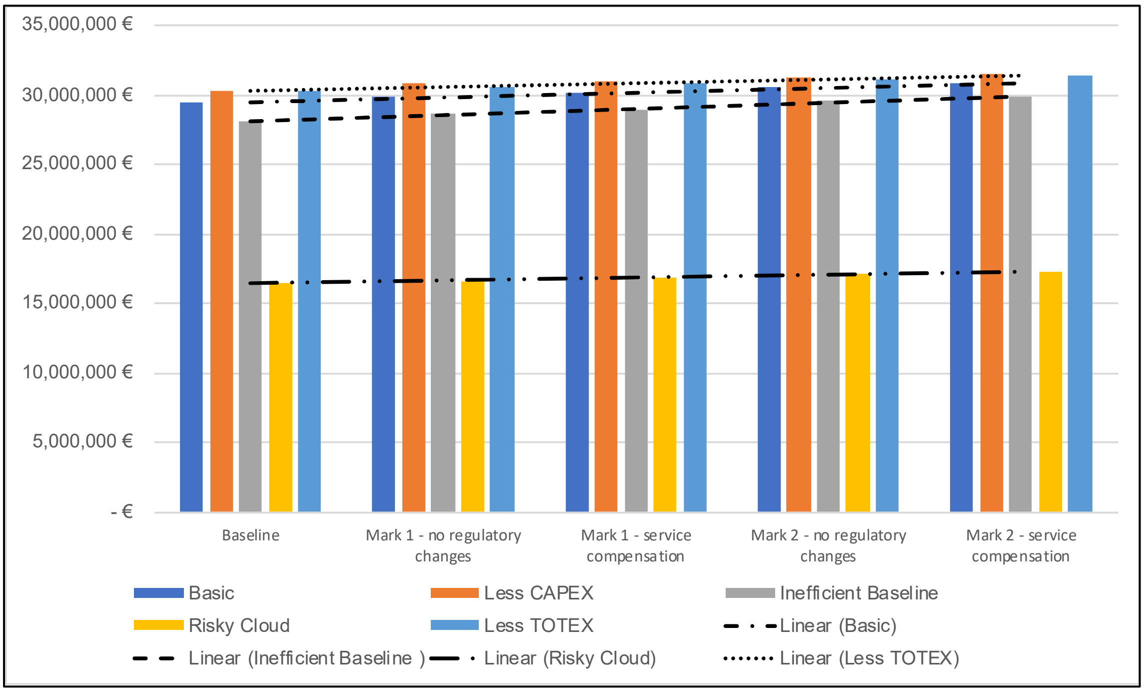

Figure 5: Net Present Value of DSO's allowed revenues

As compared to the Basic scenario, the NPV increases when smart grid service utilisation will not only increase operational performance but also decrease the sum of CAPEX required (Less CAPEX scenario) and the sum of OPEX required (Less TOTEX scenario). Operational performance monitoring and corresponding information exchange between implementation projects for smart grid services is vital to understand the benefits of Mark-1 and Mark-2 solution in practice. The more substantial the amount of public knowledge regarding the benefits and risks of open platform approaches as trialled in SOGNO is, the higher the decision-making quality of both the regulator - in deciding which type of costs are efficient to which extent - and also the decision-making quality of the DSO itself - in deciding on the use of cloud-based smart grid services can be. We can further observe that the potential for financially improving the DSO's business model through the use of smart grid services is highest in the "Inefficient Baseline" scenario (see Figure 6). That is, the more inefficient the cost situation in the Baseline model, the higher benefits can be gained through the implementation of Mark-1 or Mark-2 solutions. In the "Inefficient Baseline" scenario, the changes in NPV are only based on OPEX reductions and associated cost-efficiency improvements according to Table 2, respectively without considering any potential gain in operational performance improvement and associated changes in quality of supply incentive payments. The better the estimates of service-reduced cost reductions are, the more precisely can potential of cloud-based smart grid services be determined. Additional effects on DSOs cash flows from business model innovation, e.g. through load aggregation or Demand Side Management, can also be relevant when considering the business case of particular smart grid service modules that serve those purposes.

From a regulatory perspective, the compensation of smart grid service-related OPEX incentivises DSOs to flexibly test and potentially deploy new smart grid services which are potentially advanced as compared to those that can be obtained via existing SCADA systems. The Clean Energy Package of the European Commission already recommends the so-called TOTEX model (allowance to offset OPEX besides CAPEX) for this purpose, among others. The implementation of the TOTEX model simultaneously requires national regulatory authorities to sensitively evaluate the costs incurred by DSOs and related them to the quality of service and resulting efficiency improvements and derive their decisions on the extent of CAPEX- and OPEX-compensation based thereupon. Regulators are facing a trade-off between increasing the extent of service-related OPEX compensation and reducing the sum of allowances for CAPEX and OPEX according to the potential cost reductions or cost-efficiency improvements that can be expected as a result of smart grid service utilisation when decisions on allowances for expenditures are made.

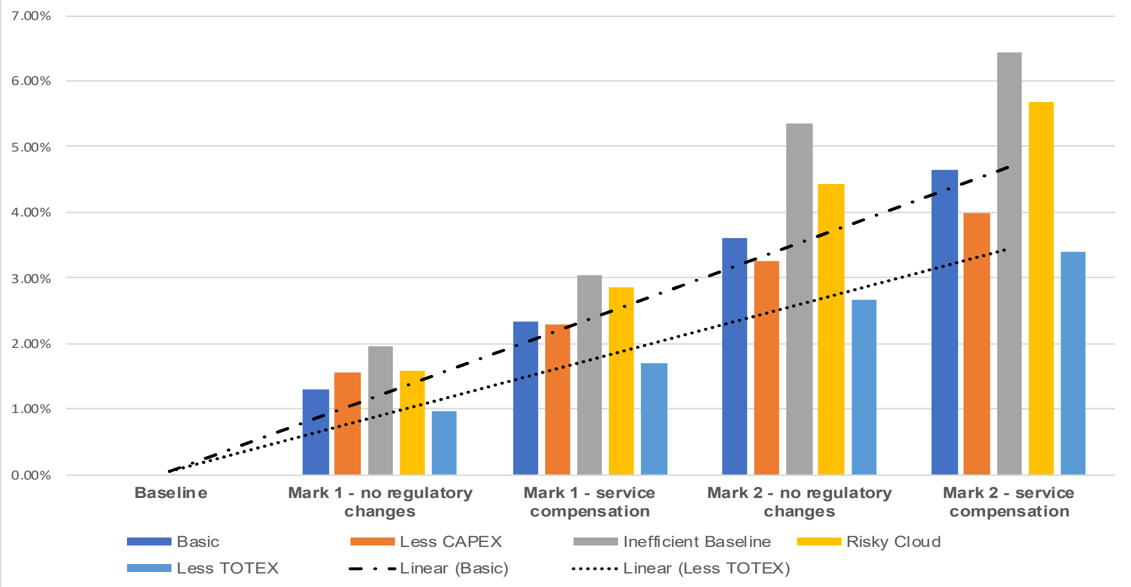

Figure 6: Changes in the Net Present Value of allowed revenues

From a societal perspective, it is important to distribute the potential monetary benefits of using smart grid services (as considered in the NPV analysis) fairly between the DSOs and the clients. Our analysis shows the total allowed expenditures - funded via network tariffs and potentially affecting end-user electricity prices - to increase in the Basic, Inefficient Baseline and Risky Cloud scenarios from Mark-1 to Mark-2 and when respectively comparing the solutions to the Baseline, in which none of the solutions is implemented. Only in the Less CAPEX and Less TOTEX scenarios, the solutions show potentials to successively reduce network tariffs. When service-related OPEX are compensated, annual network tariffs per client (Figure 7) increase. Hence, the regulators should aim at incentivising scenarios which increase the NPV of allowed revenues from an investors perspective while at the same time bearing the potential to reduce clients' network tariffs.

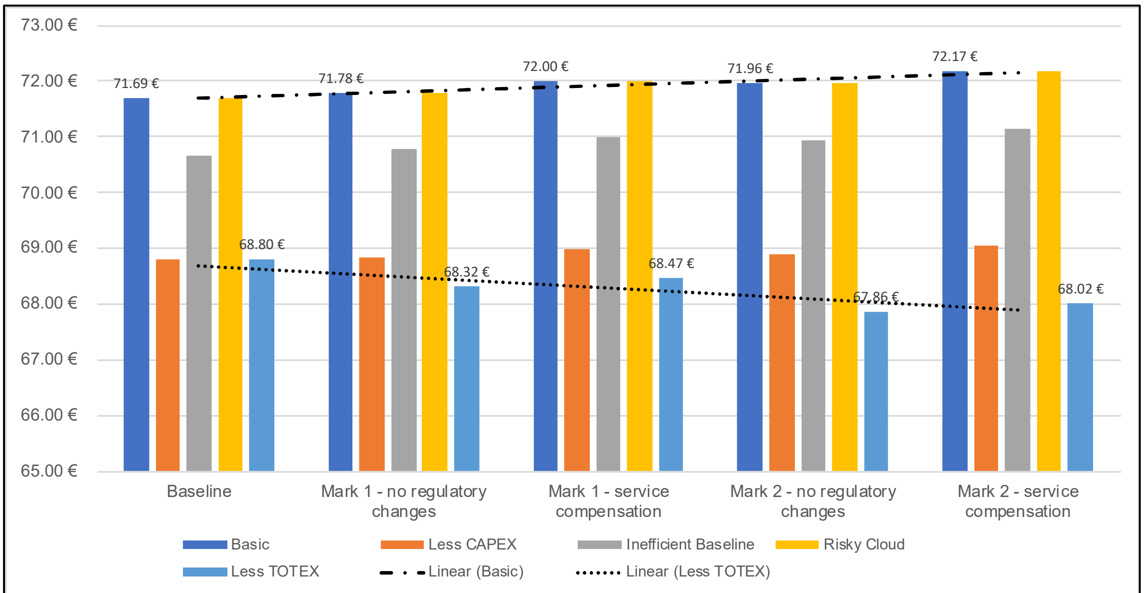

Figure 7: Annual network tariffs per client

As seen in Figure 8, only when both the investments in the regulatory asset base (e.g. for physical network expansion) and the OPEX required to be compensated (Less TOTEX scenarios) decrease with the implementation of Mark-1 and Mark-2 solutions, our analysis shows the potential of annual network tariffs to decrease as compared to the Baseline model. Therefore, regulatory frameworks must take into account the specific needs and concerns of DSOs and the opportunities of decentralised market structures and cloud-based smart grid services procurement from open platforms in relation to its potential effects on the quality of electricity supply and network tariffs in order to develop sophisticated incentivisation schemes that allocate potential benefits fairly between DSOs' shareholders and the clients served.

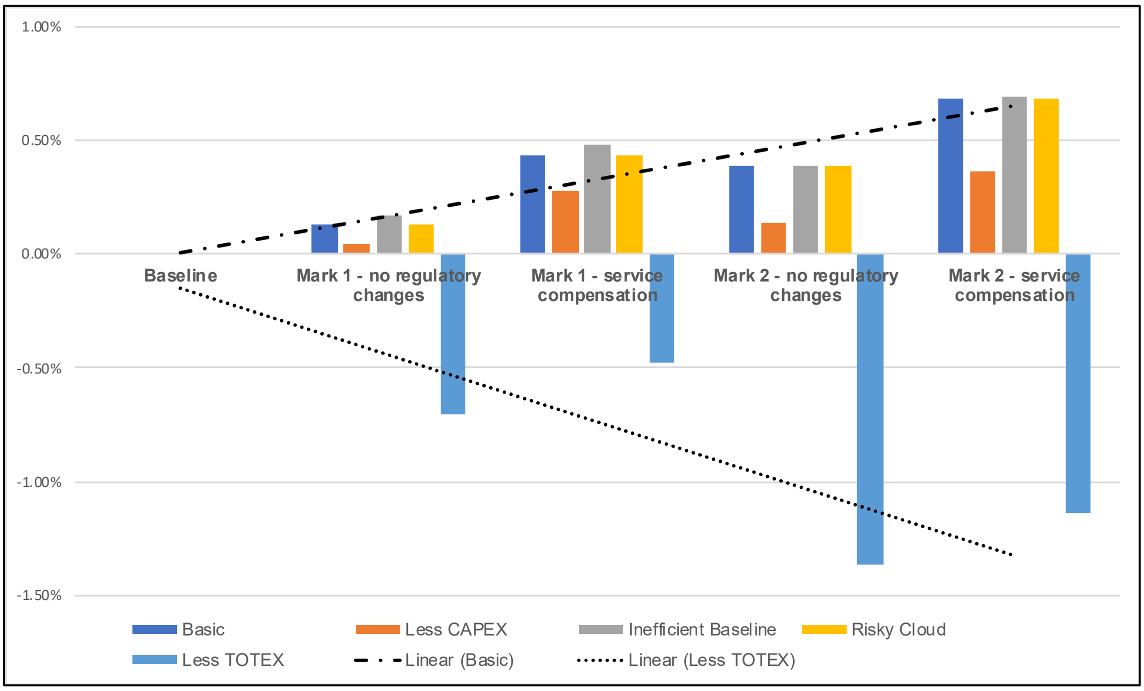

Figure 8: Changes in annual network tariffs

The increasing complexity of grid operation necessitates an increasing number of DSOs to further develop their business strategy involving advanced network management. Especially smaller DSOs with its business processes being less integrated can benefit from having the opportunity to access up-to-date smart grid services which enable adaptive, intelligent grid operation with proactive voltage and distributed generation unit control, automatic fault recovery, automated reaction to unusual transient behaviour and real-time grid-monitoring driven by ICT-connected measurement devices [1]. The complexity of DSOs' tasks requires high quality standards of new network management services to be procured while the few existing large-scale ADMS providers struggle to develop software services that fit the ever more differentiated needs of particular DSOs. A more open market for network management services would lead in foreseeable future to higher quality standards and faster development of those, attractive opportunities for business model innovation and potentially lower overall system costs. However, as complete migration from existing SCADA systems to cloud-based systems is widely perceived as risky and potentially involves high switching cost, DSOs can benefit from market conditions that allow them to flexibly test and potentially deploy new software services - which are potentially better or beyond-state-of-the-art as compared to the functionality of existing ADMS systems - in parallel to their existing network management system without affecting its functioning and without upfront investments. Regulatory frameworks could consider this proficiency for DSOs through allowances of OPEX corresponding to the payments of rates per time-unit for trailing and potentially continuously implementing new smart grid services. In this way, new smart grid services which best meet individual DSO requirements will be implemented while improvements of operational performance and societal and environmental benefits can be expected (see also SOGNO Deliverable 6.4).In order to address current requirements, the following chapter develops - based on the results of SOGNO - recommendations with the following purposes First, contribute to the development of an innovative market environment for cloud-based smart grid services based on cutting-edge Information and Communication Technology (ICT) which is expected to encourage business model innovation, substantive knowledge gains and job creation in the European Union. Second, contribute to the development of a European-wide regulatory framework which removes the barriers for DSOs to use "Software-as-a-Service". Third, encourage DSOs to try mastering the complex challenges of energy transition with the help of smart grid services. Fourth, emphasise the importance of socially sustainable electricity supply in terms of ensuring that the benefits of using smart grid services are fairly distributed along the value chain and do not lead to increasing in electricity prices.

Table 3: DSO business model calculation scheme (Scenario: “Basic”)

DSO business model calculation scheme		Baseline	SOGNO Mark-1 solution (present and short-term future)		SOGNO Mark-2 solution (medium or long-term future)	
			no regulatory changes	the cost for purchasing cloud-based smart grid services are compensated by the regulator	no regulatory changes	the cost for purchasing cloud-based smart grid services are compensated by the regulator
Revenues	**Network tariffs**	**€ 5,734,921.07**	**€ 5,742,399.71**	**€ 5,759,712.15**	**€ 5,756,862.10**	**€ 5,773,853.15**
	Compensated CAPEX	€ 2,686,698.85	€ 2,686,698.85	€ 2,686,698.85	€ 2,686,698.85	€ 2,686,698.85
	Compensated OPEX (Software "as a service")	€ -	€ -	€ 10,000.00	€ -	€ 10,000.00
	Compensated OPEX ("efficient" OPEX)	€ 826,000.00	€ 826,000.00	€ 826,000.00	€ 826,000.00	€ 826,000.00
				€ -		
	Quality element (performance-based)	€ (36,000.00)	€ (12,000.00)	€ (12,000.00)	€ 12,000.00	€ 12,000.00
	Depreciation	€ 2,222,222.22	€ 2,229,700.86	€ 2,237,013.30	€ 2,244,163.25	€ 2,251,154.30
				€ -		
CAPEX	**Net investment in regulatory asset base (e.g. physical grid extension/reinforcements)**	**€ 2,558,760.81**	**€ 2,558,760.81**	**€ 2,558,760.81**	**€ 2,558,760.81**	**€ 2,558,760.81**
OPEX	**Total OPEX (excl. Smart grid services)**	**€ 826,000**	**€ 826,000**	**€ 826,000**	**€ 826,000**	**€ 826,000**
	Ancillary services (e.g. RES curtailment)	€ 96,000	€ 96,000	€ 96,000	€ 96,000	€ 96,000
	thereof compensated	100%	100%	100%	100%	100%
	Energy losses	€ 480,000	€ 480,000	€ 480,000	€ 480,000	€ 480,000
	thereof compensated	100%	100%	100%	100%	100%
	Operation and maintenance costs	€ 250,000	€ 250,000	€ 250,000	€ 250,000	€ 250,000
	thereof compensated	100%	100%	100%	100%	100%
	Software procurement "as a service"	**€ -**	**€ 10,000**	**€ 10,000**	**€ 10,000**	**€ 10,000**
	thereof compensated	0%	0%	100%	0%	100%
	Compensated costs for software "as a service"	€ -	€ -	€ 10,000	€ -	€ 10,000
				€ -	€ -	€ -
Financial outcome	Cash Flow	€ 2,314,160.26	€ 2,335,638.90	€ 2,352,951.34	€ 2,374,101.29	€ 2,391,092.34
	Return on Capital	€5,008,413.46	€5,025,053.43	€5,041,323.61	€5,057,232.24	€5,072,787.34
	Allowed rate of return	5%	5%	5%	5%	5%
	Net present value (5-year regulation period)	**€ 29,500,046.09**	**€ 29,881,808.85**	**€ 30,189,521.43**	**€ 30,565,442.02**	**€ 30,867,442.26**
	Change compared to Baseline		1.29%	2.34%	3.61%	4.64%
Operational Performance	SAIDI	7	5	5	3	3
	Reference SAIDI	4	4	4	4	4

3. SOGNO Recommendations

3.1 Recommendations for Distribution System Operators

1. **Distribution system operators should consider the encouraging results of the early trials of cloud-based services based on integrating smart sensors as well as decision and optimisation algorithms in an open and modular software architecture.**

Providing smart grid services as modular components rather than as services integrated into legacy systems from large ADMS providers encourages DSOs to access distribution network management services in a more agile way. The open and modular platform approach allows DSOs to flexibly test and potentially deploy advanced smart grid services - which possibly better fit their requirements than those that can be obtained via legacy systems - in parallel to their existing distribution network management system without affecting its functioning and without upfront investments. Using cloud-based services means that the software can be upgraded remotely. Hence, the service can be maintained entirely by the service provider which makes it affordable and (practical and) accessible for DSOs. As a consequence, energy system operators can save controllable maintenance cost which otherwise directly reduce their income.

2. **Distribution system operators should investigate the potential of field-trial validated machine learning-based algorithms to optimise their measurement and analysis systems.**

SOGNO has developed and trialled system awareness services and autonomous self-healing services that bear significant potentials to increase DSOs' operational performance while contributing to social welfare and environmental protection (see also SOGNO Deliverable 6.4). The potential benefits of following the SOGNO-trialled approach should be considered in relation to the learnings from the SOGNO field trials (e.g. SOGNO Deliverable 5.2) to avoid potential problems and inefficient transaction costs.

3. **Distribution system operators should investigate the potential of 5G services, currently being rolled-out throughout Europe, to provide low latency, highly reliable, secure wireless connections and edge-computing capabilities to the many measurement and control devices they will need to deploy in their networks in the coming years.**

SOGNO has trialled the use of 5G (for transmission speed and low latency) available with Edge-Cloud (to support the distributed architecture of sub-stations in future smart grids, scalability and automation, network slicing for priority, reliability and privacy) and thus gained knowledge on its potential. As data can be considered the new oil of the 21st century, energy system operators can benefit from being able to manage large volumes of grid, prosumer and market data in in order to improve operational decision-making. When the SOGNO Mark-2 solution is implemented with 5G being the dominant mobile internet access standard, smart grid services are expected to exploit network slicing, lower latency and increased reliability as compared to Mark-1 solution.

3.2 Recommendation for European Policy Makers and National Regulators

4. **National regulators should adopting the TOTEX model of the Clean Energy Package enabling distribution system operators to choose between distribution grid automation as a service or through the purchases of physical assets or software.**

The compensation of smart grid service-related OPEX incentivises DSOs to flexibly test and potentially deploy new smart grid services which are potentially advanced as compared to those that can be obtained via legacy systems. Allowing DSOs to offset OPEX corresponding to periodical payments to service providers for testing and/or using software functions, increases DSOs' financial leeway for service trialling and implementation while it reduces capital risk. It is conducive to the development of an innovative market environment and business model innovation, as it facilitates (e.g. through lowering upfront investment risk) trial-and-error learning for network operators, manufacturer of measurement devices and software developers [16].

3.3 Recommendation for Consumer Organisations

5. **Depending on the respective national legal framework, consumer organizations should consider initiatives to promote the potential to reduce grid charges and electricity prices which the use of cloud-based smart grid services offers.**

SOGNO raises the awareness that DSOs' operational decision-making quality can improve from implementing system awareness and autonomous self-healing services. The SOGNO results show the potential of the SOGNO Mark-1 and Mark-2 solutions to decrease overall distribution system costs including upfront CAPEX requirements (e.g. through lower rates of physical network expansion) and OPEX efficiency. As a consequence, the sum of network tariffs to be financed via electricity prices potentially decreases depending on the respective national legal framework. Further, prosumer- and consumer participation in grid-relevant data exchange processes is becoming more important with increasing network decentralisation, distributed generation and load aggregation going on. In this context, consumers' expressions of interest could encourage the DSO community to increase their network management capabilities through the utilisation of cloud-based smart grid services and contribute to achieving a win-win situation for both DSOs and stakeholders (such as consumers, prosumers, TSOs, etc.)

3.4 Recommendation for Environmental Organisations

6. **Environmental organizations should consider that the use of cloud-based smart grid services can reduce photovoltaic and wind energy curtailment and potentially alleviates the need for physical network expansion.**

SOGNO raises the awareness that especially advanced system awareness services, such as the SOGNO Power Control service, facilitate the integration of volatile electricity from renewable sources by optimising grid operations with the objective of avoiding curtailment. Moreover, the use of the advanced SOGNO service bears the potential to increase the hosting capacity of distribution grids in a way that increasing the installed capacity of renewable energy sources is to a lower extent to be accompanied by physical network expansion and to be substituted by e.g. more sophisticated inverter control strategies [17]. With lower curtailment rates and lower rates of physical network expansion, higher shares of renewable generation can be utilised at lower total system costs. In addition, (cloud-based) smart grid services potentially substitute hardware requirements and thus potentially lower not only the costs for measurement technology but also total material throughput and corresponding life-cycle emissions (see also SOGNO Deliverable 6.4).

4. Conclusion

SOGNO considers alternative value chain structures for smart grid service supply and corresponding business model changes of both service vendors and DSOs. The SOGNO-trialled approach is to provide DSOs with flexible access to distribution network management services (e.g. with system awareness services and autonomous self-healing services) via (potentially open) IOT platforms on which multiple algorithm implementers can install grid management services while DSOs can choose between them in a modular way.

The project has gathered knowledge on trialling innovative software solutions for DSOs in the field and frequently validated its findings through consultations with various stakeholder groups. The learnings from the SOGNO field trials, the feedback from relevant stakeholders as well as SOGNO-specific economic, technical and societal research build the foundation of the recommendations formulated within this Deliverable 6.5. The development of those recommendations has benefited from iterative feedback and information exchange processes in which the entire consortium participated. The recommendations directly address Distribution System Operators, European Policy Makers and National Regulators, Consumer Organisations and Environmental Organisations but concern all relevant stakeholder groups.

5. List of Tables

6. List of Figures

7. List of References

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8. List of Abbreviations

ADMS	Advanced Distribution Management Systems
CAPEX	Capital Expenditure
DG	Distributed Generation
DSO	Distribution System Operator
DNM	Distribution Network Management
DSM	Demand Side Management
FLISR	Fault Location Isolation and Service Restoration
ICT	Information and Communication Technology
IOT	Internet of Things
LGF	Load- and Generation Forecast
NPV	Net Present Value
OPEX	Operational Expenditure
PC	Power Control
PQE	Power Quality Evaluation
RES	Renewable Energy Sources
SAIDI	System Average Duration Index
SCADA	Supervisory Control and Data Acquisition
SE	State Estimation
TAR	Total Allowed Revenue
TSO	Transmission System Operator
WACC	Weighted Average Cost of Capital