SOGNO

D6.3 v1.0

Identification of economically feasible value chain designs

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Abstract

The present deliverable outlines the economic value of the SOGNO 5G-based software services for scalable automation and proactive monitoring of smart electricity distribution grids. The report demonstrates how SOGNO service utilisation is related to Distribution System Operators' (DSOs) operational performance. It substantiates exemplarily how economic value is created through service-induced improvements in DSO's operational performance. Eventually, it outlines a potential Value Chain designed to sustainably create economic value through the implementation of the SOGNO services.

Keyword list

Distribution System Operators, 5G-based Monitoring & Automation Services, Key Performance Indicators, Smart Electricity Distribution Grids, Value Creation, Value Measurement, Value Chain Design, Business Models

Executive Summary

Active distribution grid management driven by ICT-based software services (as envisioned by SOGNO) is a reasonable means for DSOs to cope with current operational challenges that arise from volatile, bi-directional electricity flows and decreasing simultaneity of electricity consumption and production.

Up-to-date electricity distribution management 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 by ICT-connected measurement devices [1]. Hence, security and continuity of electricity supply are increasingly dependent on DSOs' gird data processing capabilities.

However, current regulatory frameworks do not incite DSOs to establish those capabilities by utilizing software services but tend to favour investments in network expansion for situations in which both smart distribution grid management and physical network expansion would lead to the same goal. Hence, the utilisation of innovative software services is to some extent perceived as risky from the perspective of DSOs because service-induced improvements in operational performance are less certain to pay out financially than investments in the regulated asset base are. Currently, the diffusion of services among DSOs is thus particularly dependent from the service's suitability to create noticeable economic value for DSOs.

To this end, the present working report demonstrates how economic value is created through the implementation of the SOGNO services for scalable automation and proactive monitoring. SOGNO service utilisation is strongly interlinked with DSOs' operational performance and service-induced changes in operational performance are shown to affect the regulated income of DSOs. Eventually, this report proposes a Value Chain for the SOGNO services that consists of DSO-centred Value Chain actors that collaborate agilely in order to tailor service offerings to the needs of various DSOs.

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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 develops 5G-based software services for scalable automation and proactive monitoring of smart electricity distribution grids.

1.1 Motivation and Purpose of the Work Reported in Deliverable 6.3

The changing structure of electricity markets (e. g. entrance of new players like prosumers and aggregators) in combination with bidirectional and volatile electricity flows from intermittent Renewable Energy Sources (RES) as well as decreasing simultaneity of electricity production and consumption complicate the operational tasks of DSOs, for instance, in terms of voltage and current balancing. Hence, DSOs are required to intensify their efforts in order to continuously ensure reliable electricity supply and to contribute to the energy transition. SOGNO envisions supporting the DSOs in doing so and the SOGNO services are consequently tailored to the current and future operational tasks of DSOs.

1.2 Contribution and Implications for the Second Project Period

The work reported in the present Deliverable 6.3 demonstrates how SOGNO service implementation can create economic value for DSOs and recommends ways in which that value can be measured and captured by DSOs as well as by the service providing economic entities in the SOGNO value chain. A model for measuring the economic value of the SOGNO services - that is easily adjustable to various regulatory frameworks - has been developed and its functionality has been proven based on data from CEZ Romania (consortium partner) and a specific Romanian regulatory framework.

In the second period of the project, the evaluation model will be refined using data from the SOGNO field trials and extended by the social and environmental dimension of value creation as well as by various distribution grid characteristics.

1.3 Collaboration Within SOGNO and Outline of the Work Report

The first steps towards designing customer-centred, economically feasible value chains must always be those of the determination (chapter 3) and the prognosis (chapter 4) of the economic value that is to be created through collaboration along the value chain. Thereupon, value chains can be purposefully designed in order to determine how the value can be continuously delivered and captured by the individual economic entities that participate in the value chain (chapter 5). For the work reported in the present deliverable, WP6 particularly cooperated with

- WP1-WP4 to derive the impact of SOGNO use cases[1] on DSOs' operational performance (see in particular the deliverables D1.1 & D3.1),
- WP5 to receive data for the present analysis and consider DSOs' needs,
- WP7 to contribute to the dissemination concept for the SOGNO services.

[1] We define use cases as exemplary operations relating to DSOs tasks that show how the SOGNO services could be utilised by DSOs.

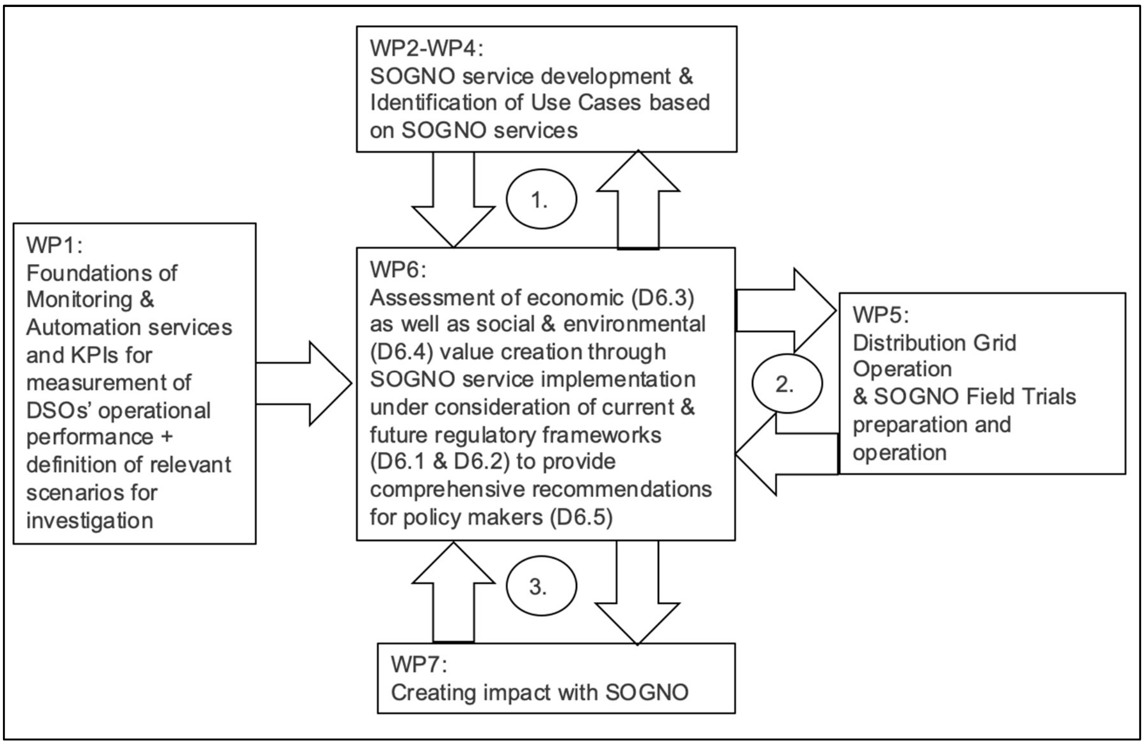

Figure 1: Collaboration Within SOGNO from the Perspective of WP 6

Main components of collaboration within SOGNO for the work reported in the present Deliverable 6.3	
1.	WP1-WP4 & WP6: Evaluation of Impact of Use Cases on DSOs' operational performance
2.	WP5 & WP6: Information Exchange on DSOs' needs & Data Supply
3.	WP7 & WP6: Information Exchange on Value Creation & Dissemination Concept Development

Figure 2: Main Components of Collaboration for the Work Reported in D6.3

2. Electricity Distribution Systems

2.1 Distribution System Operators

DSOs are "natural or legal person[s] responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area (…) for ensuring the long-term ability of the system to meet" [2] the electricity demand of "end-users [connected to the medium-voltage grid (MV) and the low-voltage grid (LV)] in a secure, reliable and efficient manner" [2].

2.1.1 Operating Principles

The daily work of operational staff in grid operating companies encompass all activities necessary to continuously ensure a reliable operation of the electricity grid such as monitoring and balancing of voltage and current or asset maintenance and repair. DSOs are exclusively responsible for all - strategic and operational - grid-related decision-making.

Unlike electricity generation and supply, electricity distribution is not coordinated by the principles of competitive markets but functions as a natural monopoly. Therefore, DSOs' operations are exposed to regulatory control. Across Europe, different schemes that regulate the allowed income of DSOs are in place such as 'cost-plus' (e.g. Belgium), 'incentive-based' (e. g. Czech Republic, Germany), 'revenue, price or income cap' (Poland, Sweden), and combinations of those schemes (e. g. Switzerland, UK) [3]. Most commonly, the regulatory framework allows DSOs to only 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 regulated asset base (RAB), the weighted average cost of capital and the operational expenditures. The RAB represents the value of the DSOs [sic] asset base" [4]. The purpose of regulatory control is to ensure that DSOs do not exploit their powerful market positions (e. g. by charging monopoly prices or by discriminating clients) and to incentivise them to execute measures necessary to attain overarching operational goals - maintain continuity of electricity supply, ensure power as well as commercial quality and avoid curtailment of electricity from RES [4].

Increasing decentralised electricity production from intermittent RES is currently challenging the complexity of DSOs' tasks while technological developments such as 5G-connected smart measurement devices bear opportunities to cope with that. In particular, volatile, bi-directional energy flows and decreasing simultaneity of electricity production and consumption hamper DSO's efforts to avoid congestions, overvoltage and interruptions. In contrast to the conventional 'passive network management' approach, according to which investments in physical assets to expand the grid are the main remedy to handle electricity peaks by intermittent RES ('fit and forget'), an 'active network management philosophy' [1] based on contemporary ICT and innovative monitoring equipment allows for efficiency gains in terms of, e.g., grid capacity utilisation and RES integration [4]. Consequently, DSOs are required to process large amounts of data while making use of contemporary communication standards for reliable and secure data transmission in order to optimize daily operational work.

2.1.2 Software-as-a-Service for DSOs

Up-to-date electricity distribution management is about adaptive, intelligent grid operation with active voltage and DG unit control, automatic fault recovery, automated reaction to unusual transient behaviour and real-time grid-monitoring driven by ICT-connected measurement devices [1]. In this context the upcoming 5G communication standard supports wide area communication to manage a massive increase of connected devices, low latency, cyber security, highly reliable and scalable communication to provide decision-support for DSOs and to improve resource allocation in the grid [5].

In order to benefit from current developments DSOs are required to build up new grid data processing capabilities. That is, DSOs need to handle new solutions to process all the data required for effective and efficient grid monitoring. However, neither working hours needed for internal development of those capabilities (Installation and operation of hardware and software for data measurement, data visualisation, data analysis, data transfer, etc.) nor purchases from third-party vendors of machine-learning based software services for real time grid data processing (as envisioned in SOGNO) are directly governed by regulatory control. "In traditional incentive-based regulation DSOs are not allowed to include all new investments into the regulated asset base: i.e. no automatic pass-through of investment costs to end-consumers is allowed" [4]. Hence, the utilisation of innovative software services is to some extent risky for DSOs, as service-induced improvements in operational performance are less certain to pay off financially than investments in the regulated asset base are.

Technology diffusion among DSOs is thus particularly dependent from the technologies suitability to deliver noticeable operational benefits. Thorough impact assessment is hence necessary to account for the benefits of service utilisation transparently. However, potential regulatory changes would also affect the diffusion of innovative software services. As for the case of SOGNO, two perspectives are to be considered to anticipate DSOs willingness to adopt new technologies

- Incentives for SOGNO service utilisation if regulatory frameworks are subject to change (SOGNO Deliverable 6.1, 6.2 & 6.5).[2] In particular, it will be analysed in these deliverables the possible consequences if regulation changes in a way that it allows software being part of the regulated asset base using a total cost ('TOTEX') approach.
- Incentives for SOGNO service utilisation given current regulatory frameworks (SOGNO Deliverable 6.3).

2.2 Quality Regulation

Although regulatory frameworks vary from country to country, they usually bridge DSOs' overarching operational goal attainment (reliability and continuity of supply as well as low RES curtailment) and DSOs' economic success. Consequently, DSOs are measuring (and are obligated to measure) operational performance using certain KPI's (see SOGNO deliverable D1.1 for further details on KPI's that DSOs use to measure operational performance) in order to monitor, report, analyse and improve the quality of supply. In this regard, the 'frequency of interruptions', the 'duration of interruptions' and the amount of 'electrical energy not supplied' are the main categories to determine DSO's operational performance with respect to continuity of supply (see SOGNO deliverable D1.1 also for a comprehensive overview on additional voltage quality and voltage continuity disturbance phenomena monitored by DSOs).

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 [3]. Regulatory regimes differ in that they are implemented as macro-level incentives and/or penalties (e. g. Denmark / France) or micro-level incentives and/or penalties (e. g. Italy / Estonia). The continuity of supply among French DSOs, for instance, is regulated on the macro-level using incentive regulation based on a DSO's annual SAIDI (system average interruption duration index). Micro-level penalties for DSOs in form of compensation penalties to clients (which either need to be requested by affected clients or are automatically charged by DSOs) for non-compliance with required quality levels are also widely spread. Commonly, DSOs compensate based on either aggregated values on duration and number of interruptions in total or according to individual durations of planned (only in Romania and Slovenia) and unplanned interruptions [6].

There are many approaches towards the calculation of compensation payments. More precisely, payments are calculated "as a percentage of yearly network tariffs (the Czech Republic, Finland, Sweden), determined through customer research (Great Britain), based on international comparison (Hungary, Italy), on estimated costs of interruptions (the Netherlands, Portugal, Romania, Slovenia) or on the cost of energy during the period of interruption (Poland) [6]. In the Czech Republic, for example, DSOs compensate for every interruption that lasts for more than 8 hours (Prague) or 12 hours (elsewhere in Czech Republic) by paying for every affected client 10% of the yearly network tariffs paid but a maximum of 250€ at the LV and of 500€ at the MV [6].

This chapter thus shows that it is vital to understand both the impact of service utilisation on DSO's operational performance (chapter 3) and the influence of service-induced changes in operational performance on the regulated income of DSO's (chapter 4) to assess the economic value of the SOGNO services.

[2] SOGNO Deliverable 6.1 for analysis of SOGNO results regarding regulatory standards and Deliverable 6.5 for the resulting recommendations for policy makers. Deliverable 6.2 assesses from the perspective of a DSO the economic and regulatory conditions that influence preferences for and against software services and draws recommendations for the market exploitation of the SOGNO services.

3. Value Creation by implementation of SOGNO Services

3.1 Linkages Between SOGNO Services and DSOs' operational Tasks

This subchapter shortly summarizes the SOGNO services and explains the associated use cases[3]. It also infers qualitatively the direct and indirect benefits for DSOs associated with the utilisation of the SOGNO services.

3.1.1 State Estimation

According to D1.1 and pursuant to the service description provided by WP2, "the State Estimation (SE) service computes the operating state of the network at a given instant of time, allowing the real-time monitoring of the grid (see D2.2 for more details)." From the SOGNO approach to SE (D1.1), use cases and corresponding direct and indirect impacts on DSOs' operational performance have been inferred as follows.

In general, SE gives awareness on how the grid works, how it is evolving during time, and allows identifying possible criticalities that in the short or long term could translate into power supply disruptions. Thanks to SE the DSOs have a better view of how their grid work, they can identify solutions to improve the operational performance (efficiency and reliability improvements) and have a much more solid basis as support for strategical decisions and future planning. For instance, SE evaluates power losses in the grid by estimating the amount of technical power losses in the electric grid. This directly improves DSOs' understanding of the grid and, in particular, highlights the understanding of loss reduction possibilities to facilitate corresponding planning activities. Provided that the operational staff process the information output by the SE algorithm optimally, power losses will be reduced and - in (possible future) situations where power losses are penalized by the regulatory authority - fines would be avoided.

In combination with Power Quality (PQ), SE supports several more use cases.

3.1.2 Power Quality

According to D1.1 and pursuant to the service description provided by WP2, "the Power Quality (PQ) service will be provided by the Advanced Power Measurement Unit (APMU) that is being developed by MAC. The APMU will measure classical electrical quantities (such as: voltage, current, power and frequency) on LV and MV lines, advanced power quality parameters (such as: harmonics, reactive power, power factor, unbalanced phases, earth-fault currents, voltage sags & dips, etc), as well as over-voltage, over-current, and overload detection using algorithms that run on-board in the APMU and are updated over the air for local grid-edge intelligence. The algorithms will be updated depending on the operational/business monitoring objectives of the DSO for specific parts of their networks or issues that they are encountering, which could be as simple as changing over-voltage/current thresholds or as complex as defining new PQ indices or alarm conditions to be monitored. All of the measurements are time-stamped." (see D1.1 and D2.2 for more details). From the SOGNO approach to PQ (D1.1), use cases and corresponding direct and indirect impacts on DSO's operational performance have been inferred as follows.

In combination with SE, PQ enables the detection of

- voltage violations by checking whether the voltage is within the allowed thresholds,
- overloading conditions by checking whether the power flow is within the maximum value allowed by the electrical component (e.g. line, transformer)
- current unbalance by checking whether the currents' imbalance across the 3 phases is outside the set thresholds,
- and high reactive power by checking whether the reactive power is within the set thresholds.

These use cases directly improve the DSO's understanding of potential issues in the grid and enhance the planning of corresponding countermeasures.

Moreover, these use cases cause indirect improvements for the DSO provided that the operational staff processes the information output by combined usage of both PQ and SE

[3] We define Use Cases as exemplary operations relating to DSOs tasks that show how the SOGNO services could be utilized from a DSOs.

algorithms optimally. First, the detection of voltage violations effects better compliance with voltage ranges according to EN 50160 and thus increases customer satisfaction. Second, the detection of overloading conditions and the application of countermeasures reduces power losses and lessens the stresses of assets. Consequently, both CO_2 emissions and Capital Expenditures (CAPEX) will be lowered. Third, the detection of current unbalances enhances the compliance to power quality standards. Fourth, the detection of high reactive power reduces both power losses and overload issues that could cause unplanned interruptions.

In addition, PQ enables the detection of

- current flow direction by indicating the direction of current flow,
- LV outages by checking whether there is a fuse event on an LV feeder phase,
- harmonic issues by checking whether the harmonic distortion levels are within the desired thresholds.

Out of these use cases, the detection of current flow direction and the detection of LV outages directly improve the planning of the grid operation and facilitate congestion management in particular. Harmonic issues detection directly improves the DSO’s understanding of potential issues in the grid and enhance the planning of corresponding countermeasures. Whereas the latter also indirectly improves the reliability of electricity supply and the compliance with power quality standards, LV outages detection will have a positive impact on customer satisfaction, provided that the operational staff processes the information output by the PQ algorithm optimally,

3.1.3 Power Control

According to D1.1 and pursuant to the service description provided by WP2, “the Power Control (PC) service defines the optimal set points of active and reactive power for the converters interfacing (…) DG units to the distribution grid” (see D2.2). From the SOGNO approach to PC (D1.1), use cases and corresponding direct and indirect impacts on DSOs’ operational performance have been inferred as follows.

PC reduces

- power losses by controlling DG units accordingly,
- overvoltage by controlling DG units accordingly,
- renewable active power curtailment by controlling DG units accordingly

Consequently, these use cases cause indirect improvements for the DSO provided that the operational staff process the information output by the PC optimally. First, as the reduced amount of power losses will lead to lower power generation costs on average. Second, as the compliance with voltage ranges according to EN 50160 increases customer satisfaction increases. Third, in countries where curtailment is penalized by the regulatory authority, the DSO avoids corresponding fines. The reduction of RES power curtailment also decreases the need for grid expansion and thus reduces DSO’s CAPEX in the long run. Additionally, CO2 emissions of electricity production generally decrease with increasing integration of electricity from RES enabled by PC.

3.1.4 Load and Generation Forecasting

According to D1.1 and pursuant to the service description provided by WP3, “the Load and Generation Forecasting (LGF) services are basically two services: The Load Forecasting (LF) and the Generation Forecasting (GF) service. The Load Forecasting (LF) service provides the power grid with future electricity demands, based on the history information of customers’ power consumptions. On the other hand, the Generation Forecasting (GF) service provides the power grid with the future generated power in a photovoltaic (PV) system based on the weather information, such as solar irradiance, temperature, humidity, etc.” (see D3.1 for more details). From the SOGNO approach to LGF (D1.1), Use Cases and corresponding direct and indirect impacts on DSOs operational performance have been inferred as follows.

LGF predicts

- day-ahead generation by predicting the daily curve of power generation,
- day-ahead load by predicting the daily curve of load consumption one day in advance
- and, consequently, congestion in the grid by using the load and generation forecasts.

These use cases directly improve the DSOs understanding of potential issues in the grid and enhance the planning of corresponding countermeasures. In particular, the accuracy in day-ahead load and generation forecasting will increase.

Moreover, these use cases cause indirect improvements for DSOs provided that the operational staff processes the information output by the LGF algorithms optimally. That is, with increasing avoidance of congestion in the grid, less RES curtailment and less grid expansion is necessary and benefits emerge as mentioned in Section 3.1.2.

3.1.5 Fault Location, Isolation and Service Restoration

According to D1.1 and pursuant to the service description provided by WP3, "the Fault Location, Isolation and Service Restoration (FLISR) service is capable of detecting fault in the power grid. Upon detection, the fault location is isolated, and the service makes sure to restore the service by connecting the resulting isolated loads back to the power source" (see D3.1). From the SOGNO approach to FLISR (D1.1), a major use case and corresponding direct and indirect impacts on DSOs' operational performance have been inferred as follows.

FLISR enables fast power supply restoration using an automation mechanism that, after a fault, quickly restores the power supply in those sections of the electrical grid that are not directly affected by the fault. This directly affects the 'duration of unplanned interruptions' - a KPI measured by each DSO. It also increases customer satisfaction indirectly, as minutes without electricity decrease.

3.2 Value Creation as a result of SOGNO service-induced changes in DSO's operational performance

As mentioned previously, FLISR directly decreases the 'duration of unplanned interruptions'. Consequently, the impact of FLISR on DSOs operational performance is directly quantifiable as the 'duration of unplanned interruptions' is measured for every interruption and associated with the number of users affected at every reconnection step. KPIs such as SAIDI incorporate the duration of interruptions. For DSOs operating in countries in which the 'duration of unplanned interruptions' is subject to regulatory rewards or penalties, also the monetary value of FLISR is quantifiable. To do that, in SOGNO, data will be generated in the field trials to determine the impact of FLISR utilisation on the reconnection time after unplanned interruptions. Accordingly, initial calculations based on historic data and preliminary assumptions are performed in chapter 4.

Whereas a direct link exists between FLISR and DSO's operational performance, the links between SE, LGF, PC, and PQ and the DSO's operational performance are less obvious. SE, LGF, PC and PQ have in common that they enhance the operational staff's understanding of the grid by providing 'beyond-state-of-the art'-information during grid-monitoring processes. Thus, the services enable better operational decision-making.[4] Accordingly, better operational decision-making is associated with decreasing probabilities of network congestion, overloading conditions or excessive neutral currents to arise as well as with enhanced recognition of loss reduction possibilities. This results in more efficient grid utilisation. For instance, if one section is temporarily at its maximum capacity, the grid topology could be reconfigured to avoid congestion. Consequently, the probability of DSO-caused unplanned interruptions to occur decreases. Additionally, the probability of situations to occurring, in which loss reduction possibilities are exploited increases. Thus, it can be inferred that there is a link between the utilisation of SE, LGF, PC and PQ and KPIs that incorporate the 'number of unplanned interruptions', e.g. the System Average Interruption Frequency Index (SAIFI), and the 'electrical energy not supplied' (ENS).

Besides the DSO-centred operational economic value as mentioned above, the implementation of the SOGNO services promises the creation of social and environmental value. For instance, utilizing electricity from RES more efficiently (enabled by PC and LGF) reduces the need for fossil-fuel combustion processes and thus lowers CO_2-emissions. In addition, lower power generation cost (e. g. enabled by PC) positively effects electricity prices. Eventually, higher reliability of supply (all services contribute to that), decrease the 'Value of Lost Load' and increase customer satisfaction. However, there are also critical aspects like privacy concerns, data security and energy justice (Who finances the grid if everyone is a self-sufficient prosumer?) that emerge in

[4] Provided that the operational staff processes the information output by the algorithms optimally.

Smart Grids as envisioned by SOGNO. To consider these issues thoroughly, critical analyses on the social and environmental impact of the SOGNO services will be performed in D6.4.

The following chapter shows how the DSO-centred economic value of SOGNO service utilisation can be assessed before chapter 5 qualitatively outlines the economic infrastructure to continuously deliver and capture that value.

4. Value Assessment

This chapter provides the fundamentals of value measurement for SOGNO and shows how the economic value of the SOGNO services is determined using Monte Carlo simulation based on real historical data.

4.1 Approach

As mentioned in the last chapter, the SOGNO services create value by improving the operational performance of DSOs that is measured by Key Performance Indicators (KPIs). Therefore, comparisons between DSOs' KPIs in the status quo (without SOGNO Service implementation) and in future statuses (with SOGNO Service implementation) will quantitatively indicate to what extent the SOGNO services potentially affect DSOs' operational performance.

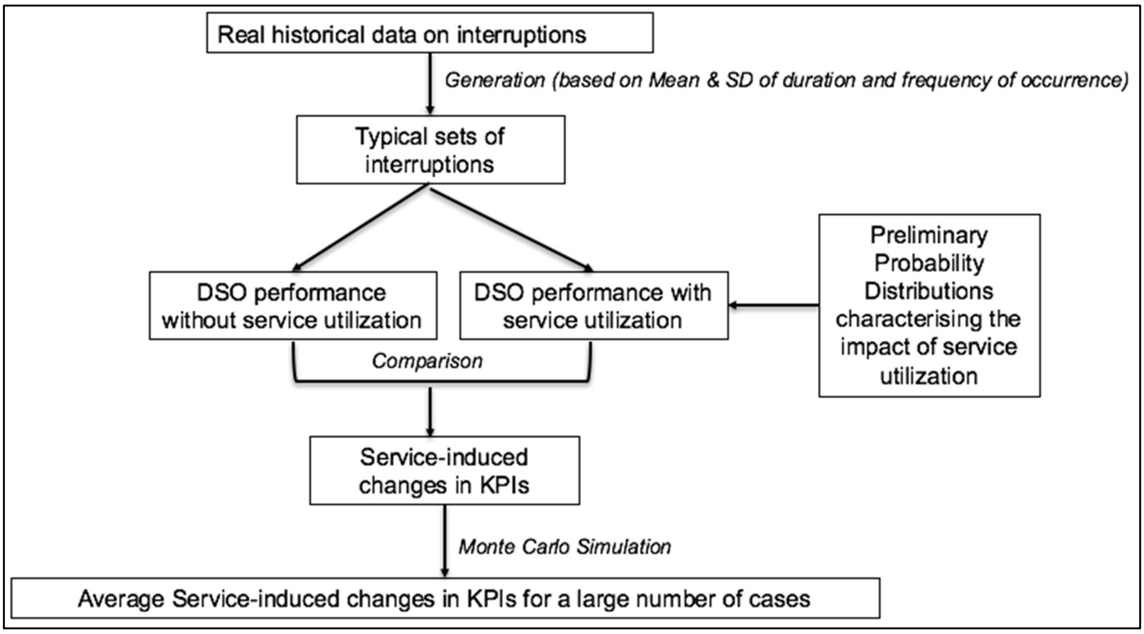

Figure 3: Preliminary Value Assessment Procedure

However, changes in KPIs are not related to economic value creation straightforwardly. Reducing the reconnection time after a single unplanned interruption that has affected 100 users and would have lasted for 200 minutes without FLISR, for instance, by 50 minutes through FLISR, will bring the service-implementing DSO monetary benefits according to country-regulation. Whereas the Irish DSO would save penalty costs that correspond to 5000 customer minutes lost (every unplanned interruption > 3 min is penalised in Ireland), there is no financial consequence for a county-seat municipality in Romania as only interruptions that last for more than 240 minutes are penalised according to national regulations. The regulations in different countries need thus to be thoroughly analysed and associated with changes in KPIs induced by SOGNO as specific regulatory frameworks seriously affect DSOs' willingness to pay for the services. At this stage of the project, value measurement focusses on fundamental linkages between service-induced changes in KPIs of DSOs. D6.1 and D6.5 will deepen the insights on how regulatory changes affect SOGNO-service-induced value creation.

4.2 Monte Carlo Simulation

As real data on changes in DSO's performance after service implementation will not be accessible until the SOGNO field trials have progressed in the second period of the project, a Monte Carlo simulation is used to generate the data types needed to feed the valuation model preliminarily. "Monte Carlo simulation is a method of analysis based on artificially recreating chance process (usually with a computer), running it many times, and directly observing results" [7]. In the underlying analysis, Monte Carlo simulation is used to generate 1000 cases that respectively represent DSO's annual operational performance in terms of 'customer minutes lost' and 'no. of unplanned interruptions' before and after SOGNO services have been implemented.

4.3 Database and Data Processing

For two areas that are operated by CEZ Romania (Oltenia and Babaita), the consortium partner provided data on interruptions that respectively occurred in MV and LV. For every interruption in 2017, CEZ Romania provided the data types listed in table 1

Table 1: Data Types provided from CEZ Romania

No. of Interruption
Voltage Level
Nature of interruption (planned / unplanned)
Cause of interruption
Date, time and minute of commencement of the interruption;
Date, time, and minute of the end of the interruption for all users affected by the interruption
Total time (from voltage dropping to reconnection) in minutes, of the interruption or the refuelling stage, if applicable;
Number of users, on MV level affected by the interruption, correspondingly of each stage, if any;
Number of users, on LV level affected by the interruption, correspondingly of each stage, if any;
Number of phases affected by the interruption if it occurs in the low voltage network
Energy not supplied [MWh]

To ensure the highest possible focus on the link between SOGNO-service-induced changes in DSO's operational performance, planned interruptions, and interruptions that were caused by extraordinary events not in the DSO's area of responsibility were excluded. In order to mirror the characteristics of the remaining samples of unplanned interruptions in terms of duration, number of users affected per interruption and frequency of occurrence, Mean and Standard Deviation were respectively calculated for the no. of interruptions per year, the duration of interruptions, and the no. of clients affected per interruption for both areas and grid-levels (see table 2)[5]

Table 2: Data Processing

Grid Level	**LV**		**MV**	
Area	**Oltenia**	**Babaita**	**Oltenia**	**Babaita**
No. of unplanned interruptions	90	124	24	64
Mean 'No. of clients affected/interruption'	1.26	1.62	901.25	818.42
Standard Deviation 'No. Of clients affected/interruption'	1.2	1.73	213.67	206.66
Minutes without electricity / client	15.66	30.27	2.93	3.35

[5] The letters are applied below to refer to the definition of figures for the formulas below.

No of penalized interruptions / year	20	36	5	3
Share of interruptions penalized	22.22%	29.03%	20.83%	4.69%
Penalty threshold (min)	240	240	240	240
Penalty Costs / client	6.50 €	6.50 €	43.10 €	43.10 €
Mean 'Duration of Interruption' (min)	172.75	216.51	46.37	46.37
Standard Deviation 'Duration of interruptions'	106.9	203.84	88.86	88.86

Based on these figures, sets of interruptions which are typical for the respective areas - were generated.[6] The regulatory framework that holds for county seat municipalities in Romania was applied in order to calculate the economic effects of service utilisation. For every interruption that lasts at least 240 minutes, county seat municipalities in Romania are charged 6.50 € / 43.10 € for every client affected in the LV / MV.

For the further calculations on the impact of services on DSOs' operational performance, we distinguished between services that affect the 'duration of unplanned interruptions' (FLISR) and services that affect the 'number of unplanned interruptions' (SE, PQ, PC, LGF). In both cases, the impact of service implementation is quantified through a comparison between the status quo (without service utilisation) and a future status (with service utilisation).

To determine the impact of FLISR, first, we calculated characteristic sets of unplanned interruptions, for which 'duration' and the 'no. of clients affected' were randomly generated based on mean and standard deviation of the respective area. Second, we created a preliminary probability distribution on the potential impact of FLISR on the 'duration of unplanned interruptions' according to table 3.[7]

Table 3: Probability Distribution - FLISR impact

Prob.	Reduction of Duration	Min (%)	Max (%)
20%	up to 5%	0	5
40%	up to 10%	6	10
20%	up to 15%	11	15
10%	up to 25%	16	25
10%	up to 75%	26	75

For every interruption, we randomly estimated the percentage by which FLISR decreases its duration based on the given probability distribution. Hence, we yielded, for every interruption, the duration with and without FLISR utilisation and the product of 'duration' and 'no. of clients affected' (Customer Minutes Lost). Subsequently, the cumulated penalty costs - with and without FLISR utilisation - for a given constant number of interruptions per year were determined based on the applied regulatory framework mentioned above. The difference between both values for the cumulated penalty costs expresses the economic value of FLISR utilisation for a constant number

[6] Hence, the model can be easily adjusted to other areas.

[7] Obviously, these assumptions are critical for economic value determination. As soon as the respective data are available from the SOGNO Field trials these tables will be updated in order to increase the accuracy of impact determination.

of unplanned interruptions per year.[8] Based on that, Monte Carlo simulation was applied to generate - for a constant number of unplanned interruptions - a data table that yields the annual penalty cost reduction related to FLISR utilisation in 1000 cases. Eventually, mean, standard deviation and the 95% confidence interval were calculated over these 1000 cases to determine the FLISR-induced penalty cost reduction.

To estimate the impact of the services that are assumed to mainly affect the ‘number of unplanned interruptions’, first, we determined for every of 8760 hours (one year), whether an unplanned interruption starts in that particular hour. Whether one particular hour is affected by an unplanned interruption was determined by a random number between 0 % and 100 %. If this random number takes on a value between 0 and the ‘share of hours without electricity’ according to the real data (e. g. 5,11 % in Babaita, LV), it was assumed that an unplanned interruption starts in that particular hour. For every interruption that occurred, we, secondly, calculated randomly its duration and the number of clients affected. As in the case of FLISR, we then assumed that the service utilisation decreases the number of unplanned interruptions according to a certain probability distribution (table 4).

Table 4: Probability Distribution - SOGNO services (other than FLISR)

Prob.	Reduction of No.	Min (%)	Max (%)
25%	up to 5%	0	5
35%	up to 10%	6	10
24%	up to 15%	11	15
14%	up to 25%	16	25
2%	up to 75%	26	75

After that, a random number between 0 and 100 was generated to yield a percentage that indicates the decrease in the ‘number of unplanned interruptions’. We then integrated service utilisation by reducing the ‘share of minutes without electricity’ by the percentage that was generated based on the probability distribution in table 4 and calculated, again, for every 8760 hours whether an interruption occurs. Eventually, we compared the figures with and without service utilisation to determine the service-induced changes in KPIs.

[8] For this step, we used the number of unplanned interruptions that occurred in the respective area in reality.

4.4 Initial Results and Implications for further work

Applying the probability distributions as mentioned above and the regulatory framework for county seat municipalities in Romania, the results suggest that the utilisation of FLISR reduces the DSO's penalty costs for the LV (MV) on average by 17.39% (32.77%) in Babaita and by 33.24% (54.54%) in Oltenia (table 5).

Table 5: Economic Value Assessment of FLISR implementation

FLISR				
Iterations:	Babaita	Oltenia	Babaita	Oltenia
1000	LV	LV	MV	MV
Interruptions (No. / year)	124	90	64	24
	Penalty Cost	Penalty Cost	Penalty Cost	Penalty Cost
MEAN	-17.39%	-33.24%	-32.77%	-54.54%
Standard Deviation	6.69%	13.77%	43.95%	24.91%

Moreover, the results indicate that utilisation of the services which affect the 'number of unplanned interruptions' reduces the DSO's ''SAIFI' by 8.9 % (8.83 %) with a standard deviation of 8.12 % (19.96 %) in Babaita LV (MV) and by 8.31% (6.7 %) with a standard deviation of 11.65 % (20.96 %) in Oltenia LV (MV).

Obviously, the meaningfulness of the work in this deliverable is less substantiated by the demonstrated percentage changes in KPIs and penalty costs but rather by the functionality of the valuation model itself with which the results have been calculated. As soon as the relevant data types are available from the SOGNO field trials the probability distributions that characterise the impact of the services will be updated and integrated into the model to refine the results. Moreover, the model can easily be adjusted to various regulatory frameworks by changing the penalty thresholds or the scheme on how the penalty cost per interruption / client is calculated.

In addition to that, it is possible to determine the impact of the services on DSOs' operational performance even more precisely: Once a sufficient number of observations on KPIs can be obtained during service utilisation periods, a regression model would be suitable to determine the causal relationship between service utilisation and changes in DSOs' operational performance. An exemplary regression model is shown below illustrated with FLISR utilisation in the Babaitan LV.

The advantage of developing regression models to assess service's impact is that it allows the impact of the respective service to be isolated by controlling for any other factors that affect the operational performance (here measured as 'average duration of unplanned interruptions') of DSOs' besides FLISR. As listed and defined in table 6, these additional factors could encompass the 'amount of decentral feeding points', 'residual load volatility', 'feeding volume', 'number of feeding points' and 'supplied area'.

Given that the number of observations is sufficiently high and that the respective data are

$$DUR\_UI_{LV\_Babaita} = \beta_0 + \boldsymbol{\beta_1 * FLISR} + \beta_2 * DG\_LV + \beta_3 * Res\_Load + \beta_4 * FV + \beta_5 * FP + \beta_6 * SA + \ldots + \varepsilon$$

available, the aim should be to include more control variables suggested by DSOs in order to assess changes in operational performance according to the model.

Table 6: Possible Regression Model Variables (to be extended)

Acronym	**Definition**	**Type**
DUR_UI	Average Duration of unplanned interruptions	$\mathbb{Q}$: Minutes
FLISR	FLISR utilisation	$\in \{0,1\}$
DG	Amount of decentral feeding points	$\mathbb{N}_0$: {0,1, 2, …, n}
Res_Load	Residual Load Volatility	$\mathbb{Q}$: $\sigma_{(Con\_t - FV\_DG\_t)}$
FV	Feeding Volume	$\mathbb{Q}$: KWh
FP	Number of Feeding Points	$\mathbb{N}_0$: {0,1, 2, …, n}
SA	Supplied Area	$\mathbb{Q}$: km^2
…	…	…

5. Value Chain Design & Business Models of Value Chain Actors

As mentioned in sections 3.1 and 3.2 and complementarily in chapter 4, value through SOGNO service utilisation is created by service-induced improvements in the operational performance of DSOs. However, continuous value creation requires a functioning infrastructure that coordinates the flow of information, money, hardware and software between the parties that are involved in the creation of value via diffusion of the SOGNO services and the DSOs as their customers - the so-called 'Value Chain'.

According to their traditional conceptualisation, Value Chains are sequential sets of activities (e.g. melting, moulding, hardening etc.) that companies perform in order to add economic value to services or products [8]. There are intra-organisational Value Chains (e. g. subsequent production steps) and inter-organisational Value Chains (e.g. supplier-buyer relationships[9]). Meanwhile, the understanding of and the operation of Value Chains have evolved. The contemporary logic of value creation has outpaced independently performed activities and emphasizes collaboration, process-orientation and customer-centralisation. Value[10] is thus increasingly created by collaborating economic entities that combine services and products "into activity-based 'offerings' from which customers can create value for themselves" [9]. So also in the case of SOGNO: Tailored to the activities of DSOs, the consortium is developing and testing the SOGNO services as combinations of hardware and software (D1.1) with which DSOs can create value for themselves. Concordantly, it is foreseen that the DSO should not be urged to contract with various hardware, software or ICT providers once market exploitation takes place. The DSO only transacts with one economic entity that delivers automation functions and information as a service while the ICT-, hardware, and software-related transactions necessary for service-provisioning are coordinated and collaboratively performed in the background. The economic entity that transacts with the DSO will have to account for various DSO characteristics (No. of clients, No. of DG units, underground-ratio, IT-level, etc.) by being able to offer the bundle of 5G-connected hard- and software components with variable degrees of data visualisation and scalable automation complemented by flexible pricing schemes (e. g. upfront investment vs. periodical service fee) that fit to the need of the respective DSO. Consequently, the economic entity that transacts with the DSO primarily has to coordinate and contract agilely while offering strong customer-support.

The Value Chain connects the operations of individual economic entities that respectively dispose competencies for certain value-creating activities. What has never changed, however, is that the intra- and inter-organisational activities and transactions among the Value Chain actors require proper guidance by sustainable business models to enable continuous value creation.

Based on the technical foundations of the SOGNO services (D1.1) and the SOGNO-concept of value creation (chapter 3), an initial design of the SOGNO Value Chain is provided according to figure 4 and complemented with the explanation of business models that it encompasses (table 7).

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[9] For instance, between raw material supplier and manufacturer.

[10] Deliverable 6.3 focusses on economic value (creation). Social and environmental aspects of value, value creation and value chains are analysed in the Deliverables 6.4 and 6.5. In particular, it will be ensured that no value chain partner or stakeholder is worse off compared to the status quo once market exploitation took place.

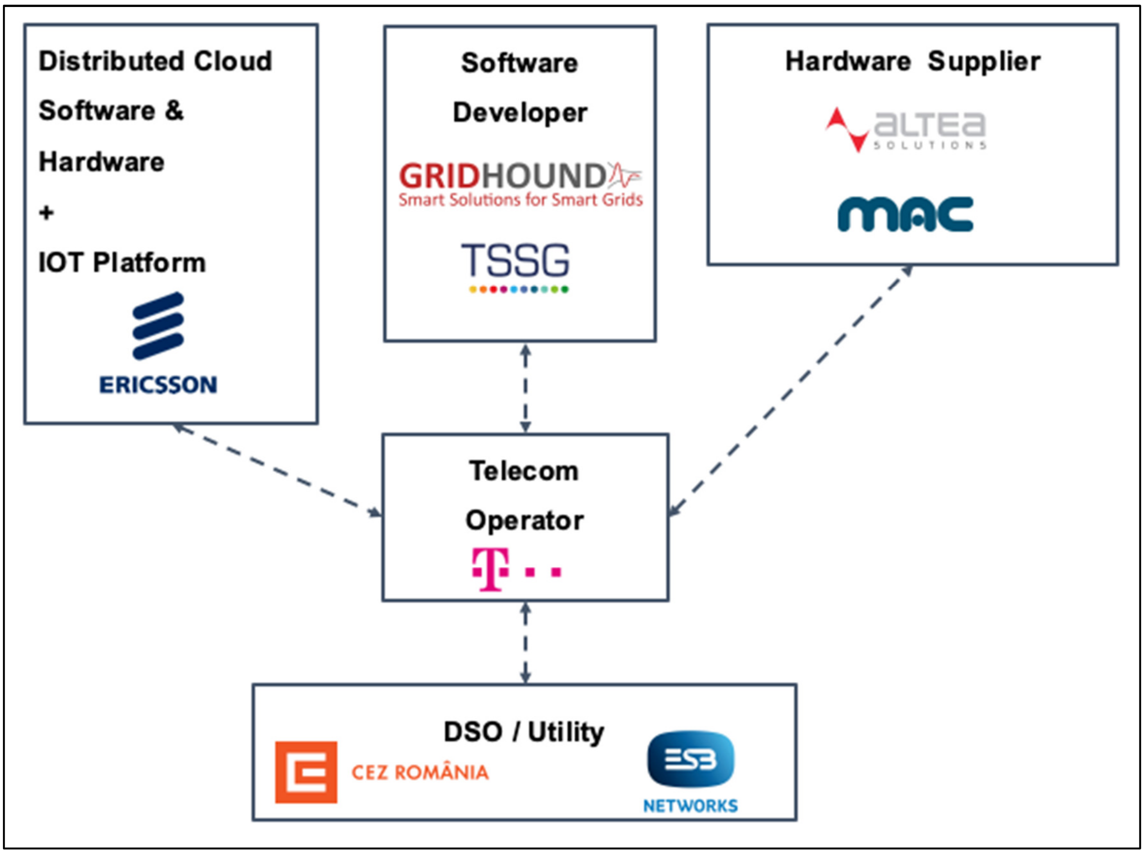

Figure 4: SOGNO Value Chain (to be discussed in detail)

A business model is defined as "a conceptual tool that contains a set of elements and their relationships and allows expressing the business logic of a specific firm. It is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value and relationship capital, to generate profitable and sustainable revenue streams [10]".

Relating the consortium partners to possible roles in the SOGNO Value Chain, there is, as mentioned above, a telecom operator, experienced in terms of agile contracting, that transacts with the DSO. At the same time, the suppliers of measurement devices, the provider of distributed cloud hard- and software, IOT platform provider as well as software developer coordinate their value creating activities according to their core competencies. How in detail, activities and resources will be arranged among the Value Chain actors to launch the SOGNO services, is to be determined by the consortium partners in the second period of the project. Eventually, the business models need to be designed so that they efficiently capture the value that is created by the SOGNO services. Table 7 provides a preliminary overview on the business models of the Value Chain actors.

Table 7: Business Models of SOGNO Value Chain Actors

<table>
<tr><th></th><th>Telecom Operator</th><th>Measurement Devices Supplier</th><th>Distributed Cloud Hard- and Software Provider</th><th>IOT Platform Provider</th><th>Software Developer</th></tr>
<tr><td>Value Proposition</td><td>Agility in Contracting, Customer support</td><td>Low-cost devices / Advanced power measurement</td><td>Low latency / 5G based network slicing</td><td>Data visualisation / Data security / User-friendliness</td><td>Scalable automation / AI / Data visualisation</td></tr>
<tr><td>Target Customer</td><td colspan="5">DSO</td></tr>
<tr><td>Distribution Channel</td><td rowspan="2">Service Contract with DSO</td><td colspan="4">Via Telecom Operator. To be discussed in the consortium.</td></tr>
<tr><td>Customer Relationship</td><td colspan="4">To be discussed in the consortium.</td></tr>
<tr><td>Value Configuration</td><td>To be discussed in the consortium.</td><td>Manufacturing and distribution of sensors, PMUs and APMUs</td><td colspan="3">To be discussed in the consortium.</td></tr>
<tr><td>Core Competency</td><td>Effective contracting</td><td>Product development</td><td>Communication technology</td><td>User understanding</td><td>Innovative problem-solving</td></tr>
<tr><td>Cost Structure (dominated by:)</td><td>CAPEX (Infrastructure) + OPEX (Transactions, personnel)</td><td>CAPEX (Physical assets) + OPEX (Material, personnel)</td><td>CAPEX (Physical assets) + OPEX (Material, personnel)</td><td>OPEX (Transactions, personnel)</td><td>OPEX (Personnel)</td></tr>
<tr><td>Revenue Model</td><td>Service fee. To be discussed in the consortium.</td><td colspan="4">To be discussed in the consortium.</td></tr>
<tr><td>Partner Network</td><td colspan="5">See figure 4.</td></tr>
</table>

6. Conclusion and Outlook

The present working report initially delineates the operating principles of DSOs with regard to the regulatory frameworks that govern their businesses as natural monopolies. Furthermore, active distribution grid management driven by ICT-based software services for grid monitoring and automation (as envisioned by SOGNO) was introduced as a reasonable means for DSOs to cope with current operational challenges that arise from volatile, bi-directional electricity flows and decreasing simultaneity of electricity consumption and production. The deliverable marks the lack of current regulations to directly incentivise DSO's to prefer software service utilisation over investments in network expansion for situations in which both would lead to the same goal. With a view to the market adoption of the SOGNO services, it was derived therefrom the importance to assess for DSOs the value of service utilisation, which arises from service-induced improvements in DSO's operational performance.

Prior to value assessment, linkages between the use cases for the SOGNO services and DSO's operational performance were qualitatively determined in intense collaboration with the partners from Work Packages 2-4. Thereupon, value measurement for the SOGNO services was conducted based on historical data from CEZ Romania (Work Package 5) and preliminary assumptions on the operational effect of SOGNO service-utilisation. These assumptions will be refined once the SOGNO field trials have progressed in a way that the relevant data types on DSO's operational performance for a period of service utilisation are available. On the example of the regulatory framework for Romanian county seat municipalities, it was shown that it is possible to quantify the economic value of SOGNO service utilisation for DSOs. This is because service-induced changes in DSO's operational performance – e.g. shorter durations or lower frequency of interruptions - directly affect DSO's regulated rewards and penalties.

Further work in SOGNO Work Package 6 is not only about determining the economic value for DSOs even more precisely with data from the SOGNO Field trials but also about evaluating the environmental and the social value of SOGNO service utilisation (deliverable 6.4). The present evaluation model can easily be adjusted to different regulation schemes and is to be extended in order to account for different distribution grid characteristics (see section 4.4). Encouraging and substantiating business discussions among the consortium partners in the second period of SOGNO, the present report concludes with a possible value-chain design (chapter 5) that demonstrates how the value of the SOGNO services could continuously be delivered once the services are ready for market launch.

The work reported in the present deliverable 6.3 has contributed to the progress of SOGNO by demonstrating how economic value is created through implementation of the SOGNO services and by recommending how that value can be assessed and captured by DSOs as well as by the service providing economic entities in the SOGNO Value Chain.

7. List of Tables

8. List of Figures

9. Bibliography

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10. List of Abbreviations

CAPEX	Capital Expenditures
DG	Distributed Generation
DSO	Distribution System Operator
ENS	Electrical energy not supplied
FLISR	Fault Location, Isolation and Service Restoration Service
KPI	Key Performance Indicator
LGF	Load and Generation Forecasting Service
LV	Low Voltage Grid
MV	Medium Voltage Grid
OPEX	Operational Expenditures
PC	Power Control Service
PQ	Power Quality Service
RAB	Regulated Asset Base
RES	Renewable Energy Sources
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SE	State Estimation Service
TAR	Total allowed revenue

ANNEX

A.1 Nine Business Model Building Blocks [10]

Pillar	Business Model Building Block	Description
Product	Value Proposition	Gives an overall view of a company's bundle of products and services
Customer Interface	Target Customer	Describes the segments of customers a company wants to offer value to.
	Distribution Channel	Describes the various means of the company to get in touch with its customers.
	Relationship	Explains the kind of links a company establishes between itself and its different customer segments.
Infrastructure Management	Value Configuration	Describes the arrangement of activities and resources
	Core Competency	Outlines the competencies necessary to efficiently offer and commercialize value.
	Partner Network	Portrays the network of cooperative agreements with other companies necessary to efficiently offer and commercialize value.
Financial Aspects	Cost Structure	Sums up the monetary consequences of the means employed in the business model.
	Revenue Model	Describes the way a company makes money through a variety of revenue flows.