NVE

Reguleringsmyndigheten
for energi – RME

RME EKSTERN RAPPORT

Nr. 7/2022

Split responsibility and submetering requirements

Utredning og evaluering av modell for aggregering og bruk av submålere

DNV

RME Rapport nr. 7/2022
Split responsibility and submetering requirements :
utredning og evaluering av modell for aggregering og bruk av submålere

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Forsidefotograf:	Landmåling på Nigardsbreen. Foto: Hallgeir Elvehøy/NVE

ISBN:	978-82-410-2221-0
ISSN:	2535-8243
Saksnummer:	202111867

Sammendrag: DNV har på oppdrag fra Reguleringsmyndigheten for energi i NVE (RME) utarbeidet en rapport som utreder ulike tekniske krav til såkalte undermålere. Formålet med rapporten er å utforske ulike tilnærminger for å definere undermålere i regelverket dersom de i fremtiden skulle bli en del av måleverdikjeden.

Emneord: Måling, elektrisitetsmålere, undermålere, submålere, submåling, aggregering

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Mai, 2022

Forord

DNV har på oppdrag fra Reguleringsmyndigheten for energi i NVE (RME) utarbeidet en rapport som utreder ulike tekniske krav til såkalte undermålere (eller «submålere»). Med begrepet «undermåler» menes en elektrisitetsmåler som installeres bak sluttbrukerens AMS-måler for å kunne måle energiforbruket eller -produksjon fra de fleksible enhetene (f.eks. fra en ladestasjon). En slik undermåler kan f.eks. være en innebygd elektrisitetsmåler i en ladestasjon.

Oppdraget til DNV ble begrenset til den tekniske måleinfrastrukturen hos sluttbrukeren og hvordan det kan opprettholdes en høy kvalitet på måledataen. Spørsmålet om hvordan måleverdier fra undermålere kan prosesseres videre og danne grunnlag for avregningen inngikk derimot ikke i oppdraget.

Hensikten med utredningen har vært få mer klarhet i muligheter for og konsekvenser av å inkludere slike undermålere i dagens måleverdikjede, og om det samlet sett vil kunne være en samfunnsøkonomisk effektiv løsning. RME ønsker å ha et godt kunnskapsgrunnlag for å best mulig kunne vurdere de ulike modellene for aggregering som har blitt foreslått. Vi vil ta med oss innsiktene fra DNVs rapport i vårt videre arbeid med å utvikle gode markedsdesignløsninger og videreutvikle regelverket for kraftmarkedet.

Utredningen har blitt gjennomført med faglig bistand fra Justervesenet. Vi takker Justervesenet for de gode innspillene og et godt samarbeid.

Oslo, mai 2022

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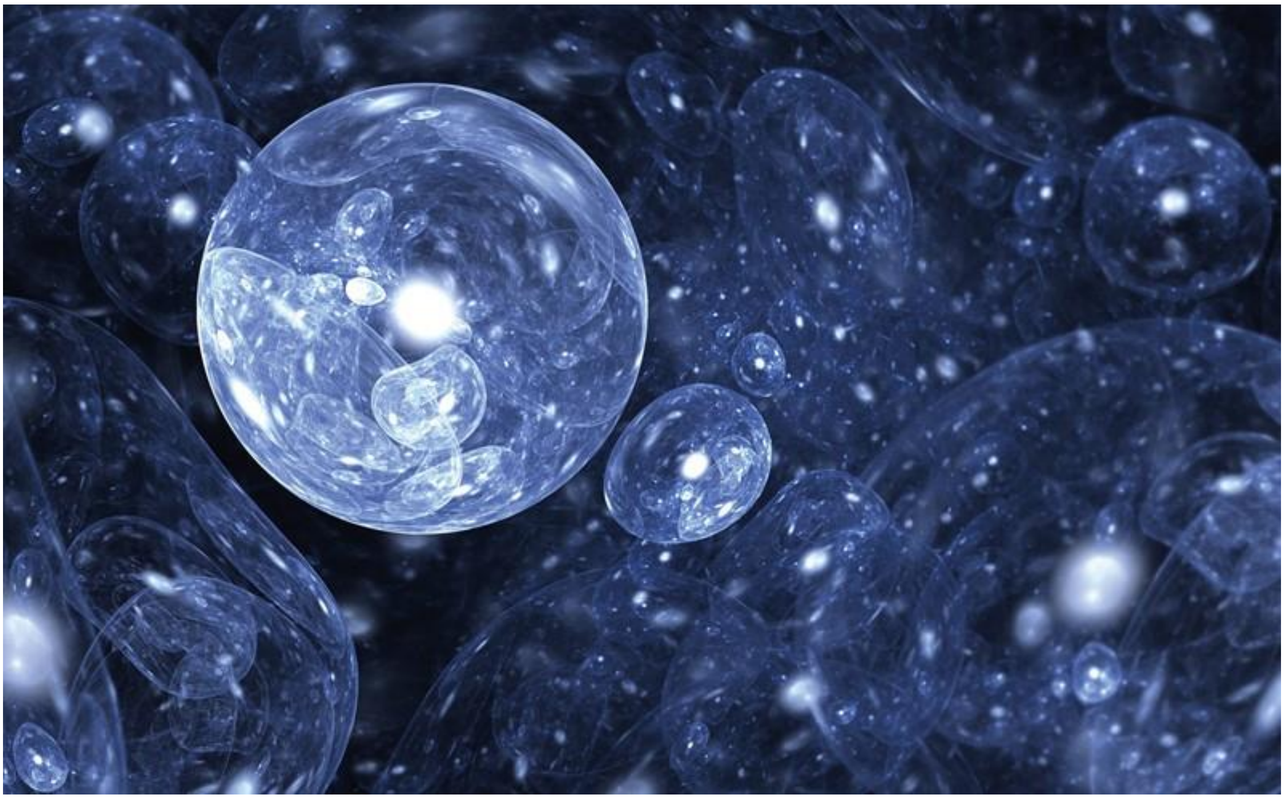
UTREDNING OG EVALUERING AV MODELL FOR AGGREGERING OG BRUK AV SUBMÅLERE

Split responsibility and submetering requirements

The Norwegian Energy Regulatory Authority (NVE-RME)

Report No.: 2022-0366, Rev. 0
Document No.:
Date: 7 April 2022



Project name:	Utredning og evaluering av modell for aggregering og bruk av submålere	DNV Energy Systems Northern Europe Veritasveien 1, 1322 Høvik Tel: +47 6757 99 00 NO945 748 931
Report title:	Split responsibility and submetering requirements	
Customer:	The Norwegian Energy Regulatory Authority (NVE-RME), Middelthuns gt 25	
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Date of issue:	7 April 2022	
Project No.:	103 12 344	
Organisation unit:	EMS	
Report No.:	2022-0366, Rev. 0	

Applicable contract(s) governing the provision of this Report:

Objective:

This report provides in the first part an overview of current requirements, roles, responsibilities, and processes with regards to electricity meters and meter data in the Norwegian electricity market. An analysis of and a set of recommendations for requirements to submeters, submeter data and the associated roles and responsibilities are provided in the second part.

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Keywords:
Independent aggregator
Split responsibility
USEF
Submeter

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
0	2022-04-07	First issue			

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Appendix A Detailed meter requirements in Norway

1 EXECUTIVE SUMMARY

When a split responsibility model (as defined by DNV GL (2020) is introduced, a second meter is needed to distinguish the energy consumed or produced with different devices, as two market actors will be active at the end user's connection point. A straightforward solution would be to demand the DSO to install a second 'standard' meter. However, the associated costs could be considered prohibitive and inefficient. Since many appliances such as EV chargers, inverters and heat pumps already have embedded electricity meters, potentially these types of meters can be used to facilitate a split-responsibility model, avoiding the costs of an additional meter.

To assess the possible options and the suitability of these embedded meters and the different configurations, this report provides in the first part an overview of current requirements, roles, responsibilities, and processes with regards to meters and meter data in the Norwegian electricity market. An analysis of and a set of recommendations for requirements to submeters, submeter data and the associated roles and responsibilities are provided in the second part, The key findings can be summarized as follows:

- The current regulation includes extensive requirements for electricity meter accuracy, as well as meter classifications and roles and responsibilities for meters and meter data.
- There is no distinction between main meters and submeters relevant for split responsibility and secondary suppliers. In current regulations, the use of a secondary metering point is only possible through the installation of a second smart meter by the DSO. To allow 'simpler' submeters to be used (e.g., embedded meters in EV chargers), current regulations need to be modified.
- A small bias in meters used for private households and other relatively small customers, can easily imply hundreds of million NOK in lost revenue or saved payments. Hence, it is of utmost importance that market participants can have trust in the different meter data and how they are used in the various processes.
- Currently, there is a clear process and strict requirements in place for collection, validation and submission of data from the customers' main meters. Data quality requirements for submeter data should be similar.
- Despite obvious concerns for neutrality and biased incentives, we recommend that the secondary suppliers themselves are responsible for the submeters in their customer portfolio, including data extraction, validation and transfer. Alternatively, a specific role (secondary metering point responsible, SMPR) is defined, where the secondary supplier needs to assign the SMPR (where it could perform this role itself)
- We further recommend that Elhub has the same role for submeter data as it currently has for main meter data
- An additional validation should be performed on all sub-meter data by Elhub, by comparing this data with the data from the corresponding main meter, enriched (when available) with information on the type of device where the sub-meter is placed. Elhub should subtract the submeter data from the main meter data, in order for eSett to allocate the right volume to the primary supplier.
- The major concerns with the recommended model are the potential benefit for secondary suppliers of installing low-quality meters, savings on quality systems or manipulating measurement data at the very start of the meter data chain. To deal with this risk, secondary suppliers should be obliged to develop and use a quality system, with clear routines and documentation that routines are followed.
- This quality system should be subject to inspection from the Norwegian Metrology Service (Justervesenet), The current requirements for quality systems applicable for (main) electricity meters serve as a good model but should be adjusted to take into account the differences between the suggested requirements and the regulatory strategy for submeters as compared to main meter requirements.

Based on our analyses, we have concluded that the requirements should be centred around requirements to the meter data delivered from the secondary suppliers or SMPRs and the documentation they must develop to demonstrate how the level of quality is achieved and maintained.

The table below summarises our recommendations for the submeter data.

Table 1-1 Suggested requirements for submeter data

Topic	Suggested requirements on data from submeter
Accuracy	**+/- 10 %** This is similar to the current requirement on main meter data accuracy
Completeness	**Meter data needs to be 100 per cent complete** There must be an actual meter reading or an estimated value for each meter for each settlement period (hour or 15-minute block, see Resolution). This is similar to main meter data requirements. Missing data may be estimated. Estimated values must be replaced by actual meter readings within five days, such that at least 99 per cent of the data is based on physical measurements. Estimation for an individual meter is only allowed for a limited time (e.g., a month), after which the split responsibility model for that customer (or device) must be discontinued. The estimation process needs to be described in a quality system
Conformity	**Meter data needs to be transferred to Elhub in a standardised format** The data format and the transfer method should be as specified by Elhub, similar to the requirements for meter data from the main meter
Data access (display)	**Customer should have access to (raw) meter data** locally, either through meter display, appliance display, or app connected to the device. This is different from the main meter requirements, where access must at least be possible via a meter display.
Precision	**Metering values needs to be registered in kWh, including 3 decimals**
Representation	**Off-take and feed-in of active energy should be specified separately** Every settlement period both values can be non-zero (no netting). For active energy, this is similar to the requirements for the main meter data. Unlike for main meters, we do not suggest a requirement to also meter reactive flows
Resolution	**Data collection should be with 15-minute intervals**, or higher. Depending on the individual use cases, submeter data can (will) be aggregated somewhere in the meter data chain to hourly values. More granular data is optional. This is similar to the main meter data requirements
Time stamp	**All meter data must have a time stamp with the same accuracy as the main meter**
Timeliness	**Meter data needs to be provided on a daily basis** This is the same timeline as for main meter data
Validity	**Validity needs to be assessed** Invalid measurements need to be replaced by estimates. See also Completeness. Validation process to be described in quality plan

SAMMENDRAG

Hvis en modell med delt forsyningsansvar (heretter omtalt som split responsibility, se DNV GL (2020) blir introdusert, er det nødvendig med en ekstra strømmåler (submåler) for å skille energiforbruket eller -produksjon fra ulike apparater, ettersom to markedsaktører da vil være aktive i kundens tilknytningspunkt. En enkel tilnærming ville være å kreve at nettselskapet (DSO) installerte en ekstra 'vanlig' elektrisitetsmåler (hovedmåler, AMS måler). Kostnadene med dette ville imidlertid være prohibitivt høye og løsningen ville ikke være effektiv. Siden mange apparater, som ladere for elbiler, invertere for solcellepaneler eller varmepumper allerede har en innebygget elektrisitetsmåler, kan slike målere potensielt brukes for å gjennomføre en split responsibility modell. På den måten kan kostnadene ved en ekstra måler unngås eller reduseres.

For å evaluere aktuelle løsninger og hensiktsmessigheten av slike integrerte målere, presenterer vi i første del av denne rapporten en oversikt over dagens krav til elektrisitetsmålere, roller og ansvar, samt prosessene der målere eller målerdata er nødvendige. I del to bringer vi en analyse av og et sett med anbefalinger om krav til submålere, data fra submålere og de tilhørende roller og ansvar. Hovedkonklusjonene kan oppsummeres på denne måten:

- Dagens regelverk inneholder omfattende krav til strømmåleres nøyaktighet, herunder klassifisering av ulike målere, og til roller og ansvar for målere og målerdata.
- Regelverket skiller ikke mellom hovedmålere og submålere som er relevante for split responsibility og andre kraftleverandører (secondary suppliers; sekundære kraftleverandører). Med dagens forskrifter må DSOen eventuelt installere en ekstra hovedmåler. Dersom det skal benyttes enklere submålere (for eksempel integrerte målere i kundes apparater), må reglene justeres.
- En mindre unøyaktighet i målerne som brukes av husholdninger og andre relativt små strømkunder kan bety flere hundre millioner kroner i tapte inntekter eller sparte kostnader. Det er derfor av stor betydning at aktørene kan ha tillit til ulike målerdata og hvordan disse brukes i ulike prosesser.
- For hovedmålerne finnes det en klar og veldefinert prosess med strenge krav for innsamling, validering og fordeling av målerdata. Kvalitetskravene for data fra submålere burde være tilsvarende.
- Til tross for åpenbare spørsmål knyttet til nøytralitet og uheldige incentiver anbefaler vi at sekundære kraftleverandører selv gjøres ansvarlige for submålere i deres kundeportefølje. Dette inkluderer uthenting av data, validering og overføring til andre. Alternativt kan en definere en dedikert rolle (secondary metering point responsible, SMPR), slik at sekundære strømleverandører eventuelt må utpeke en SMPR (men slik at de eventuelt kan ta rollen selv).
- Vi anbefaler at Elhub får samme rolle for submålerdata som de har for hovedmålerne etter dagens regler.
- Elhub bør foreta en ekstra validering av alle submålerdata, ved å sammenligne submålerdata med data fra hovedmålerne. Hvis (når) mulig, bør denne valideringen også ta hensyn til hvilken type apparat submåleren er knyttet til. Elhub bør trekke submålerverdier fra verdiene fra hovedmåleren slik at eSett kan allokere riktig volum til den primære kraftleverandøren.
- De viktigste bekymringene knyttet til den anbefalte løsningen er de potensielle fordelene for sekundære strømleverandører av å velge rimelige målere med lav kvalitet, begrensninger i kvalitetssystemene eller manipulering av måleverdier helt i starten av måleverdikjeden. For å redusere denne risikoen, bør sekundære kraftleverandører være forpliktet til å utvikle og etterleve et kvalitetssystem med klare rutiner og dokumentasjon for at disse følges.
- Kvalitetssystemet bør være under tilsyn av Justervesenet. Dagens regelverk for kvalitetssystem for hovedmålerne er et godt utgangspunkt, men bør tilpasses for å ta hensyn til forskjellene mellom kravene for hovedmålerne og de foreslåtte kravene og reguleringsmyndighetenes strategi for submålere.

Basert på våre analyser har vi konkludert med at kravene til submålere bør fokusere på krav til målerdata som leveres fra sekundære kraftleverandører eller SMPR og dokumentasjonen som disse lager for å vise hvordan kvaliteten oppnås og sikres over tid. Tabellen nedenfor oppsummerer våre forslag for submålerdata.

Table 1-2 Forslag til krav for submålerdata

Mål	Foreslåtte krav til data fra submålere
Nøyaktighet	**+/- 10 %** Dette tilsvarer kravene til nøyaktighet for målerdata fra hovedmåleren
Kompletthet	**Målerdata må være 100 prosent komplett** Det må være en måleravlesning eller en estimert verdi for hver måler for hver avregningsperiode (time eller kvarter, se Oppløsning). Dette er likt kravene for data fra hovedmåleren Manglende data kan estimeres. Estimerte verdier må erstattes av avlesninger innen fem dager, slik at minst 99 prosent av målerdata er basert på fysiske målinger. Estimater for en enkelt submåler kan bare leveres for en begrenset periode (for eksempel en måned), hvoretter split responsibility må avbrytes for denne kunden (eller apparatet). Metoden for å estimere verdier må beskrives i et kvalitetssystem
Format	**Målerdata må overføres til Elhub i et standardisert format** Dataformatet og metoden for overføring bør spesifiseres av Elhub, på samme måte som tilsvarene krav for måleverdier fra hovedmåleren
Datatilgang (display)	**Kunden bør ha adgang til (ubearbeidede) målerdata** lokalt, enten gjennom et display, apparatets display, eller en app eller lignende tilknyttet apparatet. Dette er ulikt kravene for hovedmåleren, hvor display er et minstekrav
Presisjon	**Måleverdier må registreres i kWh, inkludert 3 desimaler**
Representasjon	**Forbruk og innmating av aktiv energi bør spesifiseres separat** Begge verdier kan være ulik null for avregningsperiode (ingen netting). For aktiv energi er dette tilsvarende kravene til data fra hovedmåleren. Men til forskjell fra hovedmåleren, foreslår vi ikke krav om måling av reaktiv flyt
Oppløsning	**Datainnsamling bør være med kvartersintervaller**, eller oftere. Avhengig av de ulike anvendelsene kan (vil) submåler data bli aggregert til timesverdier et eller annet sted i måleverdikjeden. Finere oppløsning bør være frivillig. Dette tilsvarer kravene til hovedmålere
Tidsstempel	**Alle målerverdier må ha et tidsstempel med samme nøyaktighet som for hovedmåleren**
Tidsfrist	**Måleverdier må rapporteres daglig** Dette er det samme kravet som gjelder for data fra hovedmåleren
Validering	**Måleverdier må valideres** Ugyldige målinger må erstattes med estimater. Se også Kompletthet. Valideringsprosessen må beskrives i kvalitetsplanen

2 INTRODUCTION

2.1 Context

Split responsibility is primarily introduced to implement Article 4 of the recast Electricity Market Directive, allowing customers to select more than one supplier (The European Parliament and Council Directive (EU) 2019/944 on common rules for the internal market for electricity). The directive further provides rules on the end user's right to offer its own flexibility, including through aggregation. The directive also introduces *independent aggregator* as a new role. In this role, the aggregator is not connected to the end user's existing electricity supplier.

To distinguish from the existing or main supplier, the 'other' supplier(s) are in this report referred to as *secondary supplier*(s), underlining that both (all) are electricity suppliers. The secondary supplier will supply (and potentially control) a part of the total load for the customer and the main supplier will be responsible for the remaining load at the connection point with the DSO. In order to be able to distinguish between the 'different' loads, electricity meters are necessary to measure the consumption supplied by the secondary supplier. In the meter data chain, this will be 'behind' the end user's main meter (AMS or DSO meter), and it is therefore referred to as a *submeter*. Submeters are thus a necessary element in a split responsibility arrangement.

The potential motivations for having more than one supplier can vary significantly among customers and between countries and range from individual preferences among buyers to public policy objectives. One particular purpose is for aggregation of consumer flexibility, such that the end user can offer its flexibility with respect to electricity consumption via a service provider that actively manages the consumption and passes on the flexibility to potential buyers (a DSO or a TSO, or simply the wholesale market). Such a service provider may be an independent aggregator (but the main supplier can also offer aggregation services).

A secondary supplier does not have to offer aggregation services. Also, there are other models for implementation of independent aggregation, some of which not requiring the aggregator to take the supplier role. However, a secondary meter is normally necessary for all independent aggregator models.

NordREG (2020) summarised the most important technical and economic challenges in introducing the role of independent aggregator in the Nordic region. In a report written for the Electricity Market Inspectorate, several models for the introduction of aggregation are analysed, including a split responsibility model (DNV GL, 2020). A purpose of the split responsibility model is to limit the technical and financial challenges associated with independent aggregation, by splitting the measurement point and by distinguishing between the end user's flexible and inflexible loads.

As part of a larger assessment, NVE-RME is evaluating the feasibility and suitability of the split responsibility model in more detail. In particular, it shall be investigated which technical and legal requirements submeters should and must meet in order to ensure a sound financial settlement.

The expected role of submeters is not only to implement a directive or to create benefits for the end-users, but also to facilitate the mobilisation and use of demand side flexibility, and ultimately contributing to the energy transition.

Hence, it is just about time to shape the rules for submeters and how flexible demand can participate in the market.

2.2 Approach

When a split responsibility model (as defined by DNV GL (2020) is introduced, a second meter is needed to distinguish the energy consumed or produced with different devices, as two market actors will be active at the end user's connection point. A regulatory and technically straightforward solution would be to demand the DSO to install a second, (parallel or serial) MID-certified meter. However, the associated costs for this solution could be considered prohibitive and inefficient (irrespective of which party will bear those costs). Since many appliances such as EV chargers, inverters and heat pumps already have embedded electricity meters, potentially these types of meters can be used to facilitate a split-responsibility model, avoiding the costs of an additional meter.

To assess the possible options and the suitability of these embedded meters and the different configurations, the approach has been to analyse and describe the current situation, and then discuss potential requirements for submeters and secondary suppliers. In Norway, there is currently no relevant mentioning of submeters in the legislation. Hence, when meter data are required for a process that is governed by law, the same requirements currently apply to submeters as for main meters.

Electricity meters used in economic transactions with end-users, e.g., customer billing, must be MID certified. There are no formal exceptions for submeters or for split responsibility. MID compliancy is one of several cost-drivers for submeters. There are also practical obstacles, as MID has not been designed to include submeters, cf. requirements for a display. MID certification is not a necessary condition to reach a certain meter data quality and trust. Hence, in agreement with NVE-RME, we have chosen to analyse potential requirements to submeters and submetering assuming MID compliancy can be waived or will be amended. Whether this is possible, is primarily a legal challenge out of scope for this analysis.

During the work on this report, DNV has had the pleasure to discuss multiple times with NVE-RME and the Norwegian Metrology Service (Justervesenet), manufacturers of electricity meters, both standalone and embedded meters, and manufacturers of devices having embedded meters (such as water heaters and EV chargers for residential use).

The structure of the report is as follows: In chapter 3, we outline the existing legal requirements to electricity meters and meter data. The current roles, responsibilities and processes pertaining to (main) meter data are described in chapter 4. In chapter 5, we take stock of the existing market for electricity meters and meter components. Part one concludes with a description of relevant experience from the Netherlands and Great Britain in chapter 6.

In Part two, we start by assessing the options for organising meter data extraction, validation and transfer in chapter 7. The key question is who should be responsible for collecting data from submeters, and what are the potential challenges with the different options. We proceed in chapter 8 by discussing relevant requirements to the output of this process; what are reasonable requirements to meter data quality? Finally, in chapter 9 we conclude by suggesting requirements to the submeter themselves.

A major conclusion is that there are some important choices to make, in particular about how to strike the balance between physical requirements to the metering technology and requirements to the output of the processes and how roles and responsibilities should be documented in a quality system. In this report we describe how submetering can be integrated in existing processes by providing generic recommendations. Additionally, we recommend to further elaborate and select specific options through a stakeholder consultation.

Part One

The aim of the first part of this report is to explain the relevant existing regulations, requirements and meters.

In chapter 3, the focus is on existing Norwegian legislation and regulation.

The existing roles, responsibilities and processes concerning electricity meters are described in chapter 4.

Chapter 5 presents the results of a survey of existing electricity meters and sensors.

There is limited international experience on the subject of submetering in the context of split responsibility, but in chapter 6 we present some experience from the Netherlands and from Great Britain.

3 CURRENT METER AND METER DATA REQUIREMENTS

Electricity meters in Norway are subject to requirements specified in secondary legislation (regulations). From a functional perspective, what essentially matters for various stakeholders are the meter data used for various purposes. In this chapter, we briefly present the existing requirements of both categories. The detailed requirements, extracted from the regulations), can be found in Appendix A.

3.1 Existing meter requirements

Requirements for electricity meters in Norway are regulated by FOR-2007-12-28-1753 ("Forskrift om krav til elektrisitetsmålere"; hereinafter referred to as the meter regulation) and FOR-1999-03-11-301 ("Forskrift om måling, avregning, fakturering av nettjenester og elektrisk energi, nettselskapets nøytralitet mv.", often referred to as the settlement regulation). While the meter regulation does not distinguish between main meters and submeters, the settlement regulation concerns main (DSO) meters only.

The regulatory texts cover a wide range of areas, including meter accuracy, classifications, communications and roles and responsibilities. DNV has undertaken an assessment of the regulatory text to ascertain what the requirements are for electricity meters in Norway, and how these requirements would impact the implementation of the split responsibility model. The full assessment of meter requirements is provided in Appendix A.

For the purpose of this report, the key points are:

- A number of different meter classifications exist, including based on temperature range, outdoor / indoor, and commercial use. The different applications based on operating temperature is shown in Table 3-1.

Table 3-1 – Meter applications

Class	Temp.	Indoor / outdoor	Residential	Holiday house	Commercial	Public lighting	Transf. connected
Class A	+5 - +30	Indoor	x				x
Class B (residential)	-25 - +55	Outdoor	x	x			x
Class B (commercial)	+5 - +30	Both			x	x	
Class C	any	Both	x	x	x	x	x

Source: DNV, FOR-2007-12-28-1753

- The meter regulation (in chapter 3) includes detailed requirements regarding meter accuracy and quality. For current (A), the allowed deviations from the stipulated range depend on the classification of the meter and the operating temperature. For voltage (V) +/-10% is allowed, for frequency (F) +/-2% (see Appendix A for further details).

There are also certain requirements with regards to the physical attributes of the meter:

- Display – according to the meter regulation (§ 22), the meter must be equipped with a metrologically controlled display or a display that the end user can read without the use of aids. It should display the measurement result that forms the basis for the price to be paid.
- Clock – not specifically spelled out in the legislation, but required to meet EU standards (62054-21)
- Communications – the meters should have a standardized interface that facilitates communication with external equipment based on open standards and be able to be connected and communicate with other types of meters. Communication between the smart meter (e.g., the main electricity meter) and central system (e.g., the

DSO's system for collecting meter data) should be protected with end-to-end encryption[1]. (The settlement regulation, chapter 4.)

- Local data storage - the measurement values shall be registered and stored in the meter until the measurement values have been transferred to the grid company (DSO) and at least until the due date for the current invoice period. (The settlement regulation, chapter 4.)

The legislation also sets out certain guidelines around maintenance and inspection of meters:

- Maintenance – the DSO is responsible for meter maintenance. Regulations set out rules for minimum inspections: The first inspection of the meter must be carried out within 3 years after the year of production. If the meter is approved, other checks must be carried out within 8 years after this. After that, checks must be carried out every 10 years. (The meter regulation, chapter 4.)
- Inspections / audits - statistical control can be carried out on groups composed of uniform meters of 18 or more units, so that the results are representative of the entire group. If meters in the statistical control do not meet the requirements, all meters in the group must be replaced within one year. (The meter regulation, chapter 4.)

3.2 Meter data requirements

There are some formal requirements to the meter data themselves, most importantly regarding the completeness of data DSOs are submitting, see section 4.2 and Appendix A. Meter data are the basis for customer billing and wholesale settlement, plus some other processes as explained in chapter 4.

Due to the magnitude of the economic transactions for which meter data plays an important role, there is also an informal requirement that everyone can trust meter data. The annual turnover in the electricity sector that somehow depends on meter values from non-industrial meters is close to 100 billion NOK.[2] A small inaccuracy in main meters used for private households and other relatively small customers, can easily imply hundreds of million NOK in lost revenue or saved payments. Hence, it is of utmost importance that market participants can have trust in the meter data and how they are used in the various processes.

3.3 Implications under split-responsibility

One key implication is that, although the regulatory texts include different classifications of meters (see above) which allow for slight differences in accuracy, they make no distinction between different types of meters, such as main meter vs. submeter. This means that all meters must meet the physical requirements stipulated in the legislation. In essence, the same requirements that exist for the customer's main meter would hence be required for any submeter installed. This would suggest that a submeter would need to have some form of display to meet the requirements, as well as local data storage and a solution for communication. In many ways, this may be overly prescriptive given what the submeter needs to accomplish under a split-responsibility model and that several of the functionality requirements for main meters may be moved to devices in which the submeter is installed. This is further analysed and explored in section 4, where we consider the different processes where submeter data are used and discuss the potential consequence of inaccurate submeter data.

[1] The encryption can be waived if using a closed system.

[2] The DSOs total annual revenue is approximately 20 billion NOK, most of which is paid by customers outside the power-intensive industries. Assuming households and 'normal' commercial and public consumers use in the magnitude of 100 TWh annually, and an average wholesale price 40 øre/kWh plus taxes yields 60 – 70 billion NOK annually (and more in extreme situations as we experience in the 2021/2022 winter).

Another important implication is that any deviation from existing requirements is likely to require a modification or change to the current legislation. This creates challenges with regards to the time required from the regulatory process, while making sure that any new regulation is future-proofed and fit-for purpose.

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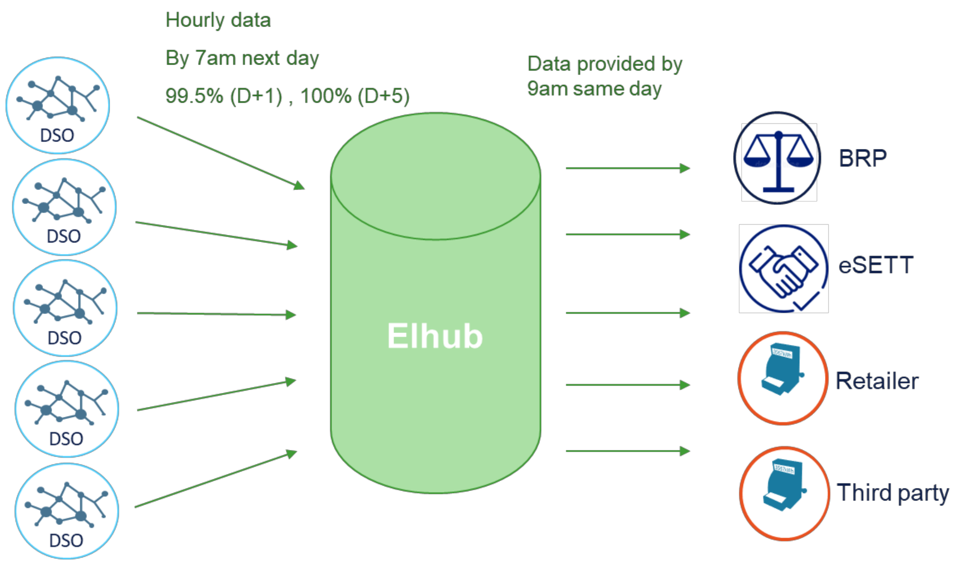
4 ROLES, RESPONSIBILITIES AND PROCESSES

This chapter outlines key roles and responsibilities with regards to the collection and distribution of customer meter data in Norway, focusing on the role of Elhub, the DSOs and other relevant market participants. These roles and responsibilities are key to fulfil various processes in the electricity market. We thus continue by explaining the processes involving submeter data, either today or potentially in the future.

4.1 The role of Elhub

Elhub acts as the Norwegian electricity market's database, storing customer information, consumption and production data, as well as providing data distribution to market participants and stakeholders, calculating aggregated metering data and overall data management. Elhub publishes monthly statistics regarding data completeness and quality, which is provided to market participants. In the event of missing or incorrect data, Elhub will estimate the values, based on extrapolation and profiles for customers without valid meter values.

Figure 4-1 – Simplified overview of meter data information flow



The DSOs are responsible for submission of hourly values for all electricity consumption, electricity production and exchange to Elhub by 07:00 for the previous day of use. The DSOs are responsible for the quality of each meter observation. Elhub provides the necessary aggregations and reporting to relevant market participants, including electricity suppliers (today, this means the main suppliers), BRPs and eSett[3] (and, in the future, presumably also aggregators and balance suppliers; BSPs[4]). Hence, Elhub is currently the only source of validated, metered values to be used for billing and settlement.

Elhub reports aggregated data to eSett (see below), which is responsible for aggregation of received metering data on a BRP level for imbalance settlement purposes. The reporting schedule is based on a 13-day period, after which the final settlement data must have been submitted to eSett. Elhub reports data to eSett no later than D+2, based on which eSett

[3] eSett OY is a company established by four Nordic TSOs, providing imbalance settlement services to electricity market participants in Denmark, Finland, Norway and Sweden, on behalf of the TSOs. eSett calculates imbalances for each Balance Responsible Party (BRP) and makes sure each party is paid and invoiced correctly.

[4] The BSP role has not yet been introduced in Norway. Hence, market participants in Norway cannot delegate their balance responsibility yet. One key explanation is that Statnett's (the TSO) IT system cannot distinguish between a BRP and actors for whom the BRP is a service provider. Market participants in Norway cannot delegate their balance responsibility yet.

will conduct a preliminary imbalance settlement. Data can be updated until D+13, when final imbalance settlement will occur.

Elhub also provides aggregated meter data directly to the BRPs (and potentially also the BSPs).

4.2 The roles of the DSO

The DSO is responsible for the submission of quality assured meter data to Elhub. As responsible for reading and collection of data from each meter, the DSOs are also expected to make a first assessment of meter readings (validation and estimation of missing or implausible values), before submission to Elhub. The current meter data requirements are summarized in Table 4-1.

Table 4-1 – Meter data requirements for Elhub submission

	Completeness		Measured and final estimated consumption		Measured and final estimated production		Measured and final estimated exchange		Temporary at D+5		
When:	D+1	D+5	D+2	D+5	D+2	D+5	D+2	D+5	Consumption	Production	Exchange
Require-ment	99,5 %	100 %	98 %	99 %	99 %	100 %	99 %	100 %	0 %	0 %	0%

Source: Elhub

In essence, the requirements mean that 5 days after the measurement day, there should be no temporary data.

In addition to meter data submission, the DSO holds several key roles and responsibilities under the current market structure, including:

- Network connection provider: responsible for providing customers with grid access. This includes providing quality assured data to Elhub regarding measurement points and maintaining up to date customer information.
- Meter operator: responsible for installing, operating, maintaining, testing, certifying and disconnecting meters.
- Meter administrator: responsible for maintaining and up-to-date database of meters.
- Measurement data collector: responsible for meter readings and an initial data quality check (can be outsourced to a service provider).
- Measurement value manager: responsible for ensuring that the measurement values are sent to Elhub. Will also handle missing metrics, including providing updated metrics and responsible for the overall data quality.
- Responsible for basic data maintenance with regards to the metering point, including metering point ID, meter information (see also section 4.3), status etc.

Recall that as there are currently no 'official' submeters, the above requirements in practice concern main meters.

As the meter owner, with overall responsibility for data collection and quality, the DSO is a key player in the current meter data chain. Under a split-responsibility model, the submeter would have a separate supplier, and this data would also need to be collected, validated and distributed to relevant market participants. The options for meter data collection under a split-responsibility model is further explored in chapter 7.

4.3 Electricity suppliers and third parties

The supplier's realm of responsibility is relatively limited under the current market structure. As the customer's power supplier, they have responsibility for standard functions such as customer billing and making sure that customer information is up to date in Elhub. The supplier in turn receives information from Elhub, including metered values for its customers. The Supplier also has the responsibility to assign (or perform) the BRP role.

A third party also has the possibility to extract customer data from Elhub, when needed to provide a service to the customer. In order for the third-party to gain access to customer data, it needs to have a direct legal arrangement with the customer. In Norway, it is not yet very common for customers with a controllable load (e.g., an EV) to have a separate arrangement with a third party, for example with an EV charging supplier for home charging, or smart water heating. Instead, such service providers have established themselves as ordinary electricity suppliers (and then, by definition, not a third party). Such 'service providing suppliers' typically provide the necessary control and communications equipment and enter into a retail agreement with the customer for smart charging, where the supplier controls the charging to reduce the overall cost for the customer. With split responsibility, such arrangements can potentially be split in two 'halves', where one supplier focus on e.g., controllable loads, such as an EV charger, where another supplier works as a traditional supplier focusing on electricity sales only.

4.4 Relevant processes and requirements

The relationship between a customer and secondary supplier has five distinct different phases, contracting, planning, validation, operation and settlement. The existence and the identity of a submeter may be relevant in all phases, but the submeter data are important primarily in the settlement phase, for these five processes:

- **Consumer billing**: With split responsibility, there will be at least two bills to the consumer – one from the main supplier and one from the secondary supplier. Submeter data will be necessary for both bills.
- **Wholesale market settlement**: Both the main supplier and the secondary supplier will be BRP (or contract someone to take care of that role). Submeter data is necessary to ensure correct settlement (by eSett) of both BRPs.
- **Flexibility service settlement** (see point v. above): The flexibility buyer must be able to verify to what extent the flexibility was delivered. When the buyer is a system operator, it is likely (common) that the product specification also includes details on (sub-)meter data and the metering process.[5]
- **EV charging and roaming**: EV charging via publicly available charging points essentially relies on submeters per charger. While there is one main meter between the DSO and the charging station, there will normally be a submeter for each charging point at the same charging station (one charging station can have multiple charging points, similar to a gas station that has multiple pumps).
- **Customer information**: While submeter data are, or easily can be, made available to the consumer via billing, there may be additional demand for access to submeter data, either from the consumers directly or via regulation.

[5] Note: if flexibility is bought form another market party, not a system operator, the energy settlement will be handled by the wholesale market settlement.

4.4.1 Consumer billing

Correct consumer billing implies that hourly[6] meter values are matched with the agreed price. For most Norwegian households[7], this is the day-ahead price for the concerned bidding zone, plus charges (påslag) and taxes. When there is only one meter involved, the process is straight forward and well understood: the DSO collects meter readings, submits daily to Elhub, and the supplier uses these data for billing.

When a second supplier is involved, the submeter values must be subtracted from the main meter values to form two sets of consumption data, one set representing the main supplier and one set representing the secondary supplier. If there are more than one additional supplier, there will naturally be more than two sets of consumption data.

There are several options for organizing the tasks related to submeters (validation, collection, etc.,). We will return to this in 7. Meanwhile, we will simply assume someone collects submeter readings and somehow make them available to Elhub.

4.4.1.1 Missing or inaccurate submeter data

When there is only one supplier, the accuracy of the main meter data dictates the accuracy of the bill. Insofar as the meter data are complete and correct, the supplier can bill his customers the consumed energy per hour.

- If some meter data are missing, billing can be based on estimated numbers. Any estimation error will be corrected when, in the next period, meter data is available again.
- If some meter data are inaccurate, e.g., the meter registering too much or too little consumption, consumer bills will be similarly inaccurate, until the inaccuracy is discovered.

When there is a second supplier and a submeter involved, the situation is a bit more complex, and the consequences of inaccuracies are different. Let us assume the main meter is correct and a submeter is inaccurate. The main meter records correctly 1000 kWh, whereas the submeter records 200 kWh while the correct value is 300 kWh, for a specific month. This gives us the following:

Table 4-2 Example customer billing with erroneous submeter reading

	Recorded and invoiced volumes	Correct volumes
Main supplier, main meter	1000 minus 200 = 800 kWh	1000 minus 300 = 700 kWh
Second supplier (aggregator), submeter	200 kWh	300 kWh
Total billed consumption, main meter	1000 kWh	1000 kWh

Hence, we can easily conclude that the customer in total will pay for the correct volume, but not to the correct supplier. One of the suppliers will bill and receive too much, while the other will bill and receive too little. This suggests that MID compliancy may be needed only on the main meter level.

Note that it does not matter whether the root cause is that some submeter readings are simply missing, if missing recordings are estimated or not, or that the meter simply records wrong numbers. If the invoicing logic is that a submeter value is subtracted from the main meter value, the consumer will inevitably pay for all the energy registered by the main

[6] When, or if, higher granularity is introduced for residential customers, this will naturally also imply more frequent meter readings, e.g., 15-minute intervals.

[7] According to Energi Norge, only 4 % of Norwegian households have fixed price contracts, while 74 % have day-ahead price and 22 % have variable price contracts (essentially relying on day-ahead prices, but price can be adjusted only on two weeks' notice). Source: https://www.energinorge.no/nyheter/2022/flere-bor-vurdere-fastpris-pa-strom/

meter, but not necessarily to the supplier that has earned it. Hence, inaccurate submeter values will have economic impacts on the involved suppliers. However, to determine if there is a definite economic loss for any of these, we will have to look at the wholesale settlement as well, see section 4.4.2.

If the prices are different for each supplier, there will also be an economic impact on the consumer. Depending on which prices are highest, the consumer will lose or benefit – in the example above by 100 kWh multiplied with the price difference.

As we cannot know whether it is the second supplier or the 'main supply' that is the largest and in economic terms the most important supplier, we cannot know if the impact of inaccurate submeter values is of significant importance for the involved suppliers, even if we happened to know the exact nature of the meter error.

Note that insofar the submeter reading is logical given the consumer's installation (e.g., not exceeding the main meter reading unless there is behind the meter generation or storage), one will not necessarily discover erroneous submeter readings (but statistical tests might of course indicate if some values are surprising or suspicious).

4.4.2 Wholesale market settlement

Wholesale market settlement implies that all meter readings associated with the same supplier are aggregated (sum for all customers of the same supplier) and compared with the trades the supplier has made in the wholesale market. If the supplier's customers have used more energy than the supplier had sourced in advance, the difference will be settled at the imbalance price since the missing volume needs to be sourced through the balancing mechanism.

For those consumers having more than one supplier, this means that 'their' submeter readings will impact the wholesale settlement of both (all) their suppliers.

When a second supplier is involved, the submeter values are subtracted from the main meter values to form two sets of consumption data for each customer and then aggregated to establish the position of each supplier towards the wholesale market. If Table 4-2 corresponds to the meter readings from one customer, the wholesale settlement corresponds to aggregating all 'similar tables' for other customers and calculate aggregated values per supplier. Random measurement or estimation errors can be expected to even out, based on the law of large numbers. However, biases in measurements or estimations will have impact on wholesale settlement.

4.4.2.1 Missing or inaccurate submeter data

Wholesale settlement is based on aggregation of the same meter values that are used in the consumer billing process. Hence, it is evident that any inaccuracy of individual submeters will be aggregated and disturb the wholesale settlement in a similar fashion as happens for the individual customer. We can thus similarly conclude that all suppliers as a group will pay for the total correct imbalance, but each individual supplier can be settled for a wrong volume and thus presented with a wrong settlement bill. Some suppliers will be held responsible for a larger consumption than their consumers actually consumed, others will be held responsible for a smaller volume, and potentially, some will not be affected even if 'their' customers' submeters provide inaccurate numbers. The latter can be the case if submeters are associated with unsystematic errors of the meter values. A relevant question is if there is also feedback from wholesale settlement based on inaccurate submeter values towards the aggregated volumes. Will a supplier suspecting that measurement data are inaccurate adapt their wholesale procurement of energy accordingly? Suppose a secondary supplier suspects the volume delivered to a fleet of domestic EV chargers is actually higher than he is held responsible for in the wholesale settlement (the submeters systematically underestimate the consumption). Will he then purchase less energy in the wholesale market? The answer is likely yes: one objective of the imbalance pricing is to incentivize wholesale market participants to reduce imbalances. The question is then if other suppliers (e.g., the main supplier) react accordingly. Again, the answer is likely yes. While the time to adjust can be different, it must be expected that over time, a systematic submeter inaccuracy will impact contracting policies for the wholesale market as well. But if so, some will procure less, and others will procure more, than they would have done if submeter data were correct. And the total volume of purchase in the wholesale market will still correspond to the total consumption, adjusted for prognosis errors as usual.

Unsystematic errors, both in submeter data and estimation processes, will not have a significant impact on wholesale settlement. Systematic errors (bias) will have an impact but are on the long run not likely to impact the balancing positions of the suppliers involved and will only have second-order impact on energy sale margins (lower/higher volumes).

4.4.3 Flexibility service settlement

Flexibility services are generally procured by transmission and distribution system operators. Often, these are procured in two steps – a capacity market where system operators ensure availability of resources, and an activation market for the actual use. For financial settlement of activation, meters are necessary. This could be the main meter or a secondary meter, depending on aggregator and flexibility buyer preferences and possibly also regulatory requirements.[8] unless DSO services are or can be settled based on main meters This is generally the case when aggregators are using the response from multiple appliances, e.g., private EV chargers, to ‘produce’ and deliver flexibility services. When the service is delivered directly from a power plant or from a large industrial unit, submetering is not an issue – the need for meter data will be covered by the main meter.

Traditionally, the markets for flexibility services are developed by TSOs to serve their needs. A TSO normally procures flexibility according to predefined product specifications via a set of dedicated markets. The most common products are FCR, aFRR and mFRR. Over the past decade, significant efforts have been made to harmonize product definitions across Europe, to both reduce barriers to entry (e.g., as suppliers can use experience gained in one country to establish activities in another country) and to ensure product designs that enable more efficient procurement processes. European standards are thus emerging for the common TSO products, and the TSOs are developing joint procurement platforms to facilitate and improve cross-border trading with such services. A common feature for TSO products is that the prequalification requirements often include details on (sub-)meter data and the metering process.

For DSOs, buying flexibility is still rather premature, although some experience is emerging, both in Norway as well as other countries. The most likely services are related to local congestion (capacity) and voltage. While TSO services to date mostly are delivered by market participants that themselves have sufficiently large resources to cope with minimum bid size, it is generally expected that aggregation of small resources will be a typical approach in the DSO segment. The individual resource owner will typically be too small (e.g., a household) to offer flexibility directly to a DSO. The most competitive assets providing services to DSOs may be such assets that are likely to be installed regardless the DSO demand for flexibility, such as private water heaters, heat pumps, EV chargers, refrigerators in grocery stores, etc. It is too early for DSOs to consider product harmonization and standardization.

Regardless the buyer, the demand for submeter data is related to the financial settlement and to allow the buyer to verify delivery of the services to be paid for (or to verify which suppliers have supplied as intended, and hence have earned the right to remuneration). To verify that the problem the system operators wanted to solve (imbalance, congestion, voltage, etc.). are indeed solved, system operators will normally use their own meters and sensors, e.g., directly connected to their own assets.

[8] Remuneration of activated energy is the main rule, but there are examples of services where activation is not remunerated, at least in the past. Even in this case, the system operator still needs measurement data to verify service delivery.

4.4.3.1 Missing or inaccurate submeter data

As submeter data in this context in the short term are important for financial settlement only, the impact of inaccurate submeter data is limited to the financial settlement. Depending on the nature of the data imperfection, the system operator may pay too little or too much to the concerned aggregators and then indirectly to the participating consumers. This is primarily a distribution issue and not so much affecting short-term efficiency.

However, to the extent there is a systematic and long-term bias in submeter values, the consequences may go beyond the purely financial: some assets or resources may be perceived as more competitive than they are, and vice versa. There is thus a risk that inaccurate submeter data have some impact on efficiency, in terms of which resources are contracted and activated, and eventually, which resources are expanded over time. If, on the other hand, measurement errors are unsystematic, no efficiency impact should be expected. Also, the risk for efficiency impacts is lower if the system operator can use own meters and sensors connected to their own assets to verify the response from the various resources.

Regardless the requirements to submeter data, it is worthwhile to gain insight in the nature of metering errors over time.

4.4.4 EV charging and roaming

In addition to home charging, where the EV owner uses the EV charger more or less in the same way as any other electrical household devices, there are at least three other business models in the EV charging market:

1. A common setup for public **charging** in Norway is that the EV owner pays directly to the charging station operator, subject to an initial registration of the customer relationship. By using an app, an RFID tag[9], or an SMS based communication, the charging point is started. Invoicing will be done according to the established contractual relationship. This typically means the EV owner will have customer relationships with multiple charging operators. The rates for charging are normally a combination of energy (kWh) and duration (time the EV is connected; minutes and seconds). The rates are often differentiated based on location and capacity (kW) and can potentially also vary by time of day/week or year.
2. Another model for public charging is based on **roaming**: the EV owner has a contract with one charging service provider. By means of roaming agreements between this service provider and multiple charging point operators, the EV owners can use any charger operated by these charging point operators, while being invoiced from his preferred charging service provider only. The rates from the charging service providers are structurally similar to the rates offered by charging station operators.
3. A third model is that a public charging service provider (also) includes **home chargers** in the service, such that the service provider is energy supplier to the home charger (while the main supplier(s) provides energy to everything else in the household), or alternatively that the charging service provider focuses on home charging only. This setup can be applied e.g., when a lease company or an employer is supposed to pick up the energy bill for a fleet of cars, or simply if the household prefers a second supplier for the EV charging at home. The main parameters for billing will be energy and timing, whereas duration of the charging process is less relevant.

All business models involve metering for each charging point. With the first business model, there is normally no need for a split responsibility arrangement; the settlement between the operator (as energy customer) and the energy supplier (or the wholesale market settlement in case the operator is also an electricity supplier) will be organized around the main meter and associated processes. Submeter data will not impact these settlement routines. However, submeters will be necessary to invoice each individual charging customer the correct amount.

[9] RFID (radio-frequency identification) is one method of automatic identification and data capture. RFID tags are made out of three pieces: a microchip (an integrated circuit which stores and processes information and modulates and demodulates radiofrequency (RF) signals), an antenna for receiving and transmitting the signal and a substrate. When triggered by an electromagnetic interrogation pulse from a nearby RFID reader device, the tag transmits digital data, usually an identifying inventory number, back to the reader.

For the second model, the roaming feature is not necessarily a part of the electricity market: While a charging point operator certainly typically has an arrangement to source electricity to the charging point, the charging sessions, including the energy for charging the EVs, may be settled between different charging service providers, but they are not necessarily trading energy and are not active electricity market players as such. But still, (final) customer billing and settlement between the operator and the service providers might rely on energy measurements from submeters.

A variant of this model is feasible, such that the charging station operator and his energy supplier will be held responsible for the energy delivered via main meter minus what other charging service providers are responsible for. The latter is then determined by submeters for each charging point. The 'other charging service providers' (and the associated energy suppliers and BRPs) will have a similar role as secondary suppliers have for households covering their main supply from one supplier and supply for dedicated appliances from another supplier.

In the third model, submeter data are essential for customer billing, wholesale settlement, customer information, and flexibility service settlement if relevant. But the processes are in principle similar to those that apply for any other customer having more than one supplier. Recall that the charging service provider also may have a role as energy customer, buying electricity either from a supplier or directly in the wholesale market.

In the second model,

4.4.4.1 Missing or inaccurate submeter data

Due to the close similarities with 'normal' or more generic examples focusing on split responsibility, there are essentially no differences with respect to the impact of inaccurate submeter data when the case is based on model 2 or 3 above (EV roaming or EV charging based on home chargers). Assuming the main meter data are correct, inaccurate submeter data will impact the split of revenues between suppliers. To the extent prices are different, the customers may also pay too much or too little. The payment 'failure' will essentially correspond to the meter data error multiplied with the difference in relevant contract prices.

For public charging, there is a larger difference with ordinary split responsibility models as inaccurate meter data in the latter are corrected in through the main meter bill, while this is not the case for public EV charging.

4.4.5 Customer information

Consumers can generally claim to see the basis for the calculation of any invoice. This of course also applies to electricity. A common interpretation in the electricity sector is that the main meters should have a display where the customer can observe the total volume metered and receive, or otherwise be given access to meter values per hour.

In the case of split responsibility, a submeter would be needed to inform the processes described in sections 4.4.1 to 4.4.4. However, none of these processes require that the consumer is given access to (continuous) information about 'submetered' consumption. Billing and settlement work even if submeter data are not visible for the consumer. The key feature from a practical perspective is that the different meter readings are available for the various calculations, and that the calculations, or the data, can be made available to the customer. How the total amount is split between two or more suppliers does not make a huge difference for the end consumer, unless one of the bills are picked up by e.g., a lease company. The most important meter reading for the customer, at least from an economic perspective, is the main meter, as this represents the total consumption that will be invoiced.

Nonetheless, the customer may have (at least hypothetically) an own interest in submeter data, e.g., for curiosity, for technical performance analysis of one or more devices, or for controlling invoices from the secondary supplier.

Consequently, the relevant question with regards to customer information is not about a display, but rather in what format and by which means submeter data should be made available to the customer. The customer should be confident that meter data made available to her are correct and not manipulated. It does not seem dramatic to argue that it does not have to be a display and that access to an online service can be sufficient, provided the supplier has a convincing quality plan (see chapter 7.4. Also, data quality is/will be covered by requirements following from the other processes described above.

5 METER ASSESSMENT

In this chapter we will present the main finding regarding our meter assessment. These results are based on desktop research and interviews with meter manufactures and manufacturers of appliances (i.e., EV wall boxes, smart water boilers). We will show the main features present in standalone meters that are often used in applications like PV inverters, EV solutions and other home domestic use cases. The results are mostly based on DIN-rail meters, but we also include our findings on embedded meters and how these compare to DIN-rail meters.[10]

5.1 Standalone submeters

During our research and interviews with meter manufacturers we have found out a lot of variation exists in these types of meters. There are several reasons, such as:

- A lot of different use cases exists. Metering requirements for facilitating these use cases are either not regulated or the regulation in different European countries differs (i.e., sometimes requiring MID-certified meters while in other cases this is not required)
- The competition between the different meter manufacturers motivates them to position themselves slightly differently in the market

Looking at specific features of the meters, we have classified them into 3 categories. Note that we only include meters that apply direct metering. Other types of meters that use current and voltage instrument transformers also exist. We have not included these type of meter setups because the price of such a setup will be much higher while the meter features will not be different.

5.1.1 Simple meters

The simplest type of DIN-rail based meters are shown in the figure below. The main characteristics of these meters are:

- Price range: between approximately 50 € to 150 €
- Single phase and 3-phase meters exist (this also influences the price)
- Only active imported energy (and voltage and current [amps]) is measured, no distinction between imported and exported energy
- Both MID-certified and non-MID-certified meters exist. The MID-certified meters have a display while the non-MID-certified meters (mostly) do not have a display.
- Accuracy class 1 according to IEC 62053-21, or class B according to MID (which is equivalent to utility/DSO main meters)
- 6 digits display (including 2 decimals)

[10] A DIN rail is a metal rail (metallskinne) of a standard type widely used for mounting circuit breakers and (industrial) control equipment inside equipment racks. The main meter is normally mounted on DIN-rails inside the household's electrical cabinet (sikringsskap).

Figure 5-1: Simple meters

These types of meters typically:

- Do not implement a communication protocol. Integration of the meter into an appliance can be based on a pulse output (e.g., a digital output where 1000 pulses correspond to 1 kWh)
- Do not have a built-in real-time clock (RTC)
- Do not store meter data
- Do not support multiple tariff metering

5.1.2 Advanced meters

A few medium-featured meters are shown in the picture below. These meters have more features than the simple meters. They support features that are also found in utility meters.

Figure 5-2: Medium meters

The main characteristics of these meters are:

- Price range: between approximately 150 € to 250 €
- Single phase and 3-phase meters exist
- They measure active and reactive energy and import and export of energy (4-quadrant metering)
- MID-certified and non-MID-certified meters exist. These meters mostly have a display
- Accuracy class 1 according to IEC 62053-21, or class B according to MID (which is equivalent to utility meters)
- 7 digits display (including 2 decimals)
- Integrated communication hardware, e.g., in the form of electronic components integrated into the printed circuit board (PCB) of the meter

- Support for a communication protocol. Two variants of communication protocols that are supported are either Modbus or MBUS (only one of the two will be implemented in a meter)
- Support for multiple tariffs is available (either 2 or 4 tariffs).
- Sometimes these meters also have a real-time clock

An uncommon feature is storage of historical data (historical metering values)

5.1.3 High-end meters

An example of an advanced meter is shown in the picture below. These meters have the same features as the advanced meters while additionally they typically include features like:

- Price range: between approximately 300 € to 350 €
- MID-certified and non-MID-certified meters exist
- Storage of historical data
- Features that are not really necessary for the split responsibility use case, like
    - Support for storage of load profiles
    - Measurements of harmonics and total harmonic distortion

Figure 5-3: Advanced meters

5.1.4 Note on MID vs non-MID meters

It is important to note that all meter manufacturers confirmed that the MID meters and the non-MID meters are physically almost the same meters, except perhaps for the display.

5.2 Embedded meters

When MID certification is not important or not required, appliances like EV chargers, PV inverters, smart water boilers, etc., may include an embedded meter (for different reasons). It is often claimed that these embedded meters are a lot cheaper (e.g., 20 € or less) than the standalone DIN-rail based meters discussed above. However, in essence, this depends on the definition of an embedded meter, and what features are supported by these embedded meters.

Practical examples of embedded meters show that the metering electronics (comparable with the metrological part of main meters) is integrated with the electronics of the appliance. The metering features (as discussed for the standalone) are essentially provided by the appliance, or its electronics in total, combining sensors and other electronics. The embedded metering part is only the sensor part (sampling of voltages and current).

All digital or static electricity meters perform sampling of voltages and current (amperes). DNV's assessment found that embedded meters use or may use similar microprocessors and integrated circuits (ICs) that are also used in standalone meters, both designed as main DSO meters or as submeters. Hence, the metrological part of an embedded meter can easily be the same as for DSO meters and provide similar accuracy, but there is of course nothing in place today to guarantee this.

One factor that makes DSO meters and DIN-rail based meters different from an embedded meter is that standalone meters implement a complete metering application around the sensor sampling. A DSO meter for example has two types of firmware:

- One firmware for the metrological part (that provides the sensor sampling); this firmware is often also called the legally relevant firmware
- A second firmware that takes care of typical metering features like tariff structures, load profile, communication protocols, historical data storage, etc.

Consequently, if an appliance with an embedded meter needs similar features as for example the main DSO meter, this functionality should be implemented in the appliance as the embedded meter will only provide the measurements. This makes MID certification complex, as some of the MID requirements relate to the appliance, rather than the embedded meter (sensor).

5.3 Factors that determine the price of the meters

As part of the assessment, DNV also identified the main items or features that determine the price of the meters:

- Quantity (number of meters): compared to utility meters, the production volumes for the types of meters described above are a lot smaller. Utility meters are based on international standards, and common specifications imposed by the DSOs and are fabricated and rolled-out by the millions. A volume discount (due to very large production volumes of a certain type of meter) in the magnitude of 50 per cent is conceivable. Large European countries like Spain, France, Italy have defined their own meter specification while smaller countries like Austria, Belgium, Luxembourg tend to require a common specification defined by an industry consortium of several meter manufacturers (e.g., the IDIS association https://www.idis-association.com/)
- MID-certified vs. non-MID-certified meter. Analysis of the prices provided by meter manufacturers shows that a MID-certified meter costs at least 10 € to 20 € more than its non-MID counterpart.
- Measurement of only active energy or measurement of both active and reactive energy (4 quadrant metering). The presence of reactive energy metering or 4 quadrant metering may also lead to an additional cost of approximately 40 € to 80 €. (Remark: It is difficult to determine the cost of this feature as it is sometimes combined with other features like multiple tariffs or the presence of Modbus communication).
- Integrated communication electronics and protocol. The presence of a communication protocol like MBUS or Modbus adds approximately 50 € or more as compared to similar meters that only provide a pulse output but with otherwise similar features.
- Meter enclosure with an IP-grade of at least IP20 (according to IEC 60529). Embedded meters do not have this cost as these meters will profit from the enclosure of the complete appliance
- More advanced metering features like tariffs, load profiles, real-time clock and historical data.

6 INTERNATIONAL EXPERIENCE

At present, there is limited international experience of implementation of split responsibility. There are, however, some relevant experience in the Netherlands and in Great Britain, as explained below.

6.1 Submetering in the Netherlands

Currently, a split responsibility model (multiple suppliers per connection) is already supported in the Netherlands. The concept of allocation point has been introduced, to allow multiple allocation points per connection. A second supplier can be contracted by installing a second meter (either parallel to or behind the main meter). The metering market is deregulated for the commercial and industrial (C&I) segment. A C&I customer that wishes to contract a second supplier needs to assign the same metering responsible party for both the primary and the secondary allocation points.

In practice, this solution is only used by few C&I customers, either to contract a second supplier for feeding in energy, or when multiple customers use the same connection.

Residential customers, in principle, can use the same mechanism, but this does not happen in practice, due to high costs and administrative and technical burden.

Triggered by concepts introduced in the electricity market directive (next to multiple suppliers: independent aggregation, energy communities, collective self-consumption and peer to peer trading), the Dutch government will (further) allow the use of on-site meters to facilitate these concepts.

Currently a new energy act is being developed, which will replace the electricity and gas acts that originate from 1998. Apart from merging these acts, also recent EU directives will be implemented. Recently a draft version was published and is now (February 2022) being reviewed by the regulatory authority on feasibility and enforceability.[11] The new act is expected to be discussed in parliament in the second half of 2022. The draft version already has elements included that can allow the use of submetering in market processes, yet most details will be included in lower legislation (governmental decrees) that still needs to be developed.

The relevant articles of the new act are:

- Article 2.44 (part 2): Reference to governmental decree describing rules for measurements at other locations than the connection point (acting as allocation point) – assigning responsibilities for installing and maintenance, data extraction and validation.
- Article 4.6 (part 7): data provision to the register operator (i.e., DSO) by the market party operating the allocation point (i.e., submeter), e.g., supplier, aggregator, energy community.
- Articles 4.3 and 4.7: receipt, use and provision of data by TSO/DSO.

The building blocks aim to allow other roles than the DSO (for the residential segment) to install and maintain the submeter, as well as to collect, validate and establish the measurements. The ministry will, in the coming period, study how this could work in practice, how to manage risks, requirements on the meter and meter data responsible party, etc., and specify this in governmental decrees.

6.2 Metering and submetering responsibilities in GB

In the last 5 years there has been a number of developments in GB with regards to submetering and split responsibility.

[11] https://www.rijksoverheid.nl/documenten/publicaties/2021/11/26/wetsvoorstel-energiewet-uht

Currently suppliers can share a consumer's volumes though the Supplier Volume Allocation (SVA) Shared Metering Arrangements. However, there are cost and competition barriers to this approach. This current approach only applies to Settlement Meters that are Half Hourly (HH) capable and requires a degree of manual intervention between the respective Suppliers and the appointed Half Hourly Data Collector (HHDC). The procedure requires Suppliers to submit information regarding how they will share supply in advance (usually as fixed proportions) and to appoint the same Meter Operator Agent (MOA) and HHDC. The SVA Shared Metering arrangements were designed for use at large, non-domestic sites. They do not offer a viable solution in terms of facilitating multiple Suppliers (including peer-to-peer trading) or use in the domestic smaller commercial sectors.

In 2019 a modification was raised to Elexon which is the Balancing and Settlement Code (BSC) Administrator and Market operator in the UK. This modification is known as the **P379 modification (**"Enabling consumers to buy and sell electricity from/to multiple providers through Meter Splitting").[12] P379 proposed to change the Balancing Settlement Code (BSC) so that meters can account for two or more different electricity suppliers or more than one consumer of electricity. For example, if a consumer leases an electric vehicle, the electricity to charge it could be assigned to the lease company and separated from the rest of the consumer's household consumption, which the customer would pay for themselves. All these arrangements could be implemented without the need for the Shared Metering Arrangement.

This proposal was withdrawn by Elexon following a CBA analysis which showed that the cost of implementing this modification was much higher than expected.[13] However, one of the conclusions from the report is that reconsidering the case for multiple Suppliers in approximately five years could be worthwhile. A five-year checkpoint would also allow time for the implementation of Market Wide Half Hourly Settlement (MHHS) and use of smart meters to be established, and for electric vehicle and heat-pump use to become more prevalent.

It has also been suggested that other modifications under approval or implementation would lead to similar outcomes. These modifications are presented below as are all relevant with submetering and split responsibilities.

6.2.1 Upcoming Changes

The P375 modification ("Settlement of Secondary BM Units using metering behind the site Boundary Point") has been approved and will be implemented by June 2022.[14] Secondary BM Units can only be registered by Virtual Lead Parties (VLPs).[15]

This change will allow metering at the asset delivering the Balancing Service, which is also called submeter or Asset Meter. The responsibility of the submeter will sit with the VLPs, who will be providing the Balancing Service and will result in the activity of smaller asset owners such as storage, and small-scale renewables to be visible in Settlement for the purpose of Balancing Services.

This modification was designed to enable greater market access for balancing services. Until recently only the main meter at the boundary level (the DSO meter) was used for the settlement of balancing services, which led to associated difficulties of parties who provided balancing services from sub-assets to provide accurate baselines and physical notifications (i.e., forecast of their consumption or generation). In addition, under the existing arrangements, where only metering at the defined boundary point can be used, it may not be possible to ensure that payments made accurately reflect actual balancing service delivery.

From June 2022, independent assets which sit behind the main (boundary) meter will be allowed to use submeters for the purpose of settlement of balancing services. Practically this modification will allow balancing related services to be

[12] https://www.elexon.co.uk/mod-proposal/p379/

[13] https://www.elexon.co.uk/documents/change/modifications/p351-p400/p379-final-cost-benefit-analysis-report/

[14] https://www.elexon.co.uk/mod-proposal/p375/

[15] VLPs are aggregators of registered units for the sole purpose of participating in the provision of balancing services. VLPs can participate in both the Balancing Mechanism and Replacement Reserve market. VLPs only participate in Settlement by offering balancing energy, they will not be subject to the same level of charges and obligations as existing BSC Parties.

separated from imbalance related activities. In this case the submeter will be under the responsibility of the Balancing Service Provider (VLP).

In case that there are multiple assets (N) and multiple VLPs behind the site Boundary Point (the connection point between the customer and the DSO), then the asset managers can still operate their assets as long as the number of asset meters is N-1.

This solution is applicable for C&I and residential assets, although cost considerations should be considered when deciding to install a submeter to the asset. As this solution has not yet been implemented, there is no available data on which segments use mostly this solution.

The above-mentioned upcoming arrangements are relevant for VLPs and for metering/submetering arrangements for balancing services which participate in GB's Balancing Mechanism. There is an upcoming change which will facilitate "access to wholesale markets for flexibility dispatched by VLPs" (**modification 415**).[16] In this case it is expected that submetering arrangements as described in modification 375 will remain in place.

16 https://www.elexon.co.uk/mod-proposal/p415/

Part Two

The previous chapters have demonstrated that Norwegian meter and meter data requirements do not distinguish between main meters and submeters. Without regulatory changes, submeters to be used in a split responsibility configuration must essentially be similar to the main meters. Furthermore, the current regulation regarding roles and responsibilities for the main meters do not identify submeters as a separate issue. The existing descriptions do not distinguish between main meters and other meters, except that the wholesale settlement regulation (avregningsforskriften) applies to the main (DSO) meters only.

The main objective of having metering requirements is to build **trust** by ensuring **correct** invoices and financial settlement, also when there is only one supplier per customer. Submeter data must be reliable! Absence of any requirements to submeters and submeter data would eventually lead to concerns for incorrect data and submeter readings not informing truthfully about the actual consumption (or production) in the relevant device. The potential causes for incorrect submeter readings might be **inaccurate** metering *technology* and (validation and estimation) *processes* and **manipulated** meter data. Having an accurate meter and metering technology does not help if the supplier, the customer or others can easily manipulate meter readings, calculations and stored values, without being revealed, and vice versa; a perfect process cannot improve inaccurate technology. The existing requirements to (main) meters and meter data processes must be understood in this context.

Because submeters will be a part of the business idea of secondary suppliers, it is worthwhile to consider to what extent the incentives for such secondary suppliers coincide with the societal needs. Whereas the DSO can be considered as neutral (DSOs have no direct benefit from manipulating meter data), the secondary supplier isn't. Could this conflict of interest impact the trustworthiness of data? Will secondary suppliers be equally (or more) interested in accurate submeter readings as other stakeholders?

Hence, in this second part of the report, we start by analysing how the existing roles related to meter data collection and validation eventually should be modified and redistributed with regards to submeter data (chapter 7). In particular, this concerns the roles of the DSOs, the secondary suppliers and Elhub. The analysis concludes that the secondary suppliers should largely have similar roles and responsibilities for submeters as DSOs currently have for main meters. However, this results in concerns for trust and trustworthiness of meter readings from secondary suppliers. We thus continue exploring the incentives towards accuracy and data reliability more systematically and suggest an approach for data validation and a requirement for a quality system to be developed and maintained by secondary suppliers.

Based on the meter value chain and a quality system outlined in chapter 7, we proceed to clarify the requirements to the meter data (chapter 8) and to discuss to what extent these should result in requirements for the submeters themselves or should be taken care of by means of the secondary suppliers approach and solution for their quality systems (chapter 9).

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7 POTENTIAL ROLES AND RESPONSIBILITIES FOR SUBMETERS

We noted in chapter 4 that DSOs have key roles for the main meters and the meter readings from these. In this chapter we will explore the relevant options for these tasks for submeters. We first focus on collection of submeter data, continue by considering the options for validation, and finally discuss quality assurance and quality systems.

7.1 Collection of submeter data

There are at least four potential alternatives for organising data collection, as illustrated in the four sketches below. The use case in the sketches is that a household has chosen a secondary supplier for the EV charger. There is a submeter embedded or attached to the EV charger. Using the submeter to enable the split-responsibility model has economic advantages to the current alternative, i.e., the placement of a second DSO meter (for residential customers, placing a second DSO meter will most probably destroy any business case for split-responsibility or aggregation). The main question is how data should be extracted from this submeter.

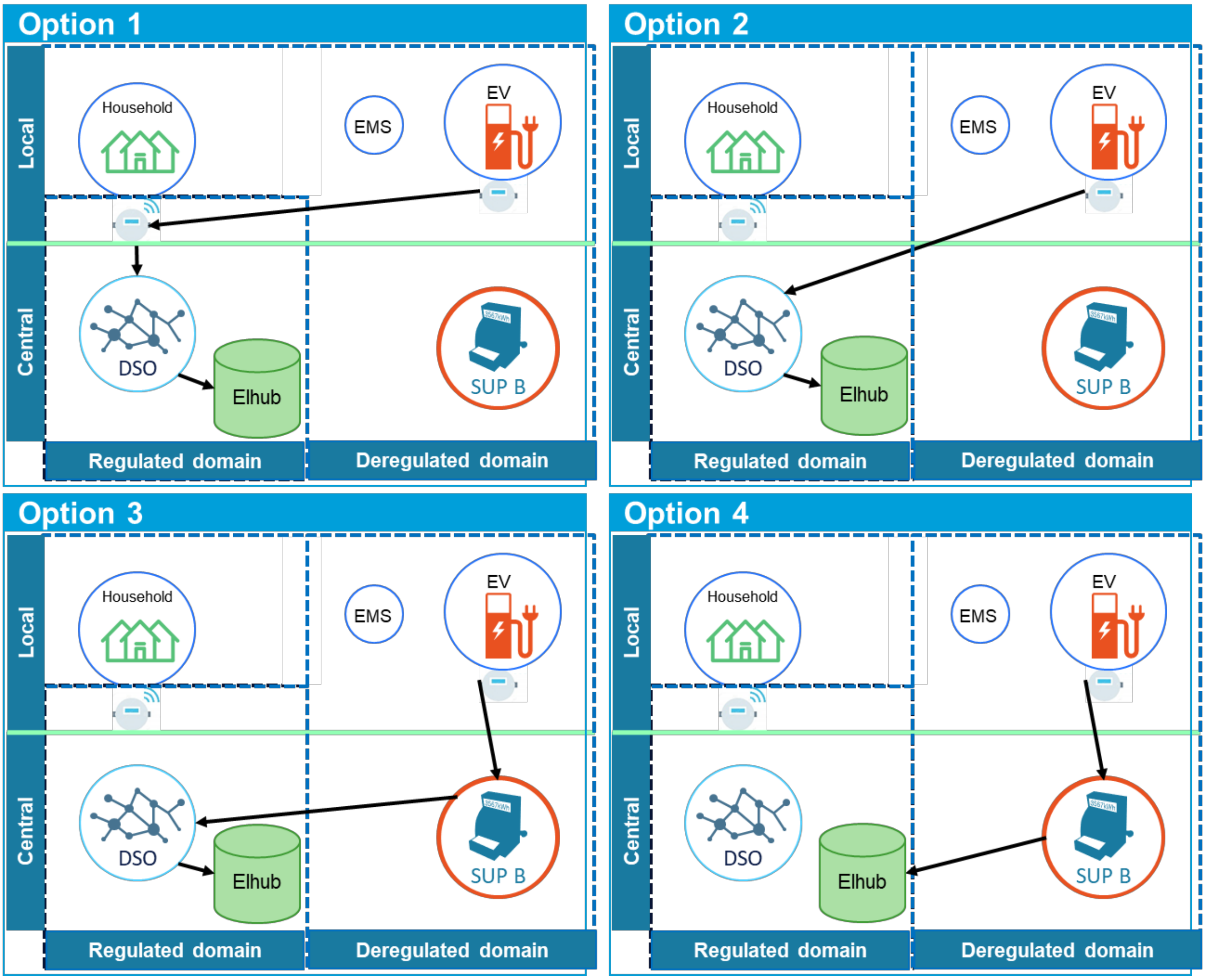

Figure 7-1 Alternative routes for extracting data from submeters

The pros and cons for each of the four options are as follows:

1. The first option is to connect the submeter to the main meter and apply the existing processes and roles for main meter data also for the submeters and submeter data. This will give the DSOs a key role and could potentially guarantee an equally high quality of submeter data processes as we already have for main meter data (but it will of course not guarantee anything for the meter itself. However, this would put strong requirements on communication between the submeter and the main meter. A communication module between the submeter and the main would be necessary. If the sub-meter does not have its own communication model (e.g., embedded metering), the communication requirements would apply to the appliance). The connection must be ensured initially and maintained afterwards. Potentially this might imply that the DSO will be responsible for connecting the submeter to the main meter and to repair the connection if it is breaks down. This also requires interoperability between the different meters, limiting the technology choices for the submeters.

2. An alternative approach would be direct extraction by DSOs. This could yield approximately the same benefits as the first option in terms of data quality, validation and trustworthiness, but will also be associated with some issues, e.g., in terms of integration efforts, identification, interoperability and security. The solution could depend on the customer's communication infrastructure (internet access) or it might imply that secondary suppliers would need to grant DSO access to their operational environment.

For both options, the DSOs would essentially take the role of a Metering Point Operator also for submeters (Secondary Metering Point Responsible - SMPR). In Norway, the DSOs already have this role for the main meters. Alternatively, someone else could take this role for submeters. Several market parties already have access to submeter data through their own infrastructure (e.g., Charging Point Operators for EV chargers). Using this infrastructure seems the most efficient way to support split responsibility models and is the main argument to consider models 3 and 4. These market parties could perform the role of (secondary) supplier, or a (secondary) supplier could enter into an agreement with such a market party (the CPO in this case) for collecting the metering data.

3. A third route is thus to ask secondary suppliers to collect submeter data from their customers and devices and feed these data further to the DSOs (the secondary supplier can outsource this activity to an SMPR). On the one hand, this could potentially open a role for the DSOs in quality assurance of the submeter data, similar to what DSOs currently do with main meter data (first round of quality assurance and data vetting). However, the main concern with this model is data integrity and trustworthiness. Secondary suppliers are not neutral in the same way the DSOs are. This also implies a secondary supplier might need to establish data exchange routines with up to approximately 100 DSOs.

4. The fourth and preferred option is a variant of the third. The key difference is to replace the DSOs with Elhub. This eliminates the second problem of option 3, but maintain the benefits, although also requiring more efforts from Elhub. As such, it contributes to reduce barriers to entry for secondary suppliers. To be specific, this solution requires that secondary suppliers (or SMPRs) extract data and provide bulk measurements data to Elhub, similar to how DSOs currently provide main meter measurements to Elhub.

However, even with a central role for a neutral body like Elhub, data integrity and trustworthiness are still valid concerns with model four. In the next section we explore the secondary suppliers' and others' incentives in this regard.

Conclusion

Despite obvious concerns regarding data trustworthiness, the best distribution of responsibilities is to require secondary suppliers to collect, validate and report submeter readings to Elhub, (almost) in line with how DSOs report main meter readings.

7.2 Incentives towards accuracy

For submeters, the use cases are potentially different from that of the main meter. The main meter must be fully functional regardless the technical environment, the consumer's choice of electrical devices, etc. For a submeter, the objective of the split supply configuration is typically to control a device and 'use' it in a clever way to maximise revenue from participation in market(s) for flexibility.[17] Such use cases require some 'minimum features', such as voltage and current sensors, a clock, ability to store data locally, and a solution for a service provider or a secondary supplier to communicate with the device (in terms of collecting information from the device and potentially give instructions to it). Hence, regardless the need for submeter data, the devices are likely to have embedded features that are helpful to ensure ability to collect meter values.

Furthermore, high accuracy and extensive data validation and control come at a cost. At least the secondary suppliers, and potentially also the customers, have an interest in keeping these costs down, while main suppliers and flexibility buyers are likely to be more concerned about the accuracy and trustworthiness the costs of data collection and validation.

First, recall that the submeter readings (correct or not) will eventually be used for a subset of these objectives: customer billing (billing main meter reading minus submeter reading), wholesale settlement of both main and secondary suppliers, settlement of flexibility procurement for products remunerating energy, settlement of roaming arrangements and customer information. Submeter data are thus used for determination of both costs and revenue for secondary suppliers (and for main suppliers). Whatever the submeter values are, the secondary suppliers will essentially be settled for the same volume that they realistically can invoice to their customers.

As seen from the secondary supplier, there are five potentially different types of errors:

1. Unbiased measurement error
   If the quality of the measurements is poor, but unbiased, then the total volume will be correct, and the secondary supplier will not be affected (only the customer).

2. Systematically biased measurement error
   If the measurements are biased (e.g., on average twice as high as the actual consumption), then the supplier will also source twice as much of energy (or at least be settled for twice as much as the actual consumption). It does not appear to offer a sustainable business model, although in some circumstances it might look attractive, e.g., if imbalance costs deviate significantly from anticipated levels. But as such deviations can be both positive and negative over time, it seems farfetched to develop a strategy around it.

3. Missing data
   If the communication infrastructure, as deployed by the secondary supplier, has a poor quality, or is used infrequently, this could lead to high volumes of missing data. In general, missing data will be replaced by estimates in the metering chain. Since estimations are never fully accurate, the quality of the processes that are informed by the metering data will be affected.

4. Manipulation of measurement data before submission to Elhub
   In this case it will be impossible for the customer or for Elhub to detect manipulation by comparing different sets of submeter readings; all available numbers are essentially from the same data set.

5. Manipulation of measurement data after submission to Elhub
   In this case, customers can easily detect if volumes invoiced from main and secondary suppliers don't add up to the main meter values.

[17] The ability to control a device may also be used 'only' for implicit demand response, e.g., cost minimisation (charge EV at lowest possible cost) or maximisation of a comfort parameter (e.g., heating). If the scope is simply to 'improve' the consumption pattern of the customer, there is not necessarily a need for a secondary meter at all, but it might be – depending on the business model for the relevant service provider. Pure implicit demand response is out of scope for this report, but in case the service provider prefers to offer implicit demand response as a service including energy, the use case can be as illustrated in Figure 7-1, and without any intention of using the EV in flexibility markets or otherwise for any other purpose than charging the EV.

Hence, it seems we are left with manipulation of measurement data before submission to Elhub as the main concern. A revenue increase by manipulation of meter data is conceivable. However, this strategy is essentially fraud and thus criminal behaviour. The risk of being discovered is lower than for type 5 above. Missing data is also a potential concern, yet it can be mitigated by imposing requirements on submeter data.

Apart from this, it is fair to assume the secondary suppliers in general are best served with high accuracy of the meter readings, and (depending on the business case) continuous communication with their devices. For most types of business models, it is actually important that the meter readings are correct and readily available to the secondary supplier. This is particularly important when smart use of the device is a central part of the value proposition towards the customer. But because high accuracy comes at a cost, there is 'always' an incentive to use cheap (and potentially low quality) meters, storage and communication solutions.

For other stakeholders, we consider the incentives as follows

- A **customer** can benefit from inaccurate or missing submeter readings if the prices are significantly different in the various supply arrangements he may have or if the bills associated with one the meters is paid by someone else (e.g., a lease company). The total volume will be correctly metered by the main meter anyway. It is not possible to determine ex ante and in general if certain type of inaccuracy is beneficial or not for the consumer. However, if there are clear incentives for the consumer, the secondary supplier and the customer have opposite objectives. The supplier can manage its interest by proper device design and data acquisition, the customer can manage its interests if he has direct access to the data.
    - Furthermore, opting for a second DSO meter (similar to the main meter) do not solve the potential problem of a creative customer installing other loads behind this second meter.
- **Flexibility buyers** may or may not benefit from inaccurate numbers depending on the prices the buyers are offered from aggregators or others acting as secondary suppliers to end users. As they cannot know in advance and for a long time whether a positive or a negative measurement error is beneficial or not, they do not have any incentives towards a particular bias. On the contrary, flexibility buyers' interests are best served with high accuracy.
- For the **main and secondary suppliers** as a group, the main issue is which supplier can invoice what volume to the consumer, and which one will be settled for each kWh. In a split responsibility context, there will by definition be at least two suppliers involved. These will not necessarily have opposite interests regarding the volumes; if the secondary supplier can benefit from an artificial volume on the submeter, the main supplier might also benefit from this. However, the opposite is also conceivable. This simply depends on the contractual positions of each supplier, both with respect to the customer contract and towards their positions in the wholesale market (hedged or unhedged, at what prices, etc.). Thus, there is not a straightforward conclusion that suppliers as a group will have incentives to anything else than high accuracy.
- For the **DSO**, it does not really matter if submeter readings are completely wrong or not; they essentially rely on the main meter. Norwegian DSOs are already responsible for the quality of the main meters, as well as responsible for the first quality assessment and for estimation of missing meter readings, before submitting to Elhub. None of these processes have to involve the submeter, and the basis for invoicing grid charges is anyway the main meter that would provide the 'official' numbers. Unless they use submetering to validate and settle DSO services, in the future, it can thus be argued that the DSOs are not really a relevant stakeholder group, and in any case, they can hardly benefit from inaccurate submeter values. For DSO services, the DSOs are depending on trustworthy and accurate data, as well (covered by second bullet above).
- For **Elhub** and **eSett**, low quality of submeter data might imply extra work, but other than that there are no direct economic consequences. Inaccurate submeter values will simply mean that someone will be invoiced too

much and others too little, while the total is still the same. Neither of them is likely to benefit from inaccurate submeter values.

Conclusion

Accurate and trustworthy data is of paramount importance, both to the customer, main supplier and buyers of flexibility services. For the main meter, trustworthiness is ensured by meter requirements and assigning responsibilities to an independent party (DSO) such as meter maintenance, meter data acquisition (through secure channels), etc. For submeters, both methods cannot simply be copied, and therefore need to be replaced, understanding that the secondary supplier is not an independent party, and may have incentives to compromise either on meter requirements (keeping costs down) or on data process (manipulating data). Secondary suppliers can potentially benefit from manipulating submeter data before making them available to other stakeholders, and the risk of being caught in flagrante is limited.

7.3 Data extraction, validation and transfer

For main meter data, the DSOs extract meter data and perform a first quality assessment each morning, before submitting bulk data for the previous day.[18] For meters with missing data, the DSOs provide estimates according to a defined procedure. Elhub continues this validation process by means of statistical tests before making the data available to suppliers, DSOs, eSett and the customers themselves.

For submeter data, a similar approach should be applied. For the relevant processes, the submeter data have a similar role as the main meter data, although less significant from some perspectives. It will not make much sense for these processes to have different quality requirements or deadlines for the two categories of meter data. Hence, to make the data as equal as possible in terms of quality, the secondary suppliers (or their assigned SMPRs) must extract meter data from ‘their’ submeters, ensure the quality is acceptable, estimate any missing data, and transfer submeter values to Elhub before 07:00 each morning, as similar as possible to the processes for main meter data.

As explained in the previous section, the main risk is that secondary suppliers manipulate measurement data at the very beginning of the extraction process. The secondary suppliers must therefore describe how the extraction process is designed and executed in a quality management system for the secondary supplier, see section 7.4. There should be a daily logging of actions to document that the data extraction is performed successfully according to these routines.

Similarly, the validation process must be described in the quality management system for the secondary supplier. The ambitions for the secondary suppliers’ validation process and efforts are i) to identify malfunction of meters by looking for statistical outliers and illogical data, e.g., by comparing data from submeters with the maximum capacity of the associated device, and ii) to replace missing or obviously wrong records with estimated values. The records must be marked, such that corrections are traceable.

Elhub’s validation and estimation processes for main meter data should be applied similarly[19] for submeter data.

In the fourth option described in section 7.1, it is Elhub that makes submeter data available to those with a legitimate need, e.g., to inform customer billing and wholesale settlement.

- Aggregated positions for each supplier (main and secondary) or their balance responsible party (BRP) to eSett; for wholesale settlement
- Corrected meter values to main suppliers (main meter minus submeter), for billing of the main supply

[18] ELhub’s requirements for the estimation and validation processes for the main meter data are described in Elhub’s VEE standard (Validering, Estimering og Endring – validation, estimation and change); https://dok.elhub.no/ediel/VEE-Standard.665190698.html.

[19] Understanding that there will be differences, e.g., main meter measurements can be compared against the physical capacity of the connection (upstream), whereas submeter measurements need to be compared against the appliance’s capacity (downstream). Also, the sign of submeter measurements embedded in an electric boiler should always be the same, a validation that is not applicable to the main meter.

- The secondary suppliers already have sufficient information to invoice their customers, both for supplied energy and/or for settlement of delivered flexibility services. However, we recommend requiring secondary suppliers to produce their invoices based on data from Elhub rather than the data collected (or estimated) by themselves. This will make sure that these invoices are based on data exposed to Elhub's vetting procedures also.
- If (main) suppliers also invoice grid fees and, as a consequence also energy taxes, a decision must be made about how this should be done in practice.[20] Grid fees are obviously based on the main meter data, while the bill from the main supplier is based on the net of main meter and the submeter. Should the grid fees be split, with one part on the main supplier bill and the other part on the secondary supplier bill? Would this even work in the case of self-consumption, if the submeter device is a PV system and not a consumption device? Should the DSO invoice the customer directly for the volume that is metered on the submeter? Or should the main supplier invoice the entire grid fee, even if only supplying a share of the total energy?

7.4 Quality system, self-declaration etc

The recommendations above leaves significant responsibility for submeter data quality on the secondary supplier, despite potential incentives to manipulate meter values to own benefit. There is thus a need for a quality system for secondary suppliers, which can serve to document which efforts a supplier actually makes to ensure accurate submeter data. The quality system should document

- Process to ensure quality of submeters at (new) customers' site
- Process to extract meter readings from submeters
- Process to estimate data in the absence of meter readings in time for submission to Elhub
- Process to validate that collected meter readings are correct
- Process to submit bulk meter data to Elhub
- Maintenance and replacement plan
    - Routines to monitor quality of submeters over time, e.g., similar to current requirements for main meters
    - Routines about what to do with failing meters, meters not communicating properly, etc. This could imply a policy for replacement, e.g., replace meter or device if communication fails repeatedly or for a longer period, or retirement, taking the device out of the split responsibility arrangement.
- Measures to prevent or discourage customers from tampering with the meter or meter data
- Process to allow customers direct access to submeter data

There is already regulation in place in Norway, requiring a quality system for those being responsible for meters and measurements of various sorts.[21] It applies to DSOs as responsible for the main electricity meters, and requires the DSOs to have a documented system such that they can demonstrate their efforts to ensure reliable meters and data, as outlined in the bullet points above. Then there are at least two alternatives for the secondary suppliers' quality systems; a) ensure that this existing regulation also applies for secondary suppliers with regards to 'their' submeters or b) develop

[20] In Norway, DSOs can let suppliers invoice grid fees to private customers. This also applies to the taxes the DSOs are required to collect (VAT and electricity consumption tax).

[21] Forskrift om krav til internkontrollsystem for måleredskaper og malinger; FOR-2016-12-20-1753.

a new regulation applicable for submeters and secondary suppliers (eventually inspired by the ‘generic’ regulation). Whether the first option is a viable and efficient strategy is primarily a legal and technical legislative question. From an electricity market perspective, it is more important that a quality system is required, that the system satisfies some minimum requirements (e.g., covers the bullet points above), that it is used in practice and not just sitting in a bookshelf, and that the systems and how they are used is subject to external control and inspection.

For the latter, external audit of quality systems, there are again at least two options; is it a task for NVE-RME or for the Norwegian Metrology Service? We note that the DSOs’ quality systems (based on the already mentioned quality system regulation) already are subject to control by the Norwegian Metrology Service. It thus seems natural to recommend a similar approach for the secondary suppliers’ quality systems.

8 POTENTIAL METER DATA REQUIREMENTS

Assuming a meter value chain and a quality system as outlined in the previous chapter, the next question concerns the requirements for the meter data themselves. By means of the process design (chapter 7.1) and the external control of data extraction, validation and transfer (chapter 7.3 and 7.4), the assumption is that the secondary suppliers are as trustworthy as possible. The next question is what level of accuracy etc., is necessary to ensure sufficient trust in the meter data and the processes relying on these data.

Ideally, the submeters should always provide 100 per cent correct information, and the delivery chain for meter data should ensure this quality remains high all the way into the processes relying on the information. However, nothing is always 100 per cent correct. Hence, we need requirements that are realistic and strike a fair balance between value and cost of providing accuracy.

Table 8-1 below summarises, in alphabetical order, our suggested requirements for the submeter data. Most of the suggested data requirements are self-explanatory, but where needed a justification is included in the table.

Table 8-1 Suggested requirements for submeter data

Topic	Suggested requirements on data from submeter
Accuracy	**+/- 10 %** This is similar to the current requirement on main meter data accuracy
Completeness	**Meter data needs to be 100 per cent complete** There must be an actual meter reading or an estimated value for each meter for each settlement period (hour or 15-minute block, see Resolution). This is similar to main meter data requirements. Missing data may be estimated. Estimated values must be replaced by actual meter readings within five days, such that at least 99 per cent of the data is based on physical measurements (see *further discussion below*). Estimation for an individual meter is only allowed for a limited time (e.g., a month), after which the split responsibility model for that customer (or device) must be discontinued. The estimation process needs to be described in a quality system (section 7.4)
Conformity	**Meter data needs to be transferred to Elhub in a standardised format** The data format and the transfer method should be as specified by Elhub, similar to the requirements for meter data from the main meter
Data access (display)	**Customer should have access to (raw) meter data** locally, either through meter display, appliance display, or app connected to the device. This is different from the main meter requirements, where access must at least be possible via a meter display. See *further discussion below*
Precision	**Metering values needs to be registered in kWh, including 3 decimals**
Representation	**Off-take and feed-in of active energy should be specified separately** Every settlement period both values can be non-zero (no netting). For active energy, this is similar to the requirements for the main meter data. Unlike for main meters, we do not suggest a requirement to also meter reactive flows

Topic	Suggested requirements on data from submeter
Resolution	**Data collection should be with 15-minute intervals**, or higher. Depending on the individual use cases, submeter data can (will) be aggregated somewhere in the meter data chain to hourly values. More granular data is optional. This is similar to the main meter data requirements
Time stamp	**All meter data must have a time stamp with the same accuracy as the main meter**
Timeliness	**Meter data needs to be provided on daily basis** This is the same timeline as for main meter data
Validity	**Validity needs to be assessed** Invalid measurements need to be replaced by estimates. See also Completeness. Validation process to be described in quality plan (section 7.4)

8.1 Completeness and estimation

Data completeness should be 100 per cent. If meter values are missing, they must be estimated (according to methods specified by Elhub and described in the supplier's quality system). Estimated values should be replaced by correct data as soon as possible. While it makes sense to aim for no estimates of main meter data within some days, it is questionable if the same requirement should apply for submeter. Hence, we have suggested that at least 99 per cent of the data is based on actual measurements within five days.

The figure 99 per cent is suggested as a starting point based on a rather pragmatic approach: 100 per cent seems unrealistic, the impact of missing data is lower than for main meter data, and 99 per cent should at least be high enough to ensure trust. We have not considered carefully whether e.g., 95 or 90 per cent would be good enough. However, we do not believe that the cost of implementing (or performing) the estimation process is depending on the percentage of missing data, assuming this is fully automated anyway. Costs related to complaints due to estimation of missing data may, on the other hand, rely on the completeness requirement.

If, as an example, meter data must be estimated due to persistent communication problems between the device and the second supplier, the supplier must eventually discontinue the split responsibility arrangement, e.g., after two months.

8.2 Data access

As explained, the main cause of concern for trustworthy data is related to the risk of secondary suppliers manipulating data before submitting them to Elhub. If customer has access to raw data as early in the data processing chain as the suppliers themselves, the incentives to manipulate are lower, simply because the risk of being caught in flagrante is higher, all else equal.

While we do think a display requirement (i.e. a physical display as part of the submeter) is not justified (see section 9.3), a requirement could be that an application that collects data from the same entry point in the device as the secondary suppliers themselves use for their daily data extraction, is made available to the customer. However, this might imply limited usability for the customer, e.g., if the local storage is limited, or if data may already be manipulated by the time they enter into the local storage.

Hence, if the quality system for the supplier is good enough, it should be considered if data access via an application that communicates with the second supplier's system rather the device directly is sufficient.

9 POTENTIAL METER REQUIREMENTS

Finally, we can discuss potential requirements for the submeters. There are two types of questions to discuss: i) features – what features or quality should we require or expect from the submeters and/or the entire process of measurements, data extraction, validation and transfer, and ii) strategy – in what form the requirements should be enforced.

9.1 Regulatory strategy

The strategic question is to what extent the desirable features should result in requirements for the submeters themselves (physical requirements) or alternatively be formulated as requirements to the secondary suppliers (process requirements). The latter implies that secondary suppliers may choose how they prefer to implement the requirements. If so, it would be reasonable to require that the solutions and necessary systems, routines, etc., are described in the quality system, and that these 'features' of the quality systems are also subject to external review, just like the already discussed items (section 7.4).

Considering that a submeter can be anything from something similar to the main meter to a few sensors combined with the electronics that anyway is included as embedded parts of a device, it might be odd to define a submeter as a physical object. A submeter can also be considered as a feature (or set of features), and thus it might be more efficient to frame the requirements as requirements to the whole process rather than to physical components.

However, this is not necessary either/or – a combination of physical requirements to cover some features and process requirements for other features might in the end be the most efficient approach.

Below, we discuss the various features for which some sort of requirement should be considered. This also includes thoughts about the choice between physical and process requirements.

9.2 Accuracy of measurements

Electricity meters normally report consumed or delivered energy based on frequent measurements of current and voltage. Energy is then calculated as the product of current, voltage and duration, registered e.g., for each hour or 15-minute period.

From chapter 5, we know that most meters available on the market, both MID certified and other meters, often rely on the same current and voltage sensors. The sensors are typically electronic components from a limited number of sensor manufacturers. Meter manufacturers often choose the same make of sensors for a whole range of different meters, both MID-certified and non-certified meters. It is generally not the choice of sensor make or design that drives the costs of a meter.

This gives reason to consider the same accuracy requirements for submeters as for the main meters. Manufacturers of submeters as well as appliances that are likely to be used in a split responsibility context should rather be encouraged to use (or require) similar sensors as are used in ordinary MID-certified meters.

This implies that the voltage measurements must be within +/- 10 per cent of the true value. The current measurement can deviate from the stipulated range depending on the classification of the meter and the operating temperature. The maximum measurement error is between 1.5 and 4.5 per cent.

Regardless the design of the process to extract, validate, estimate and transfer submeter data, it does not seem realistic that the process can improve the sensor accuracy. Also, as sensor accuracy does not seem to trigger particularly high costs, we recommend framing this as physical meter requirement.

Conclusion

Keep the same accuracy requirements that apply for main meters. Require that secondary suppliers document sensor accuracy in their quality system.

9.3 Display

The display on the main meter is one way to provide information from the meter to the customers. The display can at least report (visually) the current state, but for the consumer to learn about consumption between time t1 and t2, the readings must be noted at t1 and t2, and then compared – manually. Today, curious end users may satisfy their need for data more easily. The current display requirement for the main meter thus made more sense when smart phones and dedicated apps were less common. To have real-time access to meter data, the customer will typically have to spend some resources, e.g., by purchasing a device to connect with the HAN-port of the meter, while historic information will generally be available online from the day after consumption.

Another objective of a main meter display is to provide the customer with some sort of control, e.g., to facilitate comparison of own meter readings with those on the bill.

For a submeter in a split responsibility configuration, the case for a display requirement is challenging. The data can anyway be made available online via the secondary supplier, or potentially, via Elhub, where any customer can find 'his' meter data for free already today. Some appliances will be placed where the customers have limited or complicated access, such that a physical display is even more inconvenient as compared to an online service.

Given the potential for data manipulation by secondary suppliers before submission to Elhub, there is potential value of comparing own meter readings with those to be found online or on an invoice. This depends on how close to the source such 'own readings' can be obtained. However, this might imply providing information that is not validated to the customer, and comparison with e.g., Elhub figures may be complicated, and customers must be warned that a difference between the Elhub data and data visible in the app is not necessarily an indication of cheating. If the secondary supplier aims to cheat, it suffices to manipulate meter readings before they are displayed or submitted to a customer app, and the values to compare will obviously be equal because they are the same numbers in the first place.

Conclusion

Replace the current display requirements with a requirement on the secondary supplier to describe in its quality plan how the customer can access measurement data early in the meter data chain, to allow for validation of energy bill of flexibility services, The key objective of such a process requirement is to ensure (raw) meter data are easily available. Whether this is done via an app somehow connected to the device, through a meter or a device display or by other means should be left to the secondary supplier.

9.4 Communication

A main meter is essentially a gateway between the DSO and the customer. The meter must be fully functional regardless the technical environment, the consumer's choice of electrical devices, etc. As a major objective of introducing new meter requirements more than a decade ago was to facilitate (almost) real-time data exchange between the DSO (and/or others) and the customer, the (then) new requirements included specification of a communication solution. DSOs must at least be able to daily retrieve meter values for the past day.

Secondary suppliers may anyway need high availability of correct meter readings. Their service offerings to their customers mostly depend on reliable communication with the relevant devices. Secondary suppliers, and vendors of devices central in their business models, already have incentives to embed a communication solution between the device and the secondary supplier.

What communication platform and protocol a device manufacturer offers, or a secondary supplier requires is basically their own choice today (although there are IEC standards that may apply, depending on the type of device etc.).

A suitable approach is thus to relax the communication requirements for submeters as compared to current requirements, such that a submeter must either be able to use the communication solution embedded in the relevant device or have its own communication solution. From a technical perspective, this implies that the communication requirement is transferred from the submeter to the device or the process. One way or the other, the device, including its submeter, must be able to facilitate communication.

However, we cannot see a case for a regulatory requirement to facilitate the same type of communication that is currently expected for main meters. At least a one-way communication of meter readings should be possible, such that the second supplier can keep track of the energy consumption (or production). But the need for a bidirectional communication channel will eventually be dictated by the second supplier’s business case. The same applies for the communication technology and protocol.

Failure to comply with the communication requirements should imply the device can no longer be used in a split responsibility arrangement. This might be implemented as a requirement to replace the device or take the device or the customer out of the split responsibility arrangement in the event of failed communication for more than e.g., 30 days in a row (or more than a total of x days over the past 12 months).

The societal costs of such requirements are relatively low, partly because it will be met anyway for many potential devices, and partly because one can leave it to the vendors or the secondary suppliers to find an appropriate solution for their purpose. If the business case cannot bear the costs of a reasonable communication solution, the model simply does not comply with the minimum requirements for split responsibility arrangements.

Conclusion

The need for communication from the meter is **transferred** to a requirement for the process. The current communication requirements can be **relaxed** such that a second supplier must be able to collect meter readings daily but may decide for himself how the data are transferred. What really matters is the ability to provide validated meter data to other stakeholders. GDPR and other regulations might still apply, but these must be respected regardless the need for a submeter, and are as such related to the device, not the submeter part of it alone.

9.5 Clock and storage

The current meter regulation includes requirements that aim to ensure ability to provide meter values also in the event of a failure of the (embedded) communication. In particular, this pertains to local storage within the meter. If communication is lost, or if meter data transfers are organised in batches instead of real-time transfers, the meter must store the relevant data locally until data are uploaded to a meter data collector. A clock is necessary to ensure a correct time stamp for every record and to calculate energy; recall that energy is the product of current, voltage and duration.

Quite similar to the communication issue, the use cases for submeters are essentially different from those of a main meter. A main meter must provide useful information regardless of what appliances are connected behind the meter. For a submeter, the reason to have it in the first place is typically because a second supplier has a business idea requiring some sort of smartness, either somewhere in the device itself or elsewhere in the supplier’s delivering chain (a central server). Then most likely, the device will also have a clock and an embedded storage opportunity. If this is the case, there is no significant reason the submeter should have its own clock and own storage capacity.

On the other hand, if the device does not come with an embedded clock or storage capacity, the ability to collect meter readings would depend entirely on the communication. If communication then fails, there will be no data about energy load through the device. The impact of this might be limited, as the second supplier's services in the event of a communication failure will be suspended anyway in most conceivable cases (except for some roaming arrangements).

Considering the recommendations in chapter 7 about efforts to ensure delivered accuracy and the recommendations in chapter 8 about requirements for meter data, it seems most logical not to require a clock or a storage solution at all. Most likely, these features will be embedded in the device or the secondary supplier's process anyway. If they are not, meter data availability will depend entirely on functioning communication. If communication fails too much, the device will have to be taken out of the split responsibility arrangement anyway, see section 9.4.

Conclusion

Replace the requirements to have a clock and storage in the meter or in the device with a process requirement to ensure sufficient completeness of time-stamped meter data, as outlined in chapter 8. Even a server-based solution may be sufficient for the metering objective, although this may be insufficient for the objective of the device.

9.6 Encapsulation

Encapsulation requirements serves two purposes – to protect against malfunction due to the weather and other unintended physical impacts (potential accuracy), and to prevent data or meter manipulation (delivered accuracy).

For the former objective, there will anyway be IEC requirements for the devices having embedded meters. There is no need for additional encapsulation requirements to protect the potential accuracy. For external meters, or external control boxed containing embedded meters, relevant for retrofitting and making 'old' devices applicable for split responsibility, the encapsulation requirements should essentially be the same as for the device it will measure (unless the accuracy requirements trigger stronger encapsulation requirements, see section 9.2).

For main meters there are different methods in place to prevent and potentially inform the DSO about tampering attempts. A sensor may be used to check, and potentially report to the DSO, if someone has attempted to or succeeded in opening the 'core' of the meter. A broken seal might tell the same once the meter is subject to (physical) inspection.

The relevant question in our case is if a requirement for some sort of seal or other forms of tampering prevention is necessary and could be justified. Eventually, an embedded meter might have to be built as a separate component within a device, such that the seal cannot be broken by anyone else than 'prequalified' parties (the manufacturer of the meter component, the device manufacturer, (prequalified) repair shops and/or the secondary supplier, or a regulating entity (e.g., the Metrology Service).

Requiring a separate sealed unit within the meter appears to be a strong limitation in how devices are designed. A common approach for those devices that already contain current and voltage sensors is that these sensors are integrated parts of the electronics; they are not separate units that could easily be put inside a small and sealed container which could then be soldered to circuit boards.

The most obvious route for an approach with a seal would then be to require a seal for the part of the device that contains the meter components as well as other components that potentially have nothing to do with the metering capabilities. However, limiting who can 'legally' open the device for repair also seems as a rather strong requirement. Hence, this approach would imply that one should accept that the seal may be broken by a wide group of actors. Such seals are already common for a lot of devices; access to (parts of) the interior of electrical devices often implies breaking a seal, and if opened by personnel not authorised by the manufacturer, the warranty is lost.

It is in the interest of the secondary supplier to prevent the customer from tampering. Tampering by the customer might be easier by updating firmware or manipulating the data before they are collected by the secondary supplier, than by breaking a seal of the device and changing the electronics. This rather calls for a process requirement than a physical requirement: the secondary supplier should have a quality system in place preventing or discouraging the customer from tampering with the submeter data.

Conclusion

We recommend **replacing** the existing requirements with a process requirement aimed at ensuring that the meter data quality requirements are met, i.a., describing measures to prevent or discourage customers from tampering with the meter or meter data. Devices will obviously need to comply with relevant encapsulation requirements for other concerns, but we do not see any need for encapsulation requirements dictated by meter data quality concerns.

9.7 Maintenance and lifetime

Main meters are subject to requirements to ensure quality over time. Hence, DSOs have routines for maintenance, quality assessments at specified intervals and criteria for replacing dysfunctional meters.

The vital element for the processes relying on submeter data, is that the data quality is not deteriorating over time. Ensuring a certain technical standard of the meter or its components can help ensure a stable quality. However, knowing the status of the quality of the data measurements requires a quality system with periodic sampling. This calls for a process requirement regardless the lifetime of the metering components.

A question is thus if adding physical requirements provides any material difference. If/when discovered, a dysfunctional submeter calls for replacement or discontinuing the split responsibility arrangement. Nobody is better positioned to figure that out than the secondary suppliers. It is already in their interest to strike a fair balance between costs for the submeter hardware in the first place and the costs for inspection, maintenance, and replacement.

Another question is if there is a need for specified inspection intervals for submeters also (‘similar’ to § 44 of the meter regulation[22]), for all or for a sample of submeters. Alternatively, the inspection intervals must be decided by the secondary supplier and explained in the quality system. If there are no explicit physical requirements towards lifetime and continued quality, it seems like a fair compromise to have some specific requirements to the maintenance and inspection routines.

Conclusion

We recommend **relaxing** the current chapter four of the meter regulation with requirements for secondary suppliers to develop an inspection and control program for their submeters.

9.8 Points of attention

The following aspects are outside of the scope of this assessment but require further attention or elaboration to allow the proposed method for implementing split supply models using submetering.

- Legality: Can customers’ bills from secondary energy suppliers be based on meters that are not MID certified?
- Self-consumption: Split-responsibility models are difficult to implement for customer that have on-site generation (e.g., solar panels) or storage (e.g., battery, vehicle-to-grid), as the effects of self-consumption may be distributed over multiple market parties. This needs to be accounted for in the central wholesale settlement systems.
- Submeter data validation. Possibilities for meter data validation can be strongly augmented when the type of appliance (e.g., EV charger, V2G charger, inverter for PV, inverter for battery, heat pump), and potentially other characteristics (e.g., max power) is known within Elhub. This would allow the validation of the sign of the

[22] Forskrift om krav til elektrisitetsmålere, FOR-2007-12-28-1753

energy volume (off-take or in-feed), but would also e.g., detect PV energy that is produced at night. This benefit needs to be balanced against customer privacy and administrative burden of maintaining such a registry.

- DSO service design: Submeter data can both be used for split responsibility and for the validation of flexibility services. Whereas balancing services are typically validated and settled based on sub-meter data, for DSO services it is not yet clear whether sub-meters can be used. Disallowing the use of submeters may not only affect the viability of certain business models for aggregators and customers, it could also strongly affect the liquidity and efficiency of DSO services in general.
- Invoicing: If (main) suppliers also invoice grid fees and, as a consequence also energy taxes, a decision must be made about how this should be done in practice. Grid fees are based on the main meter data, while the bill from the main supplier is based on the net of main meter and the submeter. Should the grid fees be split, with one part on the main supplier bill and the other part on the secondary supplier bill? Would this even work in the case of self-consumption, if the submeter device is a PV system and not a consumption device? Should the DSO invoice the customer directly for the volume that is metered on the submeter? Or should the main supplier invoice the entire grid fee, even if only supplying a share of the total energy?

10 REFERENCES

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APPENDIX A
Detailed meter requirements in Norway

Existing meter requirements in Norway are found in secondary legislation: FOR-2007-12-28-1753 ("Forskrift om krav til elektrisitetsmålere") and FOR-1999-03-11-301 ("Forskrift om måling, avregning, fakturering av nettjenester og elektrisk energi, nettselskapets nøytralitet mv."). For the purpose of this review, DNV devised a framework to gather pertinent information the requirements across a few key categories:

- Metrological – the physical attributes and characteristics of the meters
- Customer information – how information is made available to the customer
- Communications – requirements regarding communication protocols, interoperability and data storage
- Privacy and security – how the customer's information is secured
- Rules and regulations – requirements regarding ownership, O&M
- Life cycle – requirements with regards to quality assurance, life expectancy of meters

The summarised review is provided in Table 10-1, below. The analysis is of 'Accuracy', 'Type certification' and 'Load range' is provided further down in the Appendix.

Table 10-1 Existing meter requirements

Characteristic	Category	Description	Requirements in Norway	Source
Accuracy	Metrological	Maximum permitted margins of error for measurement values, throughout the entire load range at which the meter is designed to operate	See "classifications"	FOR-2007-12-28-1753
Type certification	Metrological	Does the meter need to be type-certified? Which type?	See "classifications"	FOR-2007-12-28-1753
Load range	Metrological	Under which conditions should the meter operate (temperature, humidity, …)	See "classifications"	FOR-2007-12-28-1753
Clock	Metrological	Is a clock required? Accuracy (allowed deviation), precision, DST, synchronisation.	Yes, as per EU standard 62054-21	WELMEC 11.2
Power outage	Metrological	Limiting the impact of power outages	Not specified, but AMS must be able to break and limit the power output in the individual measurement point	FOR-1999-03-11-301 Section 4-2
Display	Metrological/ Customer information	Is a display required? What kind of information should be visible?	Must be equipped with a metrologically controlled display or a display that the end user can read without the use of aids. It should display the measurement result that forms the basis for the price to be paid.	FOR-2007-12-28-1753 Section 22
Local interface	Metrological/ Customer information	Is a local interface required? What are the specifications?	See above	
Communication	Metrological/ Comm / data storage	Requirements on communications module (technology, protocol / interoperability, slave meters, ….)	Meters should have a standardized interface that facilitates communication with external equipment based on open standards and be able to be connected and communicate with other types of meters. Communication in the network between AMS meter and central system should be protected with end-to-end encryption. When using a separate computer network, closed	FOR-1999-03-11-301 Section 4-2 and 4-6

Characteristic	Category	Description	Requirements in Norway	Source
			to unauthorized persons, the requirement for end-to-end encryption can be waived	
Data storage	Metrological/ Comm / data storage	Type of information that needs to be stored locally + period that it should be stored	The measurement values shall be registered and stored in the meter until the measurement values have been transferred to the grid company and at least until the due date for the current invoice period	FOR-1999-03-11-301 Section 4-5
Anti-tampering	Privacy / security	Requirements to prevent (the impact of) tampering	Measurement data, software of importance to the measurement properties, and measurement technically important parameters that are stored or transmitted shall be appropriately protected from intentional or accidental changes. Access to the AMS meter's interface shall be restricted for persons other than the end user, the grid company and other actors with legitimate needs	FOR-2007-12-28-1753 Section 19 FOR-1999-03-11-301 Section 4-6
Communication	Privacy / security	Requirements to ensure secure communication	The DSO is responsible for securing AMS and to choose solutions that provide the highest level of safety in AMS as long as the cost is justifiable after a cost-benefit assessment. Must meet the requirements for digital information systems in FOR-2012-12-07-1157 (section 6-9)	FOR-1999-03-11-301 Section 4-6
Ownership	R&Rs	Is ownership of the meter regulated? E.g. DSO, customer or metering company	DSO	Smart metering (AMS) - NVE / FOR-1999-03-11-301
Installation	R&Rs	Is installation of the meter regulated? E.g. DSO or third party	DSO responsible for rollout of smart meters	Smart metering (AMS) - NVE
Maintenance	R&Rs	Is maintenance of the meter regulated? E.g. DSO	DSO is responsible for meter maintenance. Regulations set out rules for minimum inspections: The first inspection of the meter must be carried out within 3 years after the year of production. If the meter is approved, other checks must be carried out within 8 years there after this. After that, checks must be carried out every 10 years. The timing of third and subsequent checks may change if the interval is sufficiently documented	FOR-2007-12-28-1753 Section 44
Data acquisition	R&Rs	Which party can/should extract the data from the meter remotely?	The electricity consumer has ownership over all data regarding electricity consumption. The DSO is responsible for transmitting the data to Elhub	Role descriptions - Elhub
Data validation	Metrological/ R&Rs	Is validation of the meter data regulated? Should this be the Supplier or a third party, e.g. metering company?	The DSO is responsible for transferring quality assured meter values to Elhub every day. Measurement data collector ("Måledatainnsamler") is responsible for reading the meter and doing a first data quality check. The measurement value manager ("Måleverdiansvarlig") is	Role descriptions - Elhub

Characteristic	Category	Description	Requirements in Norway	Source
			responsible of submitting the data to Elhub and the overall data quality	
Quality inspection / audits	Life cycle	How is ensured that the accuracy remains within the specified limits throughout the life-cycle? E.g. are, for each production batch, samples tested on regular intervals?	The regulation has rules for test programs and statistical sampling. Statistical control can be carried out on groups composed of uniform meters of 18 or more units, so that the results are representative of the entire group. A group should be as homogeneous as possible, but can contain meters from several owners.	FOR-2007-12-28-1753 Section 44 - 50
Malfunctioning	Life cycle	Should the meter be fixed in case of non-functioning (e.g. no response)? By when?	If electricity meters in the statistical control do not meet the requirements, all meters in the group must be replaced within one year.	FOR-2007-12-28-1753 Section 52
End-of-life / replacement	Life cycle	Is there a need to replace the meter when it reached its end-of-life?	No	
Life expectancy	Life cycle	Minimum life expectancy	No. An electricity meter shall be designed so that its measuring properties are sufficiently stable for a period of time stipulated by the manufacturer, provided that it is installed, maintained and used correctly in accordance with the manufacturer's instructions and in the environment for which it is intended.	FOR-2007-12-28-1753 Section 16
Vendor equipment	Vendor equipment	Which requirements apply for the vendor of the equipment, e.g. FMEA	If the grid company or the grid company's supplier connects other devices or systems to AMS, the security level in AMS shall be maintained or improved. The same applies if the end user or third party connects to AMS	FOR-1999-03-11-301 Section 4-6

Classifications

With regards the meter accuracy, the regulation stipulates that the manufacturer shall specify the class (A, B or C) of its meter. The class of the meter is largely determined by its application (e.g. commercial or residential) and accuracy under different operating temperatures.

Table 10-2 shows the maximum permissible measurement error as a percentage at specified operating conditions, operating temperature and defined current load levels. As a general rule, the level of accuracy is the lowest for Class A meters, highest for Class C meters.

Table 10-2 – Maximum permissible measurement error

Operating temperature	+ 5 °C ... + 30 °C			- 10°C ... + 5 °C or + 30 °C ...+ 40 °C			– 25 °C ... – 10 °C or + 40 °C ... + 55 °C			– 40 °C ... – 25 °C or + 55 °C ... + 70 °C		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
Single-phase meter; multiphase meter when operating with symmetric load												
Imax ≤ I < Itr	3,5	2	1	5	2,5	1,3	7	3,5	1,7	9	4	2
Itr ≤ I ≤ Imax	3,5	2	0,7	4,5	2,5	1	7	3,5	1,3	9	4	1,5
Multiphase meter when operating with single phase load												
Itr ≤ I ≤ Imax	4	2,5	1	5	3	1,3	7	4	1,7	9	4,5	2

I = current

Imax = maximum value of I where the meter's fault is within specified tolerance limits

Itr = the value of I where the meter's fault should be within the minimum tolerance limits corresponding to the class designation

The above table deals strictly with the meter's accuracy with regards to current. The regulation also includes maximum measurement errors regarding voltage (+/- 10%) and frequency (+/- 2%).

The regulation also sets out the different applications based on class of meter, which is summarised in Table 10-3.

Table 10-3 – Meter classifications

Class	Temp.	Indoor / outdoor	Residential	Holiday house	Commercial	Public lighting	Transf. connected
Class A	5 - 30	Indoor	x				x
Class B	-25 - 50	Outdoor	x	x			x
Class B	5 - 30	Indoor			x	x	
Class C	any	Both	x	x	x	x	x

In addition to operating temperature and application, the meter manufacturer should also specify the meter's operating conditions with regards to moisture (condensing or non-condensing), the mechanical environment (vibration and mechanical shock) and electromagnetic environment. Mechanical and electromagnetic environment has its own classes, as shown in Table 10-4.

Table 10-4 – Magnetic and electromagnetic classes

Class		Description
Mechanical	M1	Minimal exposure to vibration and shock, e.g. electricity meters that are mounted on light support structures and subjected to negligible vibrations and shocks from local blasts, construction works, banging with doors, etc.
	M2	Significant or high vibration and shock levels, e.g. caused by machines and passing vehicles nearby, or by the electricity meter being placed in the immediate vicinity of heavy machinery, conveyor belts, etc.
	M3	High and very high vibration and shock levels, such as electricity meters mounted directly on machines, conveyors, etc
Electromagnetic	E1	used in places with electromagnetic disturbances, like those found in buildings used for residential and commercial purposes, and light industrial buildings
	E2	used in places with electromagnetic disturbances, like those found in other industrial buildings.
	E3	meters that receive power from a vehicle's battery. Such electricity meters shall meet the requirements for E2 as well as the following additional requirements: voltage drops caused by charging the starting circuit of internal combustion engines and voltage transients when disconnecting the discharged battery while the engine is in operation.

DNV has used the above assessment of different meter requirements to map against the options for submeters available in the market. Please refer to Chapter 6 and 7 for this analysis.

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DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

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