CEER Paper on Regulatory Issues Related to the 'Delta In-Out' in Distribution Networks

Access Tariffs and Settlement Workstream*

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INFORMATION PAGE

Abstract

This document (C19-GS-05-03) aims to reach a more in-depth knowledge of the *Δin-out* problem, by creating a common understanding at the European level, despite possible different features of distribution networks.

[The Delta In-Out represents a difference observed when comparing the measurements at the intake points with the sum of downstream measurements of final customers off-take points, within a certain period.]

Target Audience

European Commission, energy suppliers, traders, gas/electricity customers, gas/electricity industry, consumer representative groups, network operators, Member States, academics and other interested parties.

Keywords

gas distribution networks, delta in-out, network losses, standard load profiles, gas meters

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EXECUTIVE SUMMARY

Background

This document aims to analyse the difference of measurement called Delta In-Out (*Δin-out*).

The Delta In-Out represents a difference observed when comparing the measurements at the intake points with the sum of downstream measurements of final customers' off-take points, within a certain period.

The intake points correspond to the city-gates, which are the interface point of a typical gas distribution network, connected to a transmission network and/or another distribution network, and the local production of renewable gases that is nowadays directly injected into the distribution network.

Objectives and Contents of the Document

This document aims to reach a deeper knowledge of the *Δin-out* problem, creating a common understanding at the European level, notwithstanding possible different features of distribution networks.

The analysis is performed both through a theoretical approach (Chapter 1 and 2 and 3) and empirical observations performed through a survey in the Member States (Chapter 4).

Finally, through the observation of best practices, some recommendations of possible regulatory tools to minimise the *Δin-out* effect on the market are listed (Chapter 5).

1 Introduction

This document refers to a typical distribution network, fed by a transmission network and/or another distribution network at its interface point, a so-called city-gate. Nowadays, there are also a growing number of situations where local production of renewable gases is directly injected into the distribution network. The city-gate and the local productions are, therefore, the intake points of the distribution network. The meters are located at the intake points. The meters collect a different kind of measurements such as gas flow (volumes), temperature and pressure. These data then need to be converted into energy units. This conversion uses a gross calorific value (GCV). The GCV can be measured at the city-gate metering station, within a zone or by using a conventional value.

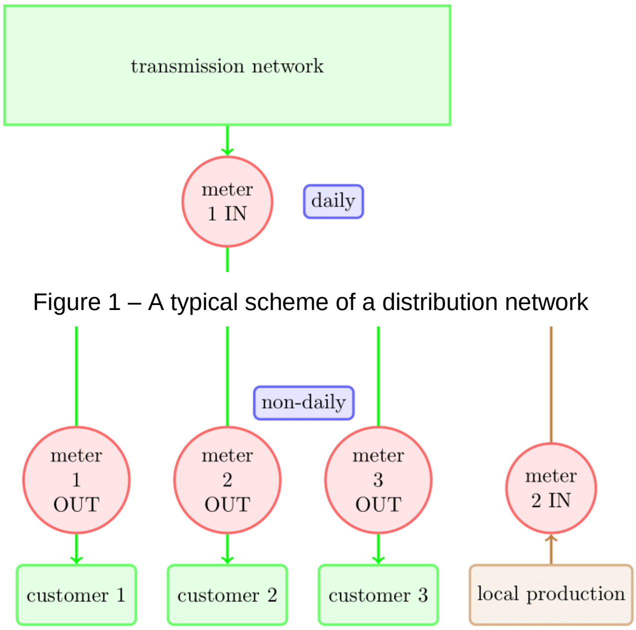

Figure 1 – A typical scheme of a distribution network

Final customers are connected to the distribution network.[1] Their off-takes are measured through different meter categories, namely (according to Art. 34, 35 and 36 of the Balancing Network Code):

- Daily metered
- Intraday metered
- Non-daily metered

In a typical situation of households and small customers, meters have different features when compared to the meter at the intake points; such as:

1. They do not take daily measures
2. They do not take the pressure, air pressure (height), temperature and GCV measurements
3. The distribution network operator has difficulties in accessing it (e.g. if located inside private properties)

Therefore, what is conventionally called "measurement" is something that has, in its entirety, a large component of estimation:

1. Because of point 1., the energy taken by the final customer in a relevant period (the gas-day) must be extrapolated from measurements taken in a different time-interval
2. Because of point 2., pressure, air pressure, temperature and calorific value are proxies of the actual values
3. Because of point 3., measurements are sometimes not available at all and the full quantity is estimated, usually based on historical values and load profiling[2].

[1] We understand that DSOs also consume for their gas operations (from compression up to preheating of metering equipment, different kinds of technological consumption up to heating of facilities). Such consumptions should be metered and processed in the same way as the final customers.

[2] The definition of load profile is the one predicted in Article 42.2 of the BAL NC.

Consequently, in this document, the term ""measurement"" refers to both the actual measurement and/or consumption data obtained through a combination of measurements and the application of load profiles.
If a comparison is made within a certain period between the upstream measurement and the sum of all downstream final customers ""measurements"", typically a difference is registered; this difference is called ""*Δin-out*"".

Taking as Figure 2 - Δin-out scheme as a reference, the *Δin-out* is the difference between

- the sum of the energy measured at the inlet points of a distribution network and
- the sum of the (corrected) energy measured at the final customers' off-take points

$$\Delta in\text{-}out = Intake - Offtake \quad (1)$$

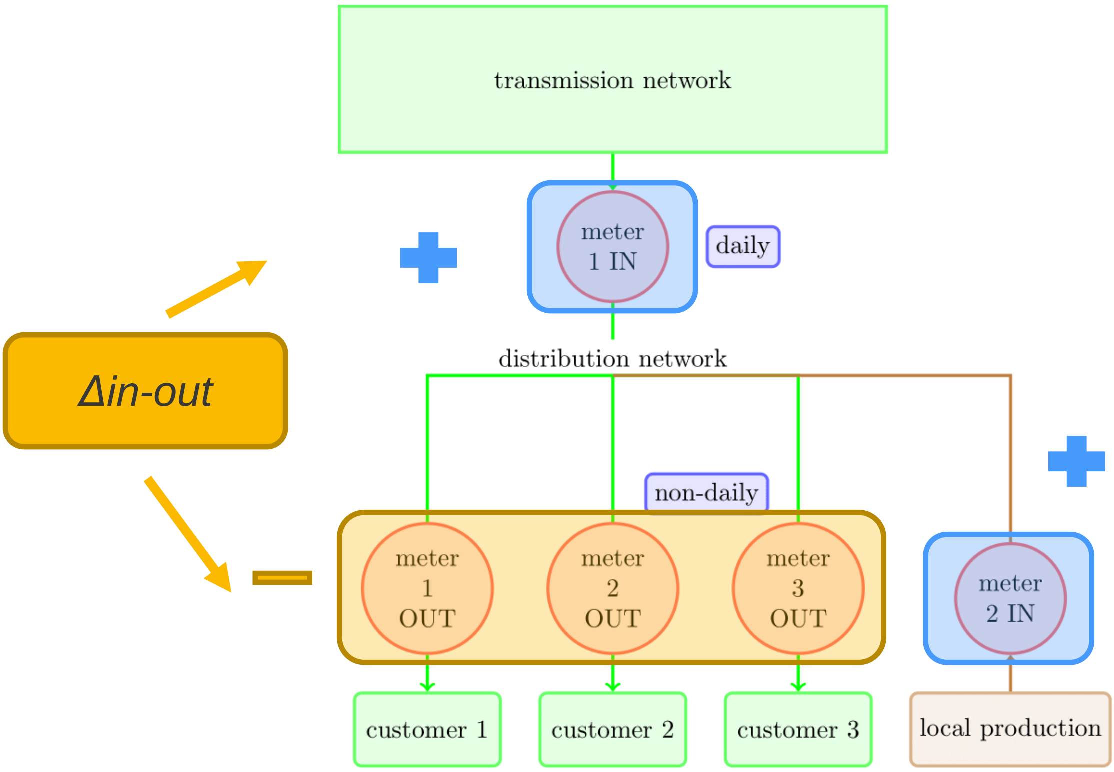

Figure 2 - *Δin-out* scheme

In the equation above, the *Δin-out* is conventionally taken as *positive* when the measured intakes are greater than the off-takes and *negative* when the measured off-takes are greater than intakes.
It must be highlighted that this definition does not specify the time: the difference can be calculated over a time span of a day, a month, a year, multiple months or years or other periods.

A deeper understanding of this phenomenon is developed in the following sections.

2 The *Δin-out* problem

2.1 Where does the *Δin-out* originate from

The *Δin-out* originates from many different factors, some of which have already been anticipated in the previous section. The full list of *Δin-out* components is the following:

1. Measurements frequency
2. Measurements accuracy
3. Linepack change
4. OBA changes
5. Blow-out during maintenance
6. Leakages
7. Theft

Some components give only a positive contribution to the *Δin-out* (*Intake > Offtake*), no matter what the observation period is: as far as leakages, blow-out and theft is concerned, the gas is injected and measured at the intake point of the distribution network, but it 'does not even reach the meter at the off-take point. Other components can have, in a given time-interval, a positive or negative impact on the *Δin-out*. The sign (+/-) of the difference can also depend on time-interval considered.

From a qualitative point of view, one could expect the *Δin-out* to be positive or negative; however, with a higher probability of positive value.

To better understand the *Δin-out,* it is necessary to isolate the effect of each component by considering all the others as null. For example, in a perfectly balanced network (the same amount of gas is injected and off-taken), with perfectly synchronous measurements between *in* and *out*, without any kind of losses, any difference in the *in* and *out* measurement can be attributed to a problem of measurement accuracy.

2.2 Measurements frequency

2.2.1 A notional example

To understand the first component (frequency of measurements) we assume the extreme notional case of a distribution network with a single intake point and a single off-take point, as represented in Figure 3 - Measurements frequency:(instead of many as represented in the Figure 1 – A typical scheme of a distribution network), equipped with a non-daily meter. Let us assume that on the distribution network:

- Both meters are perfectly accurate;
- There is no line-pack variation in the observation period;
- There are no losses (leakages, nor fuel gas, nor theft of gas).

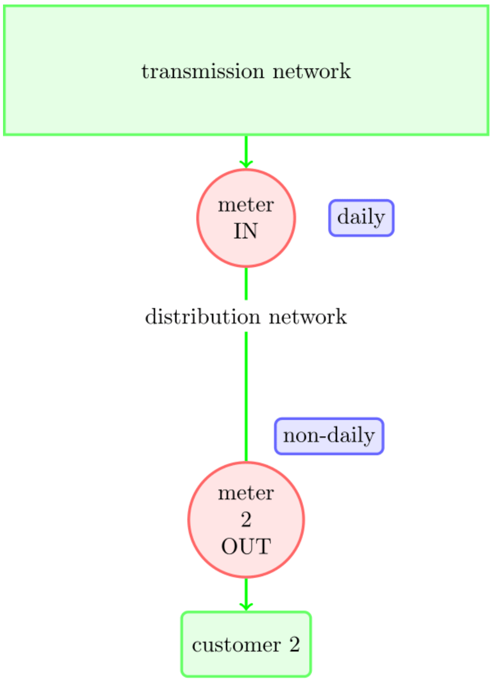

Figure 3 - Measurements frequency: notional case

Making null the referred effects allows one to focus on the effect of component 1 of section 2.1 (frequency of measurements).

If one assumes that the meter is read at the redelivery point on the 8th of January and after approximately six months (let us assume the 25th of July). The difference between the two readings is the energy delivered in that period, let us call it:

$$M_{out}^{8Jan-25Jul}$$

Considering the same quantity measured at the intake point, as the sum of daily measurements collected from the 8th of January to the 25th of July. Let us call it:

$$M_{in}^{8Jan-25Jul}$$

On the hypotheses mentioned above of perfect meters, the two quantities are equal:

$$M_{out}^{8Jan-25Jul} = M_{in}^{8Jan-25Jul}$$

Now, let us consider a day between the two, i.e. the 1st of April.

From the off-take point measurements, it is impossible to know the exact amount of gas in the two time-intervals 8th – 31st of March and 1st of April – 25th of July. That is where the load-profiling technique comes in, providing an estimated value.

It is rather intuitive that if *Δin-out* is null over the whole period, any error (plus or minus) in the estimated value of a semi-period has a correspondent error, same quantity but opposite sign, in the other semi-period.

In other words, the estimation error is, in fact, a shift of gas between two time–intervals. This conclusion can also be easily described with some algebra:

$$\Delta_{in-out}^{8Jan-31Mar} = M_{in}^{8Jan-31Mar} - M_{out}^{8Jan-31Mar}$$

or

$$\Delta_{in-out}^{1Apr-25Jul} = M_{in}^{1Apr-25Jul} - M_{out}^{1Apr-25Jul}$$

Adding term by term the two equations and knowing that the difference of measured quantity is *zero* by construction, in the whole period 8th January – 25th July:

$$\Delta_{in-out}^{8Jan-31Mar} + \Delta_{in-out}^{1Apr-25Jul} = \left(M_{in}^{8Jan-31Mar} - M_{out}^{8Jan-31Mar}\right) + \left(M_{in}^{1Apr-25Jul} - M_{out}^{1Apr-25Jul}\right)$$

which can be simplified to:

$$\Delta_{in-out}^{8Jan-31Mar} = -\,\Delta_{in-out}^{1Apr-25Jul}$$

The above equation shows that the error in the first time–interval is equal to the error in the second time–interval, with opposite sign.

From the analysis above, some conclusions and generalisations can be drawn, namely:

- The load-profiling technique is subject to errors (by definition, because it is an estimation)
- The error generates a *Δin-out* of opposite sign in adjacent time–intervals: the off-take is greater than the intake in one time–interval and the off-take is less than the intake in the other time–interval;
- This might give the illusion that gas is "generated" in the distribution network (in a given interval) or some other gas is "lost" in the same network (in another interval), but in fact, this corresponds to a shift in the allocation of gas from one time–interval to the other.

2.2.2 Generalisation of the problem

The considerations mentioned above can be generalised. In real networks, processes such as allocation, invoicing and reconciliation require that energy off-takes of the final customers are split into predefined time-periods such as day, month and year (or the gas-day, gas-year…).

Therefore, the amount of gas off-taken in the relevant periods by non-daily metered customers can only be estimated through load profiling techniques (for a graphic representation of the problem see Figure 4 - Estimation of gas consumption at the beginning of a relevant period through load profiling technique).

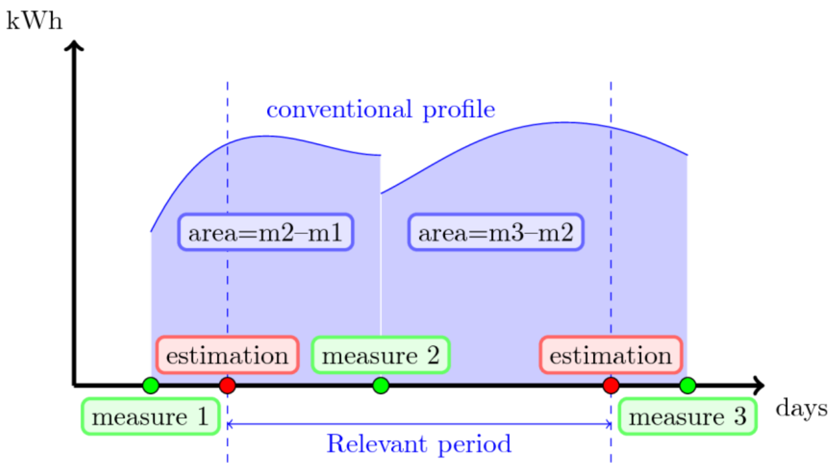

Figure 4 - Estimation of gas consumption at the beginning of a relevant period through load profiling technique

The estimate of the gas taken out in the relevant period implies that also a *Δin-out* is showing up over the same period and adjacent periods. However, as this component of *Δin-out* is a shift of gas through different time periods, the settlement of this *Δin-out* may happen in periods different to those of the actual injections and off-takes and possibly with different prices. Depending on the nature of the settlement (see Chapters 3 and 4 for details), this creates a risk of an inefficient gas procurement and balancing on the market.

To prevent such inefficiencies, NRAs may approach the problem at two possible levels: by physically reducing the amount of *Δin-out* or by making adjustments in the market design. At the first level, the amount of *Δin-out* must physically be reduced. Potential avenues towards a reduction of *Δin-out* are discussed in the following section. As a second step, if *Δin-out* is still not negligible, some adjustments in market design can be taken to ensure for an effective and efficient settlement of *Δin-out* that minimises the distortions on the market. Reduction of the impact on the market is discussed later in Chapter 3.

2.2.3 Reduction of *Δin-out* component related to measurements frequency

The analysis of *Δin-out* component 1 carried out in sections 2.2.1 and 2.2.2 also shows possible solutions to minimise its value:

1. *Enhance the quality of estimations*: from the example in section 2.2.1, it is evident how a good estimation of the off-takes implies a reduced level of *Δin-out.* Therefore, the quality of load-profiling techniques is crucial.
2. *Enhance the frequency of measurements*: the more measurements are taken close to the relevant period, the better is the estimate of the quantity over the same period.

2.2.3.1 Enhancing the quality of estimations

Good quality of estimations is technologically challenging. It requires at least an accurate definition of load profiles and the matching of the right profile with the actual kind of off-take and final customer. For example, it should be known if gas is used for heating or cooking or for technological processes, etc. This information should be updated regularly and must be managed with appropriate IT systems and exchanged between the network operators and additional parties involved.

Some countries have chosen to improve the estimations coming from a "load profiles" technique by adjusting the conventional profile day by day with a temperature coefficient (actual or forecasted). Such an "adjusted" or "dynamic" load-profiling helps to mitigate the effects outlined above. Specifically, the conventional static profile is dynamically adjusted every day with a temperature coefficient to make the estimation correspond better to the actual weather conditions; thus reducing the *Δin-out* effect[3].

2.2.3.2 Measurements frequency

Enhancing measurement frequency is an issue which is related to both technology and costs. In some countries, DSOs (or an alternative body responsible for metering) have obligations concerning the frequency of meter readings.

Incentives to DSOs can be foreseen to improve frequency and regularity and to avoid situations where meters are not read for a long time. Another set of incentives to DSOs can also be designed to enhance the quality of data validation and transfers along the process chain in a timely and reliable manner to make the data properly available to customers.

From the technological perspective, a significant improvement of the time-span between two meter-readings could be achieved with solutions such as smart meters with a remote connection which are showing up in recent years (even though at a slower pace than for electricity).

In any case, a balance should be found between the benefits and costs of data collection and management. According to the Balancing Network Code[4], the TSO should assess through a cost-benefit analysis the advantage of providing an increased frequency of information

[3] To give an example, going back to the one in section 2.2.1, supposed that the first period (8th July – 31st March) is a very cold winter. If the conventional profile associated to the offtake point is a static one, the most likely result will be an underestimation of the winter consumption and coherently an overestimation of the following (spring-summer) period. Therefore, winter will show a positive *Δin-out* (more gas injected than off taken) and the following period will show a negative *Δin-out* (more gas off taken than injected).

[4] In accordance with article 38 of the BAL NC establishing a cost-benefit analysis.

provision to network users, reduced timelines of information provision and improved accuracy of the information provided. In a cost-benefit assessment, one should also consider that increasing measurements frequency requires not only the collection and storage of a considerable amount of data but also the setup of conditions that allow it to be done efficiently; such as refinements of the standardisation of data formats and data collection procedures. Appropriate remuneration and incentive to DSOs (or third parties responsible) could be foreseen to keep the system in a good state of operation or to contribute to minimising the cost through, for example, a standardisation of meter devices.

2.3 Measurement accuracy

2.3.1 General description

The energy contained in a cubic metre of gas depends on the temperature, the pressure and the quality (calorific value). Therefore, inaccuracies in the measurement of those parameters are sources of uncertainties in the calculation of the energy balance.

According to the Interoperability Network Code, the reference conditions for volume shall be 0 °C and 1.01325 bar(a). Pressure and temperature measurements (taken in parallel with volumes) allow conversion of the actual volume flow to volume flow at standard conditions.

Special devices (so-called "volume converters") are usually installed beside the meters for industrial supplies, whereas at the household level (low-pressure grids) there are no such installations. Volume correction/conversions are performed instead through conventional coefficients that also take into account historical data of temperature ("degree-days" methodology) and altitude.

Conventional conversion is also performed related to industrial supplies if a "volume converter" is not available, but in this case, more complex formulas than in the household case are used (available in specialised literature).[5]

To convert volumes directly into energy units, GCV must be measured through individual devices (such as gas chromatography, often shortened to GC). GCV can vary depending on the source of gas and significant differences from the average can be experienced even in neighbouring areas; this is mainly the case with local injections of renewable gas into the network.

As gas chromatographs cannot be installed at every city-gate, they are typically only installed in each area where gas is presumed to have a uniform chemical composition. Therefore the tolerance in energy measurement is considered acceptable.

In any case, the accuracy of the instrument is prescribed by national regulation. In general, the accuracy range depends on the size of the meter, but in practice, precision is worse for older meters.

[5] The formula can take into account different parameters such as the true (non-linear) relation between pressure and temperature for methane instead of the ideal gas law. Moreover it can take into account the location of the meter (indoor or outdoor) which affect the operating temperature and therefore the temperature/pressure conversion.

In case of significant reductions in gas consumption at an off-take point, the meters that were originally installed may become oversized and work in the low-range (or even below the minimum range). This creates the risk that its accuracy may be dramatically reduced. Consequently, appropriateness of the meters should be monitored and, if needed, they should be replaced.

2.3.2 Reduction of *Δin-out* component related to measurements accuracy

The accuracy of measurements, in general, cannot be addressed and solved very quickly, but rather is a long-time process. As outlined, quality can be improved by the substitution of meters with new-generation devices. This usually happens at a national level through a substitution plan. Such a plan involves an installation of smart meters that allow a direct measurement of energy; as they are also equipped with a remote meter reading and remote control. Thus, the *Δin-out* effect could be reduced.

In the cases where a poor quality of measurements is the result of maintenance, verification campaigns are needed. There is also room for improvement when inaccuracy depends more on the procedures for collecting and providing data to interested parties than on the meter itself.

An incentive mechanism (premium/penalties) might address the situations where the NRAs or other technical bodies have difficulty to control certain very specific situations. In these cases, an overall indicator of performance can more efficiently address the need for a better measurement accuracy.

As discussed in section 2.3.1, it is also worthwhile to consider increasing the number of points where GCV is measured. This is particularly relevant if gas is locally produced and blended with the gas in the network. Moreover, not only metering but also GCV simulation and modelling as applied in several countries is to be considered. It appears to have merits in terms of cost-efficiency. In any case, network operators need to cooperate in providing and sharing such data closely.

2.4 Linepack changes

2.4.1 *General* description

It is well-known that the gas accumulated in pipelines ("linepack") can vary over time. Simplified, such linepack variations are calculated through the volume of the pipes and the pressure variations within sections or areas, based on technical standards or rules. The dispatching centre, controlling the pressure, thus controls also the flow in the network.

Referring only to the distribution network, the capability of accumulating gas is generally reduced because of the lower pressure level compared to the transmission network and the limited compression possibilities. However, the actual value depends significantly on the dimension of the distribution network: a small network has a negligible capability, whereas for huge distribution networks, the linepack variations can give a significant contribution to *Δin-out*.

2.4.2 Reduction of *Δin-out* component related to linepack

Based on the outlined understanding of linepack as the accumulated volume of gas in the pipelines of a specific network operator, the linepack change represents the change of this accumulated volume over the time (i.e. between start and end of a gas day). Hence, the proper determination of the linepack change is based on some prerequisites. First of all, there needs to be a proper pressure monitoring and a sufficient degree of metering at relevant nodes of the network. Moreover, linepack calculations should ideally be based on established technical rules and the accurate application thereof. If these prerequisites are sufficiently established, an empirically representative linepack change can be determined, and thus side effects on other elements of *Δin-out* avoided. This might be fostered through regulatory tools.

2.5 Leakages, blow-out and theft

2.5.1 General description

These three components can be collectively called "losses": the gas is measured at the intake point and then wasted before it reaches the off-take point. The contribution of losses to *Δin-out* is always positive (*Intake* > *Off-take*).

Leakages are technological losses which happen and can hardly be avoided at all by the DSOs. They depend on the choice of grid design (e.g. pipeline material). However, its values become more significant and critical in a case where the DSO keeps the network in a bad state of maintenance.

Theft is a special case with different relevance across countries. It originates from poor control of the DSO of the network within the territory.

Blow-out during maintenance should be avoided to the extent possible. It can also be considered as a kind of "own consumption" of the DSO that it is usually not metered but calculated.

Minimising the *Δin-out* due to losses is the core-business of the DSO: as with any shipping company, the DSO should take the delivery of gas at the inlet point and redeliver the same quantity at the redelivery points. The quantity of gas wasted along the route is a parameter that can be taken as an indicator of (in)efficiency.

Losses (in the broad sense here identified) can be accurately determined by measuring the *Δin-out* over a long enough (e.g. a couple of years) time of observation. The larger the time period considered, the less is the influence of load profiling technique to the "*Δin-out*"; because it becomes less relevant if some gas has been moved from a period to the other (e.g. from winter to summer). Therefore, the "*Δin-out*" of a long time-period converges to the sum of the values of the other phenomena: losses, leakages and theft.

2.5.2 Reduction of *Δin-out* component related to losses

To improve the efficiency of DSOs' activity (and to reduce the *Δin-out*), an appropriate combination of "negative" and "positive" incentive schemes could be put in place. If a "negative" incentive scheme is chosen, the DSO pays if *Δin-out* due to losses is above a given threshold (assumed as "normal"). Payment, in this context, means that (a share of) costs related to the settlement of *Δin-out* is not recognised by the NRA and thus cannot be recovered with network tariffs. This approach could be justified against the background that a DSO's allowed revenues should fully cover the costs of a good network maintenance and operation; therefore, the DSOs should not be paid twice for the same service.

If a "positive" incentive scheme is chosen, the DSO can earn extra-money (above the allowed revenues) if *Δin-out* is below a given threshold. This approach could be justified to foster the effectiveness of the incentive and to gradually improve the awareness of the DSO for reducing the *Δin-out*. The incentive scheme could be based on the measurement of the historical values of the *Δin-out*.

3 Implications of *Δin-out* for the gas market

Δin-out could be very critical for the functioning of the gas market, if not correctly addressed. Indeed, at the wholesale level (when calculating the balancing position) there are two possible options for accounting for the off-takes of the network users:

1) Off-takes are calculated through a bottom-up approach, by adding the "measurements" of final customers ("meter 1 out"" + "meter 2 out" + "meter 3 out" etc…). The word "measurement" is meant here, as explained in Chapter 1 (Introduction) as a combination of real measurement and load profiling. In this case, *Δin-out* is not included, and it has to be calculated separately through the subsequent comparison with the measurement at the intake point ("meter 1 IN"). A decision also has to be taken about the allocation of *Δin-out* to network users.
2) Off-takes are calculated through the "meter 1 IN": the daily measure is allocated to users who are supplying customer 1, customer 2 and customer 3; the splitting among users is performed according to predefined criteria in line with Balancing Network Code. In this case, *Δin-out* is included and automatically allocated to users.

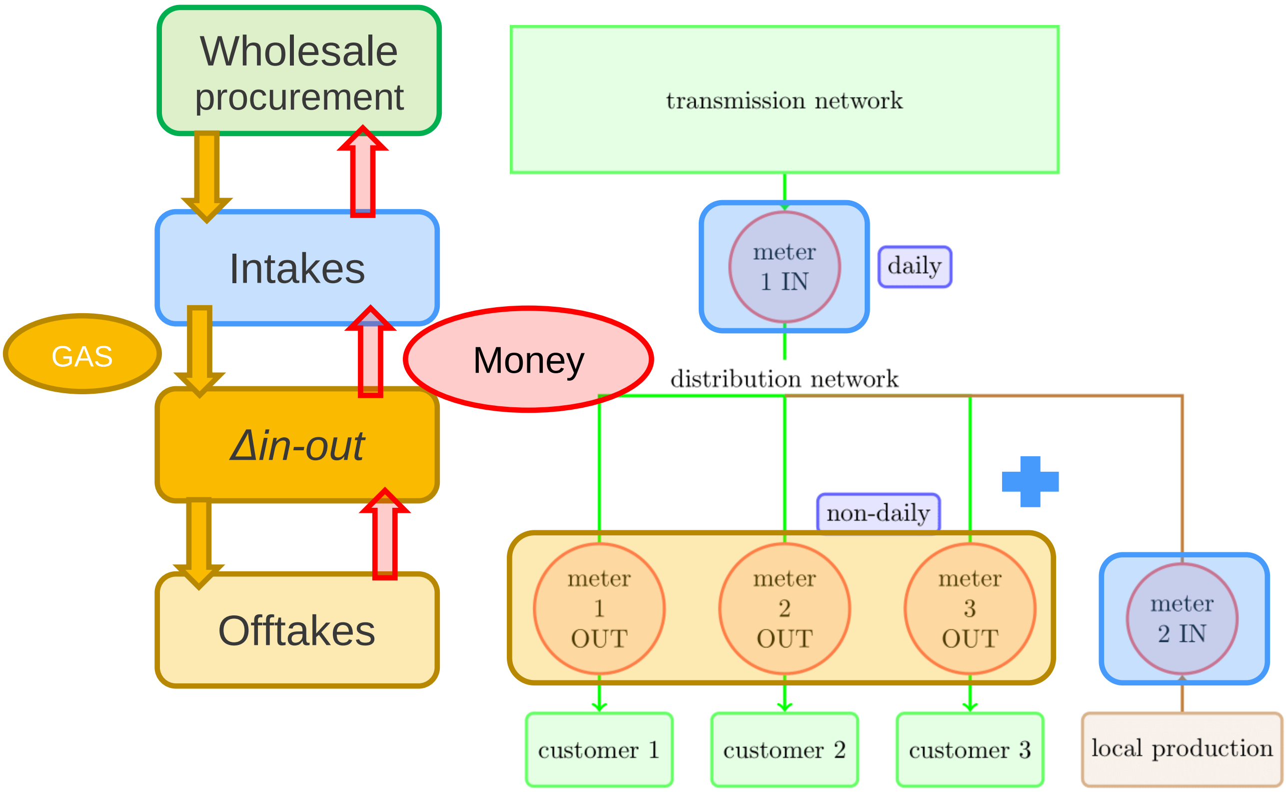

Figure 5 - Gas and money flow in the settlement provisions

The two options have different advantages and disadvantages that can be better understood by also taking into consideration the related cash flows.

With Option 1 network users are incentivised to procure the gas for their customers' needs as a result of measurements taken (actual measurement and load profiling). In other words, they tend to procure the exact amount of gas that they will invoice to their customers, hence limiting their financial risk, in comparison with Option 2. However, as load profiling represents approximation, the daily balanced position of network users does not necessarily correspond to a daily balanced position of the transmission network. The TSO should then very likely take some balancing actions to "procure" the *Δin-out,* which is no longer procured by network users, as for Option 2.

With Option 2 network users are incentivised to buy gas (at the transmission level) to match the intakes (of the distribution network), minimising their imbalance and, as a consequence, the imbalance of the whole transmission network. However, this strategy might lead to financial risk for network users as final customers pay the network users for the gas supplied, as metered by *final customers'* meters ("meter 1 OUT" "meter 2 OUT" "meter 3 OUT"). The difference of the gas procured by users (Intake) and the gas paid by final customers (Offtakes) is, by definition, the *Δin-out,* which is an entirely unpredictable component. The risk of this component could be mitigated with some tools such as an uplift compensation mechanism or a forecast of the *Δin-out* provided by the TSOs. The scope of such tools is to minimise the risk through highly conservative mark-ups by the network users on the gas supplied to the final customers.

According to this analysis, it is possible to conclude that both options are possible, but it is necessary at the same time to provide some arrangement to avoid that the entire risk of *Δin-out is* allocated to shippers. *Δin-out,* if not correctly addressed, ultimately represents a barrier to small shippers and new entrants and, on the contrary, gives a huge advantage to big and historical shippers who can benefit from:

- The statistical compensation of the randomness of the *Δin-out*, both in space (one city-gate compensate the other one) and in time (a plus of today compensates the minus of tomorrow)
- The availability of historical data to estimate the *Δin-out*

Reducing the *Δin-out* and ensuring an effective and efficient settlement of remaining differences is, therefore, a key element for both wholesale and retail markets to develop.

4 Observation and quantitative measurement of *Δin-out*

4.1 Survey

As described in the introductory section (see "Objectives and Contents of the Document" in the Executive Summary), this document aims to establish a more in-depth knowledge of the *Δin-out* problem both through a theoretical approach (Chapter 2) and empirical observations performed through a survey.

More specifically, the scope of the survey is to better understand how different countries deal with the *Δin-out* problem. The survey addressed the following issues:

1. How *Δin-out* is settled/balanced, which market roles are involved and which implications this has for the gas market and final customers in particular;
2. The amount (observed values) of *Δin-out* and in particular to identify a range that can be assumed to be "normal" in gas operation
3. If specific regulatory instruments are in place across EU countries to reduce the amount of *Δin-out* and on which concepts and trade-offs these instruments are based on.

The findings presented below are based on a survey among NRAs. In total 19 countries submitted responses[6].

4.2 Mechanism to balance and settle *Δin-out*

4.2.1 Overview of load profiling

As a first step, an overview concerning the respective national working principles of load profiling in line Art. 42 par. 2 of the BAL NC[7] are presented.

Most countries use a "straight-forward" methodology, usually composed by the following steps:

- A conventional profile is assigned by the DSO to the final customer according to a consumption "category" (residential, non-residential, cooking, heating, etc.);
- Total volumes associated with the final customer depend on historical data;
- Before the allocation, the profile is updated with the best estimation of the temperature of the following day(s);
- The methodology is defined "once" and valid for "some" years;
- After having defined the methodology, parameters of the profile (such as annual consumption, peak demand…) are reassessed every year.

[6] 1. ECA (Estonia), 2. CREG (Belgium), 3. E-Control (Austria), 4. PUC (Latvia), 5. AGEN (Slovenia), 6. CERA (Cyprus), 7. CNMC (Spain), 8. BNetzA (Germany), 9. ACM (Netherlands), 10. Ei (Sweden), 11. ERÚ (Czech Republic), 12. MEKH (Hungary), 13. ARERA (Italy), 14. CRU (Ireland), 15. ERSE (Portugal), 16. DUR (Denmark), 17. URE (Poland), 18. VERT (Lithuania), 19. NVE (Norway).

[7] "The methodology for the forecast of a network user's non-daily metered off-takes shall be based on a statistical demand model, with each non-daily metered off-take assigned with a load profile, consisting of a formula of the variation in gas demand versus variables such as temperature, day of the week, customer type and holiday seasons. The methodology shall be subject to consultation before its adoption."

Three countries (Germany, Czech Republic, Sweden) may use (exclusively or in addition) a different methodology, hereafter identified as *Residual area profile.* With such a methodology, non-daily metered (NDM) off-takes do not result from the sum of estimated off-take of the single redelivery points. Instead, they are obtained in an aggregate way, by subtracting the IDM /DM profile from the total profile of the feed-in point. The Residual area profile is then allocated pro quota to the final customers, according to their conventional profiles.

In the context of load-profiling methodology, it was also asked what the share is (in term of volumes) of final customers with load-profiling. Answers show that NDM weight on total consumptions ranges from 20% to 60%[8], meaning that a significant amount of gas must be balanced and settled on a daily basis according to load profiling.

Effective daily balancing actions of users are, therefore, crucially dependent on the accuracy of the load profiling methodology.

4.2.2 *Treatment of Δin-out* with regulation

Almost all countries (Norway is the exception) have a kind of regulation for the handling *Δin-out*. For about 50% of the cases the regulation is "primary" (laws, ministerial decrees, gas acts…) and in the remaining 50% the regulation is "secondary" (NRAs' regulation or DSOs' network codes approved by NRAs).

4.2.3 *Δin-out* calculation

The *Δin-out* calculations are in all countries aligned with the general formula as described in Chapter 1 formula 1 *Δin-out = Intake − Offtake* *(1*). The main differences among countries are in relation to the definition of some components included in the *Offtakes,* the way they are treated and the time horizon of the calculation.

For example, in some countries, a "loss" component of *Δin-out* is assumed to be known (through measurements or conventional values), whereas in other countries *Δin-out* is assumed as a comprehensive term to identify "losses", no matter of the origin. The split of components of *Δin-out* can lead to different treatment in terms of cost recovery and incentive schemes.

4.2.4 *Δin-out* settlement and management

The survey also addressed the important question of how *Δin-out* is settled/balanced, which market roles are involved and who bears the cost. Different approaches can be found across the market, as follows:

1. *Δin-out* is allocated by the TSO (or the balancing entity) to the network users according to some criteria, therefore the network user must procure it and bear the cost (sometimes there is an exception when there is an allowance for own gas/fuel gas/loss component). This is the case of Austria and Belgium.
2. *Δin-out* is procured by the TSO (or balancing entity), and the cost is split among users, but it does not modify the allocation. This is the case of Estonia, Germany, Italy, Latvia, Slovenia, Spain and Portugal).

[8] The survey showed some outliers in the data provided, e.g. 10% up to 98% of NDM. The reliability of those data should be investigated in detail, in any case, they are not significant or they do not change the general conclusions here proposed.

3. *Δin-out* is procured by the TSO, and the cost is split among final customers through a tariff component, like in the Czech Republic.
4. *Δin-out* is procured by the DSO, and the cost is split among final customers through a tariff component (as in Denmark, Ireland, Hungary, Poland and Sweden).

In conclusion, to calculate the off-takes in the imbalance formula of the network user, the market is split almost into two equal parts:

Some countries declare that, referring to Chapter 3 and Figure 5 - Gas and money flow in the settlement provisions of this document, Option 1 is in place, i.e. *Off-takes* are calculated through a bottom-up approach, by adding the "measurements" of final customers (being a "measurement" a combination of real measurement and load profiling (Austria, Latvia, Slovenia, Sweden, Hungary, Italy).

In other countries Option 2 is in place, i.e. *Off-takes* are the daily measurement of the Intake point of the DSO "meter 1IN"; the daily measure is allocated to users who are supplying final customers and split according to some criteria (Belgium, Spain Netherlands, Sweden Czech Republic, Ireland and Portugal);

Although some countries consider that they have in place an adequate methodology (such as Belgium, Estonia, Germany, Portugal and Slovenia) other countries are considering revisions and improvements.

Denmark, Hungary and Spain allocate the costs to the DSOs; the Netherlands also has shifted costs from suppliers to DSOs in 2020, Italy from suppliers to DSOs in 2020 and they see it as a positive development.

Austria has initiated a revision of the current methodology in the ongoing process of redesign the overall balancing model. Starting in October 2021, *Δin-out* will be allocated to end-users via network tariffs.

Spain is willing to introduce some improvements in the system, such as periodical reviews of the consumption estimation method, review of the legal percentage of accepted recognised *Δin-out*, have the *Δin-out* allocation made by DSO and shared by all types of users and not only non-daily metered users.

4.3 Observed values

The survey requested NRAs to provide the information of *Δin-out* observed in distribution networks; ideally national values or at least some samples of specific networks, possibly in different time intervals (day, month, year, multiple years). It was also requested to provide a possible idea of components (like losses or load profiling). Finally, it was asked if there is a range of *Δin-out* (overall or single components thereof) that is assumed to be "normal" in gas operation.

The question was left deliberately open to free responses and, as a first reaction, NRAs highlighted that this information was not available to the NRAs but only to the DSOs and it needed some time to be delivered.

Despite this general disclaimer that answers to free-response questions entail the risk of limited comparability, respondents reported quantitative indications, which are hereafter summarised and can be used as a useful reference.

Country	Period of data reported	Observation
Austria	month, year	Observed values during a single month is ≥3%, during 7 months is 2%, and during 14 months is around 1%.[9]
Estonia	year	Takes three years of *Δin-out* to calculate tariffs.
Germany		Losses of non-accountable gas are not measured and remain as a residual size in the network accounts. However, this size is accepted as negligible.
Hungary	month	Observed values in the range between 1.5% and 1.9% on a monthly basis during the thermal year 2018-2019.
Ireland		Is indicating yearly values between 0.92% and 1.57% during the period 2014-2018.
Italy	multiple years, year	Analysed data of 2961 city gates that referred to period 2013-2016 that showed an overall average of 0.53%. 70% of the input volumes fall into the range of ±2%. On a yearly basis (2013, 2014, 2015, 2016) the observed range is between -1.5% and +32.5% (including outliers).
Latvia	year	Reported ~1.2 – 1.3% of annual gas consumption. An overall value not above 1.5% on an annual basis is considered as "normal".
Lithuania	month	Provided monthly data (from 1.2% to 4.7%).
Netherlands	year	The average *Δin-out* was 0.43% in 2014, 0.27% in 2015 and 0.72% in 2016. For the three large DSOs in the Netherlands, values varied between 0.11% and 0.89% in these years
Poland	year	Observed yearly values varying from: 0.15% to 4-5%.
Portugal	multiple years, year	Portugal 2012: -0.2% 2014 0,1% 6-year average: 2012 to 2017: -84 GWh/year (-0.06%).
Slovenia	year	Off-takes from distribution systems 0.75% higher than in-takes in 2018.
Spain	year	Reported a value of 0.46% in 2017 and 0.45% in 2018, calculated as an average of five samples of DSOs.

[9] This observation confirms what is reported in section 2.5.1 about the convergences of values to pure losses in a longer observation period (thus reducing the load profiling effect).

It was also requested in the survey to clarify if in the observed values for *Δin-out* show substantial differences (% of IN) between different distribution networks (and the reasons behind those differences.

Austria and Estonia observed a higher *Δin-out* in the network where most users are NDM.

Poland observed many differences among DSOs and identified as a primary reason the quality of meters of the end-users.

Spain does not see a single reason for differences, but a combination of volumes, maintenance plans and the number of final customers.

4.3.1 *Δin-out* components

A specific question aimed to understand if a country has put in place a methodology to evaluate at least some of the *Δin-out* components listed in section 2.1

The survey showed that most countries agree with the notional identification of components stated in section 2.1 but are lacking quantitative analysis to identify the weight of each component.

Some figures were provided only by Italy and Portugal:
- According to Italian analysis, as the long-term asymptote can be assumed as a reference for losses, "normal" losses in the distribution network are around 0.5%.
- According to Portuguese analysis, load profiling does not affect the "in-out" difference, because load profiling is only used for profiling metered consumption through the days of the year. Therefore, losses in the distribution network represent around 0.2%. There is no continuous monitoring of the in-out difference.

4.4 Incentives to DSOs

Some components of *Δin-out* can only be reduced by the DSO, through proper maintenance and control over the network and accurate meter reading. Therefore, in the survey, it was asked if some incentives for DSOs are in place.

Many countries do not have any incentive scheme specifically addressed to the DSOs for reduction of the overall *Δin-out*.

Where an incentive is in place, in most cases it is in the form of a maximum allowance for losses. These quantities are recognised as eligible costs of the operators, whereas any cost beyond the allowance is born by the DSO. This allowance can also be considered as a "normal" level of losses in gas operations.

An overview of the incentives in place is provided in the table below.

Country	Observation
Czech Republic	Maximum allowance: the allowed amount is variable because it is determined for each regional DSO individually as the average arithmetic value of the actual loss values for 2014–2018. In any case, a cap of 2% is applied if the determined amount exceeds 2%.

Denmark	The DSO has to bear the cost of losses.
Germany	The balancing regime includes an incentive scheme for DSO aimed to improve the quality of SLP (standard load profiles) forecasts.
Hungary	Maximum allowances ranges between 0.57% and 2.85%, depending on the DSO.
Ireland	Maximum allowance: level was 0.85% of distribution system throughput in gas year 2018/19 and has been reduced to 0.75% of distribution system throughput by gas year 2020/21.
Italy	Incentives are related to the quality of distribution service: one incentive is about leakage, measured as “number of dispersions” identified and not as “volumes of wasted gas”.
Lithuania	Maximum allowance: percentage is 2.33%, and it is calculated on the basis of the natural gas volume for technical purposes over the previous four years
Netherlands	Declares a positive/negative incentive scheme to the DSO introduced in 2020
Slovenia	The gas deficit can be up to 2% of transported quantities.
Spain	Values were defined in 2005, based on a study grounded in real data provided by the DSOs, and they depend on network pressure: • Network pressure over 16 bar: without any legally recognised percentage • Network pressure between 4 and 16 bar: 0.39% of consumption • Network pressure up to 4 bar: 1% of consumption • Network pressure up to 4 bar supplied from a satellite plant: 2% of consumption Differences within the maximum allowance are shared with the market.
Sweden	The DSO has to bear the cost of losses.

Many countries that do not have incentives yet see a benefit in introducing them.

Austria would like to allocate costs to DSOs together with an increased level of transparency and introducing some corrections to GCV.

Belgium is discussing to set up an incentive regulation aimed at improving the quality of service (power quality, metering, the transmission of indexes to the market, complaint handling, etc.) of the DSO for the period 2020-2024.

Italy is considering incentives to reduce the overall values of *Δin-out*.

Spain intends to make a global revision next year, including maximum allowance to DSOs.

4.5 Meter update/upgrade plans

Respondents were requested to provide general information about meter update/upgrade plans (including potential smart meter roll-out plans).

Most countries do not have a meter upgrade plan, where ‘upgrade’ in this context means to upgrade to “smart meters”, with daily granularity and remote metering. As a consequence, in those countries, meters might be maintained or substituted with a new one without those “smart” features.

The main reason for this (in some answers explicitly stated, such as Poland and Spain) is the cost: some countries assess that benefits are not worth the costs.

Some countries do not impose obligations on DSOs but build a regulatory framework favourable for the DSO or make it more aware of the benefits of smart meters.

Countries that have a roll-out plan, are currently at different stages and have different approaches:

- In Portugal, a small percentage of gas consumption is not daily metered.
- In some cases, only new meters must be “smart” (Germany), and gas metering equipment without registering performance measurement can still be installed until 31 December 2024.
- In some countries, the obligation to install smart meters depends on the consumption threshold, (Slovenia: above ~75,000 cubic metres per year)
- In Italy, smart meters must be installed where the nominal flow is equal or above 10 cubic metres per hour. Large distributors have an obligation to install smart meters also at a household level, to be able to remotely read the meter, but the daily measurement is not mandatory; the end date of the roll-out plan is foreseen as the end of 2023.
- In Estonia, all metering points consuming at least 750 cubic metres of gas per annum from the network of the network operator shall be equipped with a metering system which takes into account the temperature of the gas in the metering system and enables remote reading of metering data. The data must be readable by the end of 2020.
- Sometimes the roll-out plan puts an obligation on the DSO of a certain number of replacements, usually a percentage of its volumes (e.g. Italy).
- In Latvia, the plan is to cover with the smart meters during 2019 ~ 75% of consumption.
- In some cases (e.g. the Netherlands) substitution is on a voluntary basis (of the customer). The full-scale roll-out is planned to be finalised by the end of 2020.
- In some other cases, a smart meter is needed to allow pre-payments (Belgium), and therefore it is installed where this “commercial” arrangement is required.

Also, responsibility is not uniformly allocated across Europe. In some cases (as in Germany and the Czech Republic), the Ministry (and not the NRA) is responsible for the smart-meter roll-out plan.

As a conclusion:

- Smart-meters are of course the ultimate solution, but they are often not considered to be affordable.
- Therefore, investments should focus more on:
  - Reliable measurement;

- Regular basis meter reading (uniform distribution in time of meter reading plans); and
- A reliable load profiling-forecast.

5 Summary and conclusions

Chapters 1 and 2 described the theoretical approach to the *Δin-out* problem, showing how a difference between *In* and *Out* in the distribution network is there by definition, and its amount varies depending on the time-span considered.

Chapter 3 showed in a qualitative way how the amount of *Δin-out* can have if not under control, a negative effect on the market: the gas necessary to balance the network might create undue commercial risk for network users or decrease the efficiency of TSO balancing actions.

Chapter 4 is a summary of the survey that CEER did to better understand common practices across the EU. It turned out that there are mixed approaches to this topic; these, however, can also be explained by structural differences between the countries: number of DSOs, number of final customers, network dimensions, etc.

However, some general lessons can be learnt:

1 First of all, knowledge is the basis to tackle the *Δin-out* problem. NRAs should be aware of the numbers involved, possibly through a consistent and uniform methodology of data collection. To this end, Annex 2 – Standard data collection for *Δin-out* analysis contains a proposal of a minimum set of data that should be reported during the *Δin-out* analysis. The table should facilitate potential future analysis in this area through a more harmonised approach and thus increase the value of results.
2 *Δin-out* problem can be tackled in two ways that can run together: first, some actions should be taken to physically reduce the amount of *Δin-out*. The reduction is healthy for the market, both if it is determined in a short time-span (daily-monthly *Δin-out*) or in a longer one (yearly bi-annual *Δin-out*). Second, some regulatory tools can be put in place to limit the effect of undue risks for network users which ultimately lead to inefficient costs due to inefficient balancing actions.
3 To reduce the quantity of *Δin-out* present, one can follow three different threads:
    i. *Role of DSOs*: DSOs have control over the network and its maintenance. Therefore, they play a key role to reduce all the components related to “losses” such as leakages, blow-out and theft. Some countries have chosen to incentivise the DSO implicitly or explicitly, through a maximum allowance for losses. Incentives for DSOs can be seen generally as a good practice. Where incentives are not in place, the opportunity for an appropriate incentive scheme should be investigated. However, this practice should also be reinforced through a monitoring of results and a better understanding of the drivers for *Δin-out*, Moreover, reviewing thresholds with the aim to provide additional incentives for increased ambition could be considered. Finally, it should be highlighted that in some cases, incentives might not be enough if the infrastructure is obsolete, and it requires major upgrades. In those cases, a balance between incentives and investments on the network should be investigated.
    ii. *Measurements*: measurements accuracy is the result of different factors. DSOs again can have a key role when accuracy problems can be traced back to maintenance issues. Usually, the DSO is also responsible for meter reading which implies a great effort to collect and aggregate data. Performance of the DSO should therefore also be monitored as far as the meter reading is concerned (i.e. number, quality and regularity of readings), also taking into account that they have to be provided with adequate enforcement tools if they face any limitation to read meters inside private properties. In cases where investments are needed, such as a technological upgrade, the NRAs (or in some case the ministries) play a key role in approving a consistent plan of investment. In this case, a cost-benefit analysis should be taken into account, and a quick replacement should be performed, due to

the rapid evolution of technology and the risk of installing already obsolete devices. Special care should also be taken in regard to the accuracy of algorithms, when only volume is measured, in order to properly convert it into energy. It should take into account, for example, the network pressure and the height above the sea level.

iii. *Load profiling*: load profiling is broadly used as a way of striking the balance between metering and data collection costs and sufficient information about off-takes. There is a consensus around the idea that beyond a given threshold of consumption, daily balance can be estimated in an aggregate way, without the need for a massive data collection. As a consequence, a robust load profiling methodology is another key tool for achieving cost-effectiveness of the balancing activity. Monitoring and enhancing the quality of forecasts can be a good practice for NRAs that can also create some incentives addressed to the forecasting parties.

4 Finally, once all tools are put in place to reduce the *Δin-out* physically, some regulatory tools can be considered to tackle the problem the *Δin-out*. However, it needs to be borne in mind that, by definition, it cannot be eliminated 100%.

5 In order to avoid network users being confronted with a commercial risk which they can hardly forecast and influence (thus leading to inefficient balancing actions or costs which are passed on to final customers), NRAs might consider shifting the responsibility of *Δin-out* forecast and procurement to the TSO or the DSO and to socialise related costs among (final) customers through a tariff component. The advantage of this methodology is a more accurate forecast (compared to a forecast where *Δin-out* is allocated to each network user, because the forecast is made in an aggregate way, and the statistical errors compensate for each other. Moreover, based on the arguments above, this implies advantages from a commercial perspective.

6 In any case, the procedures to determine and balance *Δin-out* should be transparent and market-based.

Annex 1 – Appendix of abbreviations

Term	Definition
BAL NC	Balancing Network Code
CEER	Council of European Energy Regulators
DM	Daily Metered
DSO	Distribution System Operator
EU	European Union
GC	Gas Chromatography
GVC	Gross Calorific Value
GWh	Gigawatt-Hour
IDM	Intraday metered
MWh	Megawatt hour
NDM	Non-daily metered
NRA	National regulatory authority
TSO	Transmission System Operator
Δin-out	Delta In-Out

Annex 2 – Standard data collection for *Δin-out* analysis

This appendix contains a proposal of a minimum set of data that should be reported during the *Δin-out* analysis, as explained in Chapter 5.

Network ID	DSO	Start date	End date	MWh IN	MWh Out	Number off-take points	Number NDM	Volume NDM	Losses MWh

Where:

Network ID	Name or ID of the Distribution Network
DSO	Name or ID of the DSO
Start date	The start date of the observation period, usually a day, the first day of the month or the first day of the year
End date	The end date of the observation period. End Date = Start Date for a single day observation period
MWh In	The energy injected in the distribution network in the observation period and measured through daily meters (Values in MWh)
MWh Out	The energy off-taken from the distribution network in the observation period as a sum of DM measurements and a combination of NDM measurements (when available) and load profiling (Values in MWh)
Number off-take points	The number of off-take points
Number NDM	The number of off-take points that are NDM
Volume NDM	The volume of NDM during the observation period as a combination of measurements (when available) and load profiling
Leakages MWh	The estimated value of leakages (component 6 as of section 2.1, excluding blow-out and stealing). It is usually calculated with conventional formulas from the grid design (e.g. pipeline material, kilometres of pipeline, pressure)

Annex 3 – About CEER

The Council of European Energy Regulators (CEER) is the voice of Europe's national energy regulators. CEER's members and observers comprise 39 national energy regulatory authorities (NRAs) from across Europe.

CEER is legally established as a not-for-profit association under Belgian law, with a small Secretariat based in Brussels to assist the organisation.

CEER supports its NRA members/observers in their responsibilities, sharing experience and developing regulatory capacity and best practices. It does so by facilitating expert working group meetings, hosting workshops and events, supporting the development and publication of regulatory papers, and through an in-house Training Academy. Through CEER, European NRAs cooperate and develop common position papers, advice and forward-thinking recommendations to improve the electricity and gas markets for the benefit of consumers and businesses.

In terms of policy, CEER actively promotes an investment friendly, harmonised regulatory environment and the consistent application of existing EU legislation. A key objective of CEER is to facilitate the creation of a single, competitive, efficient and sustainable Internal Energy Market in Europe that works in the consumer interest.

Specifically, CEER deals with a range of energy regulatory issues including wholesale and retail markets; consumer issues; distribution networks; smart grids; flexibility; sustainability; and international cooperation.

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More information is available at www.ceer.eu.