Gas smart metering in Italy: state of the art and analysis of potentials and technical issues

Bianchini A., Guzzini A.*, Pellegrini M.**, Saccani C.***

** Department of Industrial Engineering (DIN) – University of Bologna, Viale Risorgimento, 2 40136 - Bologna – Italy (alessandro.guzzini2@unibo.it, cesare.saccani@unibo.it)*

*** Department of Industrial Engineering (DIN) – University of Bologna, Via Fontanelle 40, 47121 Forlì, Italy (augusto.bianchini@unibo.it, marco.pellegrini3@unibo.it)*

Abstract:
The introduction of Smart Metering in natural gas (NG) distribution is encouraged by several positive opportunities both for distribution companies and for end-users. In fact, as justified by the Italian National Authority, NG Smart Metering allows a new philosophy of measurement respect to the traditional system, since it will be able to reach several objectives as the reduction of the operative cost for fiscal activities, the improvement of measuring performances, a more conscious use of natural gas by end-users and, last but not least, a more effective monitoring of eventual leakages from the networks. Roll-out plans have been started by distribution Companies to install almost 11 million of devices since the 2018, respecting the scheduled dates by the National Authority. However, several technical issues are still unsolved as, but not limited to, power supply batteries and remote controlled valves. Several factors have to be considered to make the best selection; in the case of installation of new batteries, for example, the electric loads, the size, the environmental conditions, the cost and safety have to be analyzed.
To analyze the topic, the paper is divided as follow: in the first part a brief overview about the implementation of the new measuring system in Italian and European market is made in order to show the state of the art of the technology; in the second part, the description of smart meters and of main technical issues are proposed with the aim to highlight the most interesting topics in which technical research should be directed to improve their performance; being the power supply one of this, in the section a simple model is proposed to classify the selection of the component. Furthermore, being no present in literature or in technical documents information about the actual level of implementation of the gas smart metering in Italian market and the required efforts to respect the scheduled roll-out plans, a simple analysis is performed with the aim to highlight possible issues.

Keywords: Natural gas distribution, Gas Smart Metering, Smart meters, Batteries.

1. Introduction

To improve the efficiency and the safety of Natural Gas (NG) distribution (Bianchini, et al., 2015), the roll-out of new gas smart meters have been started as required by the Italian national Authority in the 2008 (AEEGSI, 2008). NG smart metering, in fact, introduces a new concept for the fiscal measurement of energy consumption. Respect to the past, smart metering can be defined as a new metering philosophy in which more than one remote interacting devices (the smart meters) communicate automatically with one central unit, defined as the Central Acquisition System (SAC: Sistemi di Acquisizione Centralizzata). In this way a very close interaction between end-users and NG Operators has been created as described in (Mihajlovic, et al., 2016), (Teodoru, 2016), (Wang, et al., 2016) and (Mogles, et al., 2017).

The indication to introduce the smart metering has appeared for the first time in Europe with the Directive 2006/32/CE, that defined the necessity for each national government to implement intelligent measuring systems if economically justified by a Cost – Benefit analysis (CBA). In case of positive results, the Directive has indicated a penetration of the 80% up to the 2020. Furthermore, in this first document it was calculated that an average investment cost between 200-250 Euro/customer would be necessary to implement smart metering in Europe; also a 3% reduction of European energy consumption was estimated. From the economic analysis European countries (for instance Germany, France, United Kingdom, Italy and Netherlands) have obtained different results. In Germany, having estimated a negative CBA, the decision regarding the implementation is left to the single Operators; however, it has been reported that the electronic meters are the 36.9% of the total (almost 13.5 million for the domestic size) and that 1.4 million of traditional meters can be refitted with electronic devices (Eisenbahnen, 2016). In France the main distributor, Gazpar, has started in the 2015 a research project with the installation of 150 thousand smart meters; after the positive end of this it has been decided to substitute the other 11 million reaching the 100% since the 2022 with an estimated economic investment of 1 billion of euros (approximatively 90€ per device). In the United Kingdom the government started the promotion of smart meters in the 2009 to reach the 100% since the 2020; however, despite the objective, the decision is left to the end users that has to require the installation: British Gas assures that only the half has asked the installation even if it has offered it to 8.4 million of clients. In the Netherlands the rollout phase has started in the 2012 with the objective of the 90% (7 million of smart meters) since the 2020. For this, the four most important distributors started the supply of 3 million of new gas smart meters in the 2016 with a total investment of 470 million of euro (i.e. about 156 € per device); even if like in the U.K. the end-user has to ask the installation, a lower refusal percentage has been encountered (almost the 3%). In Italy it has been estimated that 23 million of devices should be substitutes of which almost the 50% since the 2018 by local NG Distributors.

From these data, it is immediately clear the effort that NG Distributors have to sustain to complete the roll-out in terms of human and economic resources (Bondesan, 2013). In fact, the implementation of new gas smart meters represents a very critical point for NG Distributors that have to optimize the purchase, installation, operation, maintenance and repair activities. At the same time, it has to be highlighted that very few research activities have been done before the planned roll as that showed in (Celenza, et al., 2015) leaving several possible issues unsolved. Since now, two main issues have been identified. The first one is due to the installation schedule required by the Authority. The second comprises two main technical issues: the real capacity of power supply batteries and the tightness of remote controlled valves in domestic meters as described in (UNI TS 11291 - 1, 2013) and (UNI TS 11291-6, 2013).

In the first part of the paper it is reported a brief overview about the implementation of the new measuring system in Italian market in order to show the state of the art of the technology. In the second part, the description of smart meters and of the main technical issues are proposed with the aim to highlight the most interesting topics in which technical research should be directed with the scope to improve their performances; being the battery power supply one of this, in the section a simple model is proposed to rank this component in design or offer phase. In the last part of the paper, the required efforts to respect the scheduled roll-out plans are analyzed with a simple but immediate method in order to identify all possible issues for the implementation.

2. The Italian gas smart meter market: potentials and possible issues

Although the increase of energy production by renewables, NG still plays an important role for the energy supply in Italian market. The last available report from Eurogas (Eurogas, 2015) shows that residential and commercial sectors are the first consumers with a total energy consumption of 273 TWh followed by industrial and energy producer sectors with respectively 162 TWh and 187 TWh; overall it is estimated that the 31.4% of the national consumption is derived by NG (Eurogas, 2015).

The first step for the introduction of NG smart meters is made in 2008 when the national Authority (ARERA) shared the reasons for the substitution of the existing meters with the new electronic smart meters both for Operators and end-users (AEEGSI, 2008):

1. The calculation of daily gas balance able identify the national energy commercial balance;
2. The reduction of operative costs due to the remote reading;
3. The possibility to identify abnormal consumptions or device malfunctions;
4. The possibility to introduce a ranking to classify Operators as a function of distribution efficiency;
5. The possibility to promote concurrence between NG operators;
6. The definition of bills on effective and not on estimated consumptions;
7. The possibility for the end users to identify their actual consumption and so to be aware of them.

As reported in the list, the Authority was moved by the possibility to increase both the efficiency and the quality (defined as availability and safety) of the service for all the involved stakeholders. In fact, the new philosophy ensures the possibility to have a big amount of data every day from distributed devices. Even if the data are actually used only for fiscal purpose, it is immediately clear that algorithms should be implemented to improve the planning of maintenance and inspection activities and to find NG leaks. Smart meters consequently could give data to correctly operate the system as those proposed in (Bianchini, et al., 2016) and in (Bianchini, et al., 2017).

In fact, the data received consist of the following:

- Information about gas consumption as hourly flowrate, total consumed volume and supply pressure;
- Information about device status as the occurred events and a diagnostic report.

Despite the possible advantages that could be achieved, several issues have had to be overtaken to ensure the implementation since the scheduled time. First of all, the number of devices to be substituted. At the 2008, more than 20 million of customers were connected to the distribution networks and required the substitution. Even if Authority's decision was public from three years, in the 2011 the roll-out plan was effective only for industrial size meters (>G10) that represents the 1.8% of the installed meters at the 2016 as reported in Figure 1.

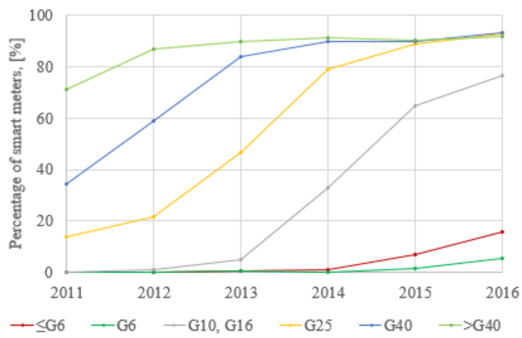

Figure 1. Percentage of installed smart meter in Italy as a function of the year and of the size. Data have been elaborated from (ARERA, 2017).

In the figure, gas smart meters are divided into classes. There are identified by the nomenclature "GX" where "G" refers to "Gas" while "X" is the nominal flowrate of the meter in [Sm^3/h].

Another important consideration regards the possible technical issues arising during the life of the devices. The short period available before the roll-out plan has not allowed the performance of tests leaving the behaviour of most elements unknown. In this way, several issues that could be solved before to put it in place appear during field operation slowing down roll-out plan. The main ones, however, are explained in more detail in next section.

3. NG Smart meters: new technology and new criticalities

The introduction of smart metering has required the design of meters with new functionalities to realize the objectives identified by the Italian Authority. Particularly, different parts can be recognized in a meter:

1. The measuring element. In traditional meters, a diaphragm mechanism characterized by moving parts is usually present. Therefore, friction can appear reducing the effective life. Respect to traditional, many smart meters have no moving parts to measure the flowrate reducing also the interference with the process. Particularly mass thermal and ultrasonic flowmeters are used. Another important difference respect to traditional meters is the measure of temperature and pressure to correct the measured volumetric flowrates and to report them to the Normal condition.
2. The communication element to transmit the values from the measuring device to the elaboration unit. Respect to the past in which mechanical gears are used, in new devices signal communication is implemented as, for instance, 4-20 mA.
3. The Central Processor Unit (CPU) in which the main differences between electronic and traditional meters can be identified. In fact, in traditional devices it only consists of a totalizer and of a visual display to read the consumption. In electronics devices there are an elaboration unit, a recording unit and a communication unit to support radiofrequency or GSM-GPRS communication with the SAC.

To improve the functionalities of domestic meters, in new electronic devices it is required the installation of a valve for the interruption of NG flowrate that can be controlled by the SAC (UNI TS 11291-6, 2013); in fact the supply should be stopped in the case of abnormal consumption or payment delay by the end-users. A motorized or a solenoid valve is installed upstream the measuring device for the scope. However, the presence of solid particle or contaminants in the gas and temperature variation can deteriorate the internal components of the valve, reducing the effective tightness and so the effective operative life. To improve it, experimental evidences appear to be necessary and should be performed in the next future to characterize the real performance of the valve.

From the brief description, it is evident the first technical issue: the power supply. Several aspects have had be considered with particular attention to safety. Even if ATEX certification is not mandatory for domestic smart meters in accordance to the (European Commission, 2014), the possible presence of flammable atmospheres introduces a risk in case of an ignition source. To reduce it, no connection with national grid is present and low voltage batteries have been consequently considered for the scope. However, as reported in next section, the correct selection and so the possibility to minimize Capital Expenditure Cost (CAPEX) and Operative Expenditure Cost (OPEX) is of primary importance.

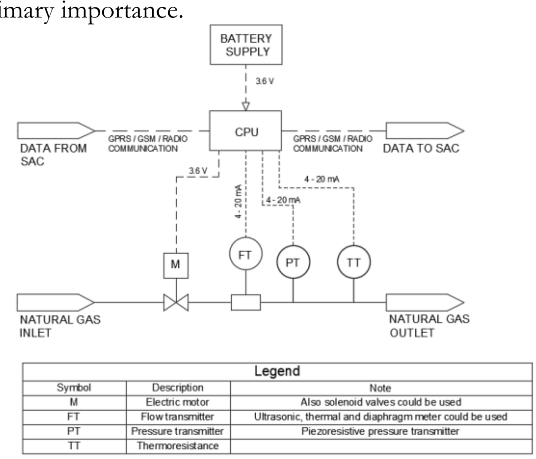

Figure 2. Schematic of NG meter with main components

3.1 A theoretical ranking method to select the batteries in gas smart meters

Even if battery power supply is performed both in industrial and domestic size, one or two battery packs are present respectively. In both the cases, however, the selected batteries should ensure energy for the defined design life. The main characteristics of the battery are summarized as follow:

- High capacity;
- Small size;
- Low voltage;
- High operative temperature range;
- Low specific cost;
- Availability;
- Low self-discharge;
- Compatibility with the environment;
- Safety

Lithium-thionyl chloride (LiSOCl2) and lithium manganese dioxide (LMO) types are used for the scope thank to the high capacity density, high electrochemical stability, low cost and high level of safety reached in last years (Levy, 1997) and (Lisbona & Snee, 2011); the main characteristics are reported in Table 1.

Table 1. Main parameters of LiSOCl2 and LMO batteries

Parameters	$LiSOCl_2$	LMO
Maximum continuous current, [A]	2	< 5
Nominal voltage, [V]	3.6	3.0
Self-discharge, [%] respect to nominal capacity	[1; 2]	2
Temperature range, [°C]	[-55; 85]	[-40; 85]
Density capacity, [Ah/g]	172	90.8
Specific density, [Ah/cm^3]	300	200
Specific cost, [Euro/Ah]	1.8 - 4.8	3.5

In literature several works are present about the LiSOCl2 (Dittrich), (Saunders, 1998) even very few are about their performance in real applications specifically in NG smart meters' power supply as in (Reuning & Joose, 2013).

To select the batteries in design or offer phase, a new method to rank the batteries of new smart meters is proposed taking into account that the deliverable capacity depends on operative conditions and particularly on discharged current and temperature (Erdinc, et al.); this method can be used especially when new models are to be introduced in the field and no experimental evaluation can be done about real performances. Regarding the capacity, if the battery is pulsed discharged, it depends also on the amplitude, on the length and on the time interval between pulses and so on the possibility of the battery to complete relaxation (Zhang & Harb, 2015). In this case, however, relaxation is neglected. In the analysis, so, continuous discharge data given by the manufacturer have been used. As reported by (Erdinc, et al.) the temperature has an important impact on battery performances. Battery capacity increases with temperature in the range of discharged current between 50-1000 mA due to the reduction of internal resistance as reported by commercial datasheets. Therefore, to estimate battery capacity C(T) at a given temperature T [K], an Arrhenius behaviour is supposed for the temperature range [-20; +50] °C as in equation 1 for the defined range of current as suggested by (Rodrigues, et al., 2017):

$$C(T) = a \times e^{\left(-\frac{b}{T}\right)} \tag{1}$$

Where *a* and *b* are coefficient expressed respectively in [Ah] and [K]; *a* is a pre-exponential term depicting an intrinsic value of the battery and *b* is considered as the ratio between the activation energy, i.e. an energy barrier, and the universal gas constant. The coefficients in the equation (1) are estimated as follows: capacity for the desired discharged current has been identified from datasheets for different temperatures and then the coefficients *a* and *b* have been interpolated by comparing equation 1 curves and datasheets' capacities. Furthermore, it is assumed that the operative temperature is environment temperature assuming that the heat generated inside the meter is not responsible for a temperature increase. Temperature can be found in local databases. For a statistic analysis the average air temperatures at one meter from the ground are elaborated considering three years and considering a 1K interval. The percentage P(T) has been calculated as in equation 2 from the data:

$$P(T) = \frac{N(T)}{N} \tag{2}$$

Where N(T) is the number of hours in which the temperature T has been recorded [#], and N is the total number of hours in the analysed period [#]. Because no memory phenomenon characterizes the real battery capacity is calculated as in equation 3:

$$C_{real} = \frac{\sum_{T=-10}^{40} C(T)P(T)}{\sum_{T=-10}^{40} P(T)} \tag{3}$$

The consumed capacity for the expected life can be approximately calculated as in equation 4. In this case, it has been considered the battery required for communication in domestic devices.:

$$C_{discharged} = (1+f) \times \sum_{n=1}^{15} m \times d \times I_{exp} \times \Delta t \tag{4}$$

Where m is the number of communication in a day [#], d is the number of day in a year [#/year], I_{exp} is the average current discharged during the communication [A] and Δt is the average duration of the communication [h]. A safety factor f has been introduced to take into account changes respect to the nominal case and take into account the self-discharge. Particularly, a value equal to 20% is considered for new applications where field data are not available; in other cases, f can be calculated as the sum of the ratio between the duration of communication in real case (recorded by the SAC) and the ideal one plus a factor that take into account of self-discharge defined by manufacturer. In the model it has also been assumed that the difference between real and nominal current is negligible. In the case of the presence of existing batteries in the field, however, $C_{discharged}$ should be statistically evaluated. So, the estimated remaining capacity at the end of the period can be calculated as in equation 5:

$$C_{Remaining} = C_{real} - C_{discharged} \tag{5}$$

The economic loss corresponding to remaining capacity not used can therefore be calculated. Defined as c the cost of the battery [Euro], the economic loss L [Euro] is:

$$L = \frac{c}{C} \times C_{Remaining} = c \times \left(1 - \frac{C_{discharged}}{C}\right) \tag{6}$$

Furthermore, a real specific cost of the battery can be calculated as in equation 7:

$$c_{real} = \frac{c}{C_{discharged}} \tag{7}$$

To summarize the procedure, the Figure 3 is introduced:

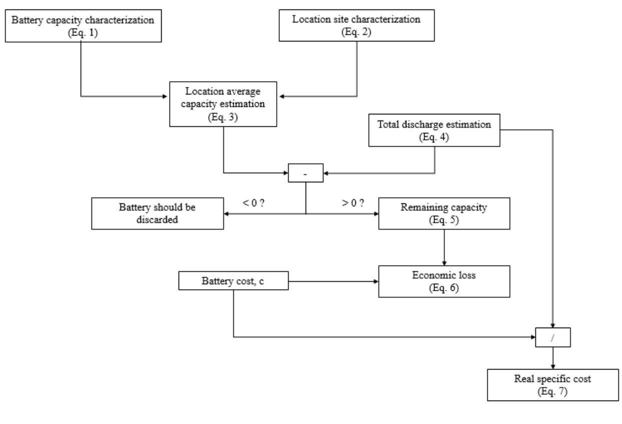

Figure 3. Method to classify batteries for smart meters

To rank the batteries a numerical vote for the real capacity, the remaining capacity, the economic loss and the specific cost is given as a function of the importance that the operators assign to each characteristic: higher is the number higher is the importance. The final ranking is obtained from equation 8:

$$R_i = \sum_{j=1}^{N} w_j \times r_{i,j} \quad (8)$$

Where R_i is the total vote for the i-th battery, N is the total number of variables that should be considered in the analysis (in our case 4 variables are considered as reported in table 4), $w_{i,j}$ is the weight for the j-th category and r_{ij} is the vote for the i-th battery considering the j-th category. Only to show the potential of the method, $r_{i,j}$ is considered between 1 to 4: 1 is attributed to the less performing battery for the selected characteristic, 4 to the best one. Instead, the definition of the w_j depends on the importance attributed in the assessment and can be evaluated by more or less complex procedures as, for example, the elicitation procedures; however, the following condition has to be respected:

$$\sum_{j=1}^{N} w_j = 1 \quad (9)$$

3.2 Battery selection for NG smart meters: results

To show the potentials of the proposed method a site in Emilia Romagna is considered. In Figure 4 the number of hours at specific external temperature is reported for three years.

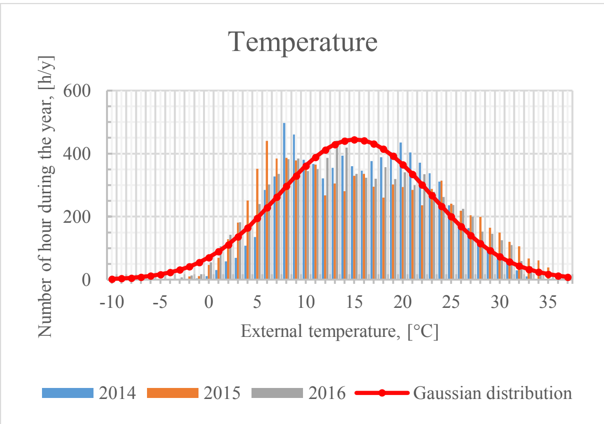

Figure 4. Annual temperature in the site considered

A GSM communication is considered with an average consumed current of 100 mA. An average duration of 60 s is considered with a single communication daily.

Table 2. Main characteristics of the analysed batteries

Battery	C, [Ah]	a	b	Cost, [Euro/#]	Specific cost, [Euro/Ah]
Battery A	19.0	4450	1700	23.52	1.24
Battery B	19.0	8500	2000	26.75	1.41
Battery C	19.0	150	850	20.80	1.09
Battery D	8.5	1000	1700	10.35	1.22

Four $LiSOCl_2$ commercial batteries have been considered for the analysis; a and b are coefficients and they have been calculated for each in accordance to equation 1. Main characteristics are reported in Table 2.

From Table 2 three batteries have capacity higher than 15 Ah; being defined at nominal condition, however, it is not possible to use that value to classify the performance of the battery at the specific test conditions. The same consideration is valid also for the specific cost.

From equation (3) and (4) the available and discharged capacities are calculated. Results are reported in Table 3.

Table 3. Performance estimated for the batteries

Battery	C_{real}, [Ah]	$\Delta = \frac{C_{real}-C}{C}$, [%]	$C_{Remaining}$ [Ah]	L [Euro]	C_{real}, [€/Ah]
Battery A	12.4	-34.7	5.1	6.3	3.2
Battery B	8.4	-55.8	1.1	1.6	3.7
Battery C	7.9	-58.4	0.6	0.7	2.8
Battery D	2.8	-67.1	<0	NA	NA

From equation 8 and 9, considering the same importance for each characteristic (w_j=0.25), a preliminary ranking of the batteries is showed in Table 4. It should be noted that the same value for w_j has been considered only for explanation purpose even if different values can be used by the management. In this case, the best battery from the model is the battery A, followed by the battery C and the battery B.

Table 4. Results of the ranking.

Battery	C_{real}, [Ah]	$C_{Remaining}$ [Ah]	L [Euro]	C_{real}, [€/Ah]	R
Battery A	4	4	2	3	3.3
Battery B	3	3	3	2	2.8
Battery C	2	2	4	4	3.0
Battery D	1	1	1	1	1.0

4. Smart meter implementation in Italian market

As showed in Figure 1 domestic meters have started to be installed only from 2013. This can be justified by the absence of technical standards, i.e. the (UNI TS 11291), and by the unavailability of devices on the market. So NG smart metering became a challenge for the whole supply chain. Another obstacle is the installation. In fact, some old meters are installed inside buildings and are not compliant with actual safety standards. Both the situations complicate the substitution of traditional meters; in the first case, the owner's authorization is required to come in the building. In the second case, adjustments in the plant have to be performed to make it compliant with standards; being this in the responsibility of the end users, these can be demotivated and less inclined to accept the installation. In both the case, the end-user is the final decision maker.

That is, Authority firstly defined the scheduled plan for the substitution of traditional meters (AEEGSI, 2013). However, a new scheduled plan has been proposed in the 2015 because of the difficulties for the entire supply chain to respect the scheduled objectives (AEEGSI, 2015). In

Table **5** the updated objective are reported for the domestic meters.

To make clear to all NG stakeholders the efforts made to respect the objectives, the estimation of the total number of men employed at national level only for the installation phase is reported in Table 5. The following hypothesis have been defined:

- Average number of meters installed in a day by a man, N_{meter}: 12 #/(man x day);
- Number of days in a year, N_{day}: 250 day/year

Table 5. Updated objectives in (AEEGSI, 2015)

Meter size	Nominal flow, [Sm³/h]	Percentage 2016, [%]	Percentage 2017, [%]	Percentage 2018, [%]
< G6	< 6	15% (*) 3% (**) 0% (***)	33% (*) 15% (**) 0% (***)	50(*) 33% (**) 8% (***)
(*) = distributors with more than 200.000 end users. (**) = distributors with [100.000; 200.000] customers. (***) = distributors with [50.000; 100.000] customers.				

The total number of smart meter to be installed in the period is calculated as in equation 10:

$$N_{SM\,i} = N_{SM\,required} - N_{SM\,i-1} \tag{10}$$

Where $N_{SM\,i}$ is the number of smart meter to be installed in the i-th year and the $N_{SM\,required}$ is the number of smart meter to be installed as required by the Authority for the i-th year.

The total number of men $N_{men,i}$ required for the installation in the i-th year is therefore:

$$N_{men,i} = \frac{N_{SM\,i}}{\left(N_{meter} \times N_{day}\right)} \tag{11}$$

In accordance to

Table **5** the number of electronic meters to be installed have been calculated considering the different percentages as a function of Operators size. The results are reported in Table 6. Operators with more of 200.000 end-users are indicated as A, Operators with a number of customers with [100.000; 200.000] customers are defined as B; others are indicated as C.

Table 6. Number of smart meters to be installed in accordance to (AEEGSI, 2015)

Operators	Customers, [k#]	Installed, 2016, [k#]	Installed, 2017, [k#]	Installed 2018, [k#]
A	16.457	2.469	5.431	8.229
B	1.023	31	154	338
C	5.520	0	0	442
Total	**23.000**	**2.500**	**5.585**	**9.009**

From the calculation it results 2500, 5585 and 9009 devices should be respectively installed in the 2016, 2017 and 2018. Using the equation from 10 to 11 it is possible to estimate the number of men that should be employed in the market only for the installation activity. From Authority's data it has been found that 3.573.000 devices have been implemented at the end of the 2016. This percentage is higher than the required (+42.9%). However, it has been assumed that the difference is only due to Operators A. Results are reported in Table 6.

As reported in Table 7 almost 670 and 1140 men should be respectively employed for the 2017 and 2018. It can be estimated the allocated cost considering the following:

- A specific cost of 20 €/(h x man) equal to almost 38.400 €/(man x y);
- A cost of 60 € for each device.

Table 7. Number of men that should be employed to respect scheduled dates

Operators	Installed, 2016, [k#]	Men employed, 2017, [#]	Men employed 2018, [k#]
A	3.542	630	933
B	31	42	62
C	0	0	148
Total	**3.573**	**672**	**1.143**

Table 8. Estimation of the total costs for the installation

Operators	Voice of cost	Total cost 2017, [#]	Total cost 2018, [k#]
A	Device	177.720.000	167.880.000
	Installation	24.192.000	35.827.000
B	Device	7.380.000	11.040.000
	Installation	1.613.00	2.381.000
C	Device	0	6.720.000
	Installation	0	5.683.000
Total		**210.905.000**	**229.531.000**

As reported, a total cost of 210 M€ and 230 M€ should be allocated for the implementation of the technology in the Italian market for the 2017 and 2018 considering only the cost of the device and the cost of the employers for the installation. Considering these voice of cost a preliminary cost of almost 67 Euro/device can be considered at national level. Consequently, not only technical and logistic but also economic issues should be overtaken by Operators and considered by Authority to identify objectives for next future.

5. Conclusion

The introduction of smart metering in NG distribution represents a significant challenge for the stakeholders of the sector. Particularly in Italy, the Authority has defined the objectives for the 2017 and the 2018 that require many efforts by Operators to ensure the scheduled times. However, technical, logistic and economic issues are arising and represents an obstacle for the effective implementation in Italian market.

About logistic and economic issues, the number of men to be employed and the budget allocated for the installation of the meters has been estimated for the 2017 and 2018. From the analysis it results that almost 670 and 1140 men should be employed while 210 M€ and 230 M€ should be allocated by NG Distributors. These numbers highlight the challenge for all the Italian NG sector due to the substitution of old meters with the new smart ones.

About technical issues, several ones have been identified. Between them, power supply battery and remote controlled valve seems to be the most important from a technical point of view and in which research activities should be performed. About the selection of the battery power supply in the case of no available experimental data, a preliminary ranking method has been proposed: has been proposed considering several variables as technical and economic during design phase. However, in the case of available data from the field, a statistic evaluation of discharged capacity is suggested.

Furthermore, very few experimental activities have been made about performances in the field. Therefore, a lot of research activities can be performed to improve the performance of smart meters considering different topics. For this reason, being one of the topics reported in the paper, experimental activities are in progress to characterize the real electric consumption and so to estimate the real life of the batteries. The results of the activity will be reported in a future paper at the end of the experimental phase.

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