Intelligent Energy Analyzers and Integrated IoT Systems: Identification and Analysis of Solutions and Funding on a European Scale

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***Abstract*—The production of electricity has a major impact on enhancing the greenhouse effect/destroying the ozone layer and in the climate changes. In order to solve this problem, two possible solutions emerge: production of green energy and promotion of low energy consumption.**

This work presents the state of the art in low carbon, carbon neutral and carbon neutral energy policies, with the aim of understanding the framework and benefits of developing a smart energy meter, with future application in our homes.

The work begins with an examination of the causes and consequences of climate change, in the short, medium and long term. A general assessment of the evolution of these changes over time is also performed. Next is discussed the inclusion in the "carbon neutral" of all types of emissions and waste, i.e., wastes in a common household, hotels, restaurants, and all types of activities that consume electricity. The technologies discussed here are: Smart Buildings and Smart Meters.

Finally, European Union's proposals to reduce the carbon footprint through the use of low-carbon technologies are explored, together with the proposal of a new smart meter that can give suggestions to the consumer. Although this topic has been the subject of intense research, its legislation is something that has not yet been considered or properly cemented. Therefore, the current status of this policy is presented and discussed.

***Index Terms*—Smart Buildings, Smart Meter, Low Carbon, Climate Neutral, Market Legislation, Privacy and Data Protection**

I. Introduction

Electricity production has a major impact on the increase of the greenhouse effect/ozone layer depletion and consequently on climate change. Two possible solutions to this problem are: to produce green energy and to encourage the reduction of energy consumption.

Green energy is energy produced from renewable sources that does not generate polluting substances or greenhouse gases, respecting biodiversity and human beings. Nature has a series of resources that can be converted into electrical energy, and the main sources of renewable energy are: solar energy, wind, hydro energy, biomass energy and geothermal energy.

Regarding the encouragement of low energy consumption, the concept of *climate neutral* is now a hot topic. This concept is based on the idea that if a company emits a certain amount of CO_2 into the atmosphere, it must also be able to reabsorb what was emitted (for example, by growing a forest area). The climate neutral must cover all types of emissions and waste, which includes waste in common housing, hotels, restaurants and all types of activities that use electricity. The technologies/concepts that greatly help the climate neutral are the *smart buildings* and the *smart meters*. *Smart buildings* are based on the use of materials with greater thermoelectric efficiency, use of renewable energy, etc. Implicit in the concept of *smart buildings* are *smart meters*, such as, for example, the digital counter.

The majority of the population has no notion of basic concepts related to energy, and, as such, they do not look at their energy consumption. On the one hand we have the electricity bill, which is a concern, but on the other hand we have the low price of less efficient technologies, which leads to a common mistake, buying cheaper equipment that consumes more. It would be better for the consumer to buy more efficient but more expensive equipment, and then recover the extra amount he paid on the electricity bill (which would decrease over time). This idea can only be instilled in consumers through energy literacy, and the existence of a smart meter, which constantly interacts with the user, providing information on consumption in real time, as well as in the medium and long term, and highlighting the consumption of each equipment. This would be a very useful tool for educating people (and at the same time optimizing energy consumption).

The simpler smart meters were initially developed with the main objective of ending estimates in electricity bills, as they allow the communication of readings to the Distribution Network Operator (ORD) to be carried out remotely and automatically.

Additionally, they allow for other changes that may be favourable to consumers, as they will have a significant impact on the management of the national electricity grid. They enable more efficient management of energy production and distribution, and, consequently, allow for a reduction in carbon dioxide emissions.

The installation of these meters is the responsibility of the

ORD, a function performed in most municipalities in mainland Portugal by E-Redes, under the supervision of the Regulatory Authority for Energy Services (ERSE).

Currently, one million state-of-the-art meters have already been installed and it is expected that by the end of 2022 meters will be installed in all facilities, according to information from e-redes [1].

It should be noted that smarter meters raise issues such as the privacy of the data collected by it, and therefore, the objective of this work is to understand how the legislation is prepared to deal with these problems.

The paper is organised as follows. Section 2 presents a study on the causes and consequences of short, medium and long-term climate changes. A general assessment of the evolution of these changes over time is also carried out, trying to establish a relationship between the way in which energy has been produced and the increase in the greenhouse effect/destruction ozone layer. Section 3 presents the notions on smart buildings and smart meters. Their evolution over time is described, as well as the future of these technologies. Section 4 is dedicated to the legislation applied by the European Union in the energy sector. The European Union proposed to reduce the carbon footprint through the use of low-carbon technologies. Although this topic is the subject of intense investigation, its legislation is something that has not yet been considered or properly cemented. Existing legislation on data protection is discussed in the light of new smart meters. Section 6 is dedicated to European Union (EU) funding of these initiatives. The paper ends with the conclusions in Section 7.

II. Climate Change

A. Causes

Scientists attribute the global warming observed since the mid-20th century to the human spread of the "greenhouse effect," the warming that occurs when the atmosphere captures heat that radiates from the Earth into space.

Certain gases in the atmosphere block heat and do not allow it to escape. Gases that remain semi-permanently in the atmosphere and do not respond physically or chemically to changes in temperature are described as "promoters" of climate change. Gases such as water vapor, which respond physically or chemically to changes in temperature, are considered "feedbacks".

The gases that contribute to the greenhouse effect are: water vapor, carbon dioxide CO_2, methane, nitrous oxide and chlorofluorocarbons (CFCs).

The role of human activity: in its Fifth Assessment Report [3], the Inter-Governmental Panel on Climate Change, a group of 1,300 independent scientific experts from countries around the world under the auspices of the United Nations, concluded that there are more than 95% of probability that human activities over the past 50 years have warmed our planet.

The industrial activities on which our modern civilization depends have increased levels of carbon dioxide in the atmosphere from 280 parts per million to 414 parts per million over the past 150 years. The panel also concluded that there is more than a 95% probability that man-made greenhouse gases such as carbon dioxide, methane, and nitrous oxide caused much of the observed increase in emissions.

B. Consequences

Human activities are changing the natural greenhouse effect. In the last century, the use of fossil fuels such as coal and oil has increased the concentration of atmospheric carbon (CO_2). This is because the coal or oil burning process combines carbon with oxygen in the air to form CO_2. To a lesser degree, deforestation for agriculture, industry, and other human activities has increased greenhouse gas concentrations.

The consequences of changing the natural atmospheric greenhouse effect are difficult to predict, but some effects seem likely to be:

- On average, the Earth will be warmer. Some regions may have higher temperatures, but others may not.
- Warmer conditions will likely lead to more evaporation and precipitation overall, but individual regions will vary, some becoming wetter and others drier.
- A stronger greenhouse effect will warm the ocean and partially melt glaciers and ice sheets, raising sea level. Ocean water will also expand, heat up, further contributing to sea level rise.

C. Low Carbon

The carbon footprint is defined as the amount of carbon dioxide emissions associated with all activities of a person or other entity (eg building, corporation, country, etc.). It includes direct emissions, such as those that result from burning fossil fuels in production, heating and transport, as well as the emissions needed to produce the electricity associated with the goods and services consumed [7]. In addition, the carbon footprint concept also often includes emissions of other greenhouse gases such as methane, nitrous oxide or chlorofluorocarbons (CFCs).

The carbon footprint concept is related to, and grew out of, an older idea - the ecological footprint, a concept invented in the early 1990s by ecologist William Rees and Swiss-born regional planner Mathis Wackernagel of the University of British Columbia [8]. An ecological footprint is the total area of land needed to support an activity or population. It includes environmental impacts such as water use and the amount of land used for food production. In contrast, a carbon footprint is usually expressed as a measure of weight, as in tons of CO_2, or, CO_2 equivalent per year.

Calculation of carbon footprint: carbon footprints are different from a country's per capita emissions (for example, those presented in the United Nations Framework Convention on Climate Change). Instead of the greenhouse gas emissions associated with production, the carbon footprint is concentrated on the greenhouse gas emissions associated with consumption. They include emissions associated with goods that are imported into one country but produced elsewhere and generally take into account emissions associated with international transport, which are not accounted for in standard national inventories. As a result, a country's carbon footprint can increase even if carbon emissions within its borders decrease.

In developed countries, the transport and use of domestic energy constitute the largest component of an individual's carbon footprint. For example, approximately 40% of total emissions in the United States during the first decade of the 21st century came from these sources [9], [10]. These emissions are included as part of an individual's "primary" carbon footprint, representing the emissions over which an individual has direct control. The remainder of an individual's carbon footprint is called the "secondary" carbon footprint, representing the carbon emissions associated with the consumption of goods and services. The secondary footprint includes the carbon emissions emitted by food production. It can be used to account for diets that contain higher proportions of meat, which require a greater amount of energy and nutrients to be produced than vegetables and grains, and foods that have been transported over long distances. Manufacturing and transporting consumer goods are additional contributors to the secondary carbon footprint. For example, the carbon footprint of a bottle of water includes the CO_2 or the equivalent of CO_2 emitted during the manufacture of the bottle itself plus the amount emitted during the transport of the bottle to the consumer [10].

D. *Issuing less:*

All economic sectors can and should contribute to reducing greenhouse gas emissions. For example, the industry needs to continue to modernize and pollute less. The aviation and maritime sectors, which are among the fastest growing sources of greenhouse gas emissions, must become more energy efficient and shift to greener alternative fuels [15].

To reduce emissions from energy-intensive industries, the EU has created an emissions trading system. The EU ETS is a market for carbon permits that establishes the amount of emissions that energy producers, industrial plants and airlines can release into the atmosphere. Permission levels are gradually reduced to cut emissions from participating industries [16].

The taxation for the production of a ton of carbon is shown illustratively in the figure **??** for the various countries of the European Union in the year 2019. Portugal appears in number 12.

We, as consumers, can also reduce our environmental footprint through our behavior and choices.

Despite the reductions, some emissions will be unavoidable. The oceans and the soil absorb carbon dioxide from the atmosphere, but forests represent the most effective way to make a difference. EU forests absorb the equivalent of almost 10% of all EU greenhouse gas emissions every year. Natural ecosystems that have the ability to absorb more carbon than they emit are called "carbon sinks". Actions to protect oceans, soil and forests are thus vital for absorbing emissions.

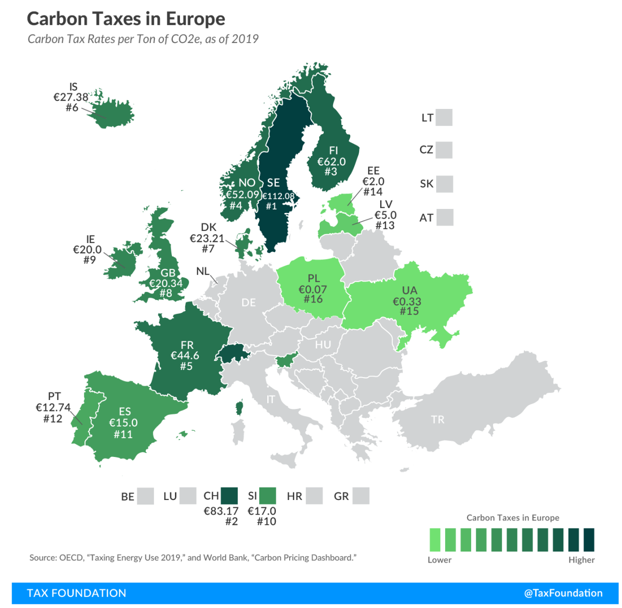

Fig. 1. Taxation for the production of a ton of carbon in the year 2019. Figure adapted from taxfoundation.org.

In December 2019, the European Commission announced the European Green Agreement as the strategy to achieve EU climate neutrality by 2050. EU leaders welcomed this Commission initiative, setting the 2050 goal of a climate-neutral EU [17].

The overarching objective is, while facing the existential threat of climate change, the EU pursues economic growth in order to create better jobs and improve people's well-being.

The Green Agreement includes measures such as:

- use technologies that do not harm the environment
- development of cleaner forms of transport by decarbonising the energy sector
- more energy-efficient buildings
- work internationally to improve standards around the world

However, while the Green Deal sets out a comprehensive roadmap for transformative policies aimed at achieving climate neutrality, climate action has long been on the EU's agenda.

In 2008, EU leaders agreed that by 2020 the EU would cut its greenhouse gas emissions by 20% from the 1990 level. This target was reached three years ahead of schedule. In 2014, the leaders set the goal of reducing greenhouse gas emissions by at least 40% by 2030. In December 2020, the European Council agreed to increase the EU's ambition. EU leaders have set a binding EU target of a net domestic reduction of at least 55% in greenhouse gas emissions by 2030 compared to 1990 [18], [19].

III. Energy Consumption

We live in a consumer society, which has energy as an essential good. This energy consumption is usually only measured at the end of each month, through an energy bill. This type of measurement is not ideal, because, in addition to the user not having a concrete vision of how that energy was spent, he does not have this information in a detailed way (daily information on when and where the energy was used), and, have the minimum knowledge to analyze their expenses, that is, a lack of energy literacy prevails among the population.

A central problem is the immateriality of energy and how we can make it visible. Electricity is an invisible and abstract force that reaches our homes through hidden wires. It has been described as being "double invisible". On the one hand, electricity is seen as a commodity and a social necessity. On the other hand, energy consumption is part of daily routines and habits that make it difficult for people to stay alert for their behavior or concrete actions, regarding energy consumption patterns [23]–[28]

Recent studies have shown that providing customers with energy consumption data can significantly reduce [29] energy bills.

Energy literacy is an understanding of the nature and role of energy in the world and in our daily life, accompanied by the ability to apply that understanding to answer questions and solve problems. Energy literacy is important for energy communities to successfully participate in clean energy transitions and contribute to the realization of those transitions. Its representatives and members need to be energy literate. As we will see below, such literacy will be most effective when accompanied by interactive feedback (use of smart real-time energy meters) [25], [30]–[33].

A. Energy Literacy

Due to the need to heat, cool and light residential buildings, the residential sector accounts for a fifth of global energy consumption. As a result, it is not surprising that energy efficiency has become more important in the residential sector in recent years.

The work by Dirk Brounen et al. [34] (see also [35]), developed in 2013, examines household knowledge, literacy and actions in relation to residential energy use. The extent to which consumers are aware of their energy consumption and whether they have taken steps to reduce their energy costs was measured using a detailed survey of 1,721 Dutch households. The results show that energy literacy and awareness among respondents are low: only 56% are aware of the amount charged monthly for energy consumption and 40% of people do not adequately assess investment decisions in energy-efficient equipment.

The results show that environmental ideology and consumer conservation attitudes have the greatest impact on energy perception. Those who drive more efficiently, conserve more, are more coordinated, and are more aware of residential energy use, and are more likely to react to energy data. Only up to a point, demographics - particularly the age of the respondent - are responsible for raising awareness. It was also possible to conclude that education is the main determinant in rational decision-making (ie, energy literacy) and is not related to the individual's philosophy or attitudes.

The thermal comfort option (ie thermostat settings) at night and the trend to decrease the setting at night were used to calculate the energy behavior. The results indicated that older respondents with higher incomes prefer higher comfort levels, and that lowering the temperature at night is negatively related to age. During winter, more moderate respondents prefer a lower comfort temperature.

One of the most important conclusions is that no evidence was found on the effect of energy awareness and literacy on actual energy consumption.

Note that the authors identified 17% of respondents who were categorized as *sleepers*, were not aware of the energy they expended, the thermostat effect, or any relationship between energy expended and comfort. These respondents might behave differently if they were dealing with smart meters.

Another interesting conclusion of this study is that ideology and mentality increase awareness of energy use and willingness to buy green energy, but not always influence actions. While "greens" (people who are concerned about green energy) can drive a Prius, there is no evidence that they actively reduce their comfort temperatures or nighttime temperatures in their homes to save energy.

It should be noted that this work does not make use of any energy feedback, such as through the use of smart meters.

The work by Tobias Schwartz et al. [23] shows a three-year study focused on placing a Home Energy Management Systems (HEMS) system in a seven-year laboratory environment families. The HEMS used in this study allowed household heads to monitor energy consumption in real time, on TV, PCs, smartphones and tablets. Using specific interfaces, the system provided real-time feedback and past electricity consumption, both in the house and in each of the appliances. The study reveals that with the use of HEMS, participants became increasingly literate in their understanding of household electricity consumption. Having this literacy changed energy consumption patterns.

The main conclusions of the study were:

- Compared to previous feedback, obtained through paper energy bills, the HEMS was used steadily over the time of the study and played an important role in cultivating energy literacy;
- Participants have developed above-average competence for track energy flows and use them for general energy management management;
- the best way to enforce energy literacy is by understanding the general and theoretical knowledge, and, through the experience of a rewarding experience, that is, action and perception are intertwined in the development of literacy [36] (participants were able to see that they gained from this study: knowledge and lower energy bills) .

Herrmann et al. [37] presented in 2018 a study on different data views, to see if users really perceive the information they receive from smart meters. The experiment evaluated changes in participants' knowledge of how much electricity their daily actions consume after being exposed to different forms of energy consumption data visualizations: (1) a line graph of an aggregated time series (consumption overview), (2) a line graph of an aggregated time series (it is possible to see the consumptions of different appliances) and (3) a normalized disaggregated view that does not emphasized the time. Participants played a game about energy before and after seeing the consumption simulation. Participants in condition (3) were more accurate and more confident in their post-test judgments about daily household electricity consumption than other participants. These findings suggest that the type of data visualization affects users' understanding of household electricity consumption. Visualizing disaggregated energy feedback at the appliance level should be considered for future generations of technology.

A more recent publication (2021) by the same working group [38] revealed that for an area-based visualization - showing the cumulative energy consumed by different appliances over a given period of time, a more accurate understanding of how much electricity the different household appliances were using.

In the work by Brandsma et al. [39], a study is carried out on how different types of energy feedback, combined with the establishment of certain targets, influence consumers' motivation to conserve electricity. The influence of energy feedback in physical units (kWh), monetary values (EUR) and environmental values (avoided CO_2 emissions) was tested. PParticipants were asked to set themselves a high, low or no energy conservation goal, and interviewees' values were also assessed: hedonic, selfish, altruistic, and biospheric - to test predictions derived from goal-setting theory. In general, individuals scoring high on biospheric values were more motivated to conserve electricity and their motivation did not increase in response to setting an energy conservation goal. Individuals with selfish values seem less willing to reduce their electricity consumption, unless in monetary feedback or high goal conditions. A high conservation target was only considered effective in combination with monetary feedback: it increased the motivation to save electricity by 6.7 percentage points compared to the low target condition and 6.6 percentage points compared to the control condition.

To better understand this topic of energy literacy (which is not as simple and straightforward as it appears at first glance), the book entitled "Why Good People Do Bad Environmental Things" by Elizabeth R. DeSombre [40] and [41], [42].

B. Literacy in Portugal

The following table shows the results of a study carried out in 2020 on energy literacy in Portugal (study carried out by ERSE - https://www.erse.pt/media/rr2iewsc/comunicado-estudo-de-literacia-dos-consumidores. pdf).

To better understand the global level of literacy of private and business consumers, a literacy index was created, which varies between 0 and 100, according to the consumers' knowledge of the energy sector. The literacy rate ranges from 42.8% for individuals to 49.7% for business. The sample consists of 812 telephone interviews -405 with private consumers and 407 interviews with business consumers -, stratified according to population distribution in Portugal.

TABLE I
STUDY CARRIED OUT IN 2020 ON ENERGY LITERACY IN PORTUGAL BY ERSE - HTTPS://WWW.ERSE.PT/MEDIA/RR2IEWSC/COMUNICADO-ESTUDO-DE-LITERACIA-DOS-CONSUMIDORES.PDF.

- **Mercado Livre:** a existência de um mercado regulado e de um mercado liberalizado de eletricidade é conhecida por 64,4% dos consumidores particulares e por 80,5% dos consumidores empresariais.
- **Distinção de atividades e de empresas:** a maioria dos consumidores tem dificuldades em distinguir produtores, distribuidores e comercializadores de eletricidade, não conseguindo igualmente identificar corretamente as empresas do grupo EDP, por áreas de atividade. (Recorde-se que a ERSE, em 2019 e 2020, emitiu duas instruções determinando a mudança de nome do comercializador de último recurso para SU Eletricidade e do concessionário da rede de distribuição para E-Redes.)
- **Conhecimento de simuladores:** apenas uma pequena fatia de consumidores particulares (24,4%) e empresariais (28,3%) sabe da existência de simuladores de preços de energia.
- **Compreensão das faturas:** no que toca às principais rubricas ou itens presentes na fatura da eletricidade, só 42,2% dos particulares e 54,8% sabem identificá-los.
- **Autoconsumo:** 88,9% dos consumidores particulares e 90,9% dos empresariais têm conhecimento sobre a possibilidade de produzirem a energia que consomem.
- **Fontes de energia em Portugal:** a maioria dos consumidores particulares (74,1%) e empresariais (74,4%) aponta as barragens, seguida da energia eólica (67,8%, dos particulares, e 63,9%, dos empresariais).
- **Eficiência energética:** cerca de 45% das empresas entrevistadas afirmam que implementaram medidas de eficiência energética nos últimos 3 anos. A alteração de lâmpadas para LED a medida mais adotada (69,8%).

Final Remarks: These works show that the energy literacy acquired through feedback results in good results, with an increase in energy savings in the order of 20%, and that this feedback must be weighted in order to provide the "best' possible information. Hence the need to bet on a market for smart energy meters that can interact in real time with users. These smart meters can range from appliances that display data on all electrical appliances and all consumption in a home, to even smarter appliances that can suggest improvements and an optimization of energy management, such as providing data on how much the user would have saved (or how much he would reduce his carbon footprint) in that month if he were using more efficient light bulbs, or for example a class A+ appliance instead of a class B appliance.

IV. TECHNOLOGY

A. Smart Buildings

Smart/Smart Buildings use technology to automate a building's energy systems and achieve greater energy efficiency. Building automation can be achieved in anything from electrical systems, HVAC to appliances. Today, most buildings incorporate building automation technologies to make them more sustainable, comfortable and safe. Note that we have a distinction between *smart buildings* and *intelligent buildings*. The difference lies in the term *intelligent* which requires a certain autonomy in "decision making" by the building.

The evolution of smart buildings has been highly reactive to changes in our environment and the progression of technology. This means that the focus has largely been on the solution (rather than the user). However, expectations for smart buildings are changing, and are increasingly focused on the individual.

There is, and will be, more demand for speed, accessibility and convenience, and buildings must be able to respond to new demands while adapting to changing environments. The key to success lies in understanding the expectations and needs of building users and implementing relevant technologies that enable these experiences to be carried out.

By focusing on results, smart buildings can deliver user experience gains for everyone involved, while continuing to adapt to new technologies, generate value and reduce costs.

In the long term, smart buildings will play an essential role in sustainability, in our relationship with the working environment and with each other. We will continue to have more smart buildings, while existing smart buildings will get even smarter and advances in technology will continue to boost the capabilities of our surrounding environment.

B. Smart Meters

Smart meters are an exciting new type of energy meter that can help save time, energy and money.

Smart meters send readings automatically so we don't have to send the reading and energy bills, are always accurate and up to date. It is possible to track how much energy we are using in euros in real time, which can help to save. From the moment a smart meter is installed, we are helping to reduce our carbon emissions - even without making changes at home to use less energy. This is because smart meters are the foundation for a smarter energy system. With the information provided, smart meters will help to better integrate renewable energy such as wind, solar and hydropower and reduce our dependence on fossil fuels. By decarbonizing our energy system, we will dramatically reduce our nation's carbon footprint as a whole.

However, without the support of strong empirical evidence, it is difficult for policy makers to make decisions about large-scale public investments in smart metering infrastructure. Hence the need for this work.

We can say that smart meters are part of a larger plan to make the energy system smarter, greener and richer in terms of data exchange. Smart meters are the number one or last item of many products, being very close to the population. They must capture the pace of daily life (in relation to the electricity needed) and measure the level of consumption that can vary according to price and time, indicating to users tariffs or price increases due to weather conditions. They encourage customers to "change their behavior".

We can then distinguish three types of intelligent systems.

item: has automatic monthly readings; the detection of spent energy only follows a single direction; has protection against abusive interventions; has a profile of the amount of imported energy. The beneficiaries (stakeholders) of this type of technology are: data reading companies, customer services, accounting, etc.AMR plus: daily or real-time readings; hourly intervals; notification of spent energy; reading some general data on the energy used. The beneficiaries of this type of technology are: data reading companies, information companies, maintenance companies. AMI: information circulates in both directions; service control switch; rates measured and calculated over time; the device can be programmed remotely; it is possible to measure power quality; has interface. Beneficiaries of this type of technology are: energy consumption forecasting companies, marketing companies, energy purchasing companies.

An intelligent metering system implies the implementation of a heterogeneous infrastructure, including metering devices, communication networks and data aggregation and processing systems, as well as associated management and installation functions. We can then say that an intelligent measurement system is based on four pillars [69]–[71]: a Smart Meter (SM) device; a data aggregation device, Data Concentrator (DC); a communication system used for the flow and transmission of data; a centralized management and control system, Control Center (CC).

We can distinguish three main measurement groups [69]–[71]: (i) upon demand: measured data flows from the consumption points to the CCs upon the specific request of the company; (ii) scheduled: measured data flows from consumption points to CCs by pre-programmed tasks and four to six times a day; (iii) bulk: the company collects measurement information from all devices several times a day.

The European Smart Meters Industry Group (ESMIG) has reduced the minimum resources of a smart meter to the following four: remote reading, bidirectional communication, support of advanced pricing systems and billing applications, remote control of power supply.

The European Union has extended the minimum desirable requirements for a smart meter (recommendation 2012/148/EU):

- Consumer: provides readings directly to the consumer and/or third parties. Update readings often enough to use power saving schemes.
- Measurement service operator: allow remote reading by the operator. Provides two-way communication for maintenance and control. Allows readings to be frequent enough for good network planning.
- Commercial Service Issues: Supports advanced pricing system. Allows remote ON/OFF control supply and/or flow or power limitation.
- Security and Data Protection: Provides secure data communications. Allows fraud prevention and detection.
- Distributed Generation: Provides consumed, generated, and reactive measurement data.

In addition to the recommendations of the European Union, smart meters have evolved into something more autonomous and more appealing, joining measurement data with additional information and other devices, allowing users and energy distributors to take advantage of this new technology (figure 2). Some of these new features are: measurement of electricity signal quality; real-time voltage measurement capabilities and communication between consumers and network controllers in order to control voltage; smart billing applications, with smart meters receiving tariff costs in real time, in advance or via pre-programmed tariffs, remote power supply cut or reset; consumption profiles, load control, remote switching of home devices, and remote consumption monitoring; household data of energy consumption used in conjunction with an algorithm to establish categories of energy consumers; analysis of energy savings generated after the installation of smart meters (in this way the user can see the gains obtained with the new technology); detection of electrical fraud, etc.

Fig. 2. Prototype of a smart meter. Adapted from www.eeef.lu.

With the evolution of artificial intelligence, smart meters follow a path without technological limits [79], having only the the issue of data privacy.

V. Legislation

While analogue meters have had security and privacy challenges, the problems associated with smart meters and digital electricity data are different from those of analogue meters, primarily because of the frequency, volume and granularity of data collection [96].

Smart meters offer an effective solution to the challenges created by the increasing production and availability of renewable energy, but they also create problems with regards to data protection. The implementation of inter-operable smart meters raises concerns regarding compatibility with the EU Fundamental Rights, Article 7. The EU should therefore adopt an area-specific protection concept, with detailed rules to eliminate concerns about the legality of smart meters [93].

It should be noted that this legislation must be considered at the root of the implementation in order what happened in the Netherlands. The initial implementation efforts in the Netherlands impressively show that the consequences of smart metering must be seriously considered from the beginning of the implementation process. If such problems are not resolved or even ignored by policymakers, the implementation process can be abruptly stopped and restarted. Dutch consumer groups protested, and a new fully updated implementation package document was created. As a result, consumers now have the right to reject the installation of a smart meter. On the one hand, measurement represents the valid wishes of the consumer, but on the other hand, it is more difficult for power distribution companies to achieve the goals and objectives of the latest technology, which include: greater energy efficiency, quality and stability of the network and customer details. Despite this hitch in the Netherlands, the legislation must be seen as something that will in the future allow both parts (consumers and energy distributors) to bring the best of smart meters.

A. The Three Fundamental Regulations

Three fundamental regulations must be taken into account when evaluating the legislative requirements governing the introduction of smart metering of electricity. The first is the European Convention on Human Rights; the second is the Third European Union Legislative Package in the Energy Sector; and the third is the [91], [101], [102] Data Protection Policy.

- Everyone has the right to respect for ”private and family life, their home and their correspondence”, in accordance with Article 8(1) of the European Convention on Human Rights (ECHR) [Convention for the Protection of Rights Humanities and Fundamental Freedoms]. This guarantee, however, is subject to certain limitations that must be ”legal” and ”required in a democratic society” (Article 8(2) ECHR). The European Court of Human Rights interpreted these provisions to establish a right to data security.
- As part of the ”third legislative package”, the European Union adopted two directives in 2009: one establishing common rules for the internal electricity market (the ”Electricity Directive”) [98] and the other that addresses the domestic natural gas market (the ”Natural Gas Directive”) [99]. The Electricity Directive provided for the implementation of digital meters in 80% of energy consumers by the year 2020 (as already mentioned in this dissertation). In Annex 1, paragraph 1 of this directive, it is established that customers must have access to their usage data within a reasonable period of time. Furthermore, consumers should be free to give or not consent to access their energy metering data to any registered energy supply company. This agreement must be very explicit and must be free. If consumers choose an intelligent system, they must be informed of their actual electricity consumption and costs. This data must be secured frequently enough to empower consumers with means of controlling electricity consumption and using energy more efficiently.
- In accordance with Article 2(a) of the EU Data Protection Directive (‘Data Protection Directive’), [100] ‘Personal data means any information relating to an identifiable natural person (“data subject”); an identifiable person is one who can be identified, directly or indirectly, in particular by reference to an identification, number or one or more factors specific to his physical, psychological, mental, economic, cultural or social identity.’ As the definition of the personal data directive can be interpreted broadly, and given that some national data protection laws of member states refer in the definition of personal data to those who belong to a ”community of persons”, the data of energy measurement can be considered personal data. Therefore, the provisions of the Data Protection

Directive apply even if more than one person lives in a house equipped with a smart meter.

In accordance with Article 6 of the Data Protection Directive, personal data must be processed fairly and lawfully, aggregated for specific and legitimate purposes and may not be processed in a way incompatible with those purposes. In addition, data processing must be adequate, relevant and not excessive in relation to the purposes for which the data is obtained. Regarding smart meters, processing can be based on several purposes: improving energy efficiency, measurement accuracy, customer information, network stability, smart billing. Thus, the obtained data can be legitimately processed for different purposes, therefore, it is subject to different processing and transmission restrictions [93]–[96].

The processing of personal data, however, does not you just have to comply with the principles mentioned. above, but must also be justified under Article 7 of the the Data Protection Policy. According to this provision, the processing of personal data can only be legitimate if one of the following conditions is fulfilled.

- data processing is necessary for the fulfillment of a obligation to which the controller is subject;
- processing is required for the performance of a contract of which the data subject is a party or the processing of the data is necessary to verify the execution of the contract;
- the data subject has provided his consent;
- processing is necessary for legitimate interests of the power distributor or by third parties or parties to whom the data is disclosed, except where such interests are superseded by the fundamental rights and freedoms of the data that require protection under Article 1 (1) of the Data Protection Directive (see citeEP2019 for more details).

Power distribution companies qualify as controllers since (like the owners of smart meters) they determine the purposes and means of data processing. The power distribution company decides what types of personal data should be collected and transferred to other parties. Such parties may include energy suppliers, government agencies, and other third parties with an interest in the measured data. The legality of processing and transmitting the measurement data must be determined for each party that will process the data [91].

The existence of a legal obligation or legal authorization to apply data by status is generally the most favorable legal basis. The Electricity Directive itself does not qualify for this feat, as it requires implementation by the national laws of the Member States. Therefore, it is currently up to Member States to provide an explicit legal basis, which can be included in the statutes that regulate the national electricity and gas markets.

In order to comply with the legal requirements applicable under Article 8 of the European Convention on Human Rights, as set out in the jurisprudence of the European Court of Human Rights, any legislation that provides a legal basis for smart metering processing would have to meet the following conditions: provide an adequate indication as to the extent and conditions of data processing; provide a determination of the possible group of data subjects and contain rules for a procedure to be followed; prohibit certain types of comments from controlling personnel with regard to data of the data subjects processed; have a regulation on the legitimacy of storing information and establish a regulation on the deletion of data.

Due to these strict and detailed requirements that the statutes must meet, there are a number of difficult issues to be resolved if any legislation is to avoid being considered incompatible with Article 8.

Contractual obligations that require data processing must be preceded by clarification that data subjects enter into two or three separate contractual relationships with the various actors in the energy supply market [91], [93]–[96].

For a balance between the use of smart meters and privacy, and an answer to the question of how much data is really needed to satisfy both parties (energy consumers and distributors) the work of McKenna et al. [94] is recommended.

Right now, one of the most significant privacy regulations is the Data Protection Regulation (GDPR) 2016, which outlined several fundamental digital privacy rights [103]. This document follows along the lines of the Fair Information Practice Principles (FIPPs) that emerged when computers began to increase their information-processing capabilities and the public became concerned about the risks to privacy. In Europe, member states and relevant companies have started to comply. with the GDPR on May 25, 2018. The cost of non-compliance is a fine of up to 20 million euros or 4% of the company's global annual turnover. Some member states already had privacy laws prior to this implementation, but these laws have been updated or replaced with the implementation. of the GDPR. In some cases, such as the Netherlands, countries had protections in addition to GDPR.

Final Remarks: The overall success of the implementation of smart meters across the EU depends on criteria widely decided by Member States. This includes regulatory provisions and the extent to which the systems to be deployed will be technically and commercially interoperable, as well as ensuring data privacy and security. Nor is there yet an EU-wide consensus on the minimum range of operations required by smart meters.

The implementation of a smart meter that manages energy at the same time requires the use of a lot of consumer data. Before proceeding with this type of implementation, for example, a survey of consumers about their interest in this type of technology should be carried out, rules for the use of the data collected should be established (for example, establish an independent data management institution), maintain the impartiality of the energy distribution company, which may also be interested in this type of data, as it also sells energy equipment. That is, not only the law that will determine whether or not to impose this type of equipment, but the fact that consumers feel safe and, above all, the demonstration that this type of equipment will bring reductions in the electricity bill . Energy literacy can be a very good thing, but if it is not accompanied by concrete savings benefits, it is just added knowledge without application.

VI. Funding

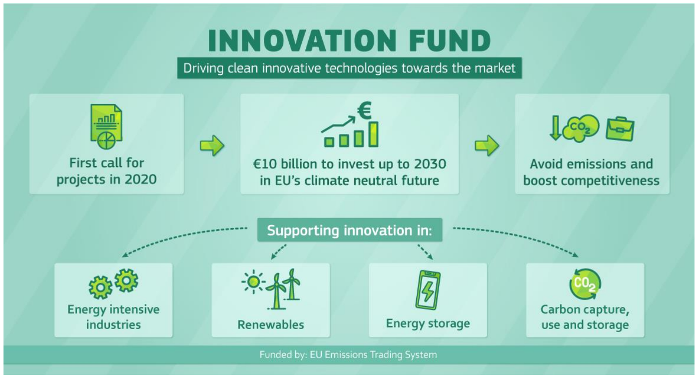

Fig. 3. European funds to be invested by 2030. Picture adapted from the European Commission website.

The EU has demonstrated its determination in the fight against climate change, using 20% of its global budget between 2014 and 2020 to fund actions that contribute to climate change mitigation and adaptation. And it intends to be even more ambitious after the agreement between EU leaders in July 2020 to increase this number to at least 30% of the EU budget for 2021-2027 and the financing of the recovery plan.

Support global efforts:

The EU and its Member States are the largest providers of public finance for the world's climate. Its total contributions, amounting to €21.9 billion in 2019, were successfully channeled into climate change mitigation and adaptation initiatives in developing countries [114], [115]. Some of these efforts are now described:

- Advised by the European Investment Bank Group, GEEREF (https://geeref.com/) is an innovative fund of funds that catalyzes private sector capital into clean energy projects in developing countries and transition economies. GEEREF is a fund of funds advised by the European Investment Bank Group; invests in private equity funds that focus on renewable energy and energy efficiency projects in emerging markets; GEEREF funds target attractive financial investments that also generate a strong positive development and environmental impact. GEEREF invested in 15 funds in Africa, Asia, Latin America and the Caribbean. The GEEREF investment period ended at the end of May 2019 and is already fully invested.
  GEEREF was structured to catalyze private sector investments in underlying funds and projects, leveraging upfront contributions from the public sector: GEEREF was initiated by the European Commission in 2006 and launched in 2008 with funding from the European Union, Germany and Norway, totaling € 112 millions. GEEREF successfully completed its fundraising from private sector investors in May 2015, bringing the total funds under management to €222 million. GEEREF invests in private equity funds which, in turn, invest in private sector projects, further increasing the leverage effect of GEEREF's investments. It is estimated that with €222 million of funds under management, more than €10 billion could be mobilized through the funds in which GEEREF participates and the final projects in which these funds invest.
- The Innovation Fund (https://www.buildup.eu/en/node/60275) is one of the world's largest funding programs for the demonstration of innovative low-carbon technologies. The Innovation Fund is a key financing instrument to fulfill the EU's economy-wide commitments under the Paris Agreement and its goal of being climate neutral by 2050, as recognized in the European Green Agreement Investment Plan. It will provide around €10 billion of support over 2020-2030 for the commercial demonstration of innovative low-carbon technologies, with the aim of bringing industrial solutions to market to decarbonise Europe and support its transition to neutrality climate. The aim is to help companies invest in clean energy and industry to drive economic growth, create future-proof local jobs and strengthen European technological leadership on a global scale.
  As a successor to the NER300 program, the Innovation Fund improves risk sharing for projects, providing more funding in a more flexible way through a simpler selection process, and is also open to projects from energy-intensive industries. Alongside the Innovation Fund, the EU ETS provides the main long-term incentive for the deployment of these technologies (source: European Commission).
  Projects can receive support of up to 60% of the capital and operating costs of the innovation, with the possibility of up to 40% of the funding being provided in the project preparation phase. The Fund will invest in highly innovative technologies, as well as large-scale flagship projects and cross-cutting projects that can lead to lower emissions across multiple sectors, including industrial symbiosis and business model innovation. Unlike NER300, small-scale projects (capital costs less than €7.5 million) will also be eligible.
- The European Energy Efficiency Fund (eeef) aims to support the European Union's climate goals (EU 2030 framework for climate and energy) to promote a sustainable energy environment and promote climate protection through projects in cities, regions and European communities to build resilient infrastructure. The Fund's objectives are: Contribute to climate change mitigation and transition to a resilient, energy-efficient and green infrastructures.
  Direct investments include project development companies, energy services companies, small scale renewable

energy and energy efficiency services and supply companies serving the energy efficiency and renewable energy markets in the target countries.

  - Investments in energy efficiency and renewable energy projects in the range of €5m to €25m. Investment instruments include senior debt, mezzanine instruments, lease structures and loan loss (in cooperation with industry partners);
  - Possible actions (co-) capital investments in renewable energy over the life of projects or equity participation in special purpose entities, either in direct cooperation with municipalities or with public and private entities acting on behalf of these authorities;
  - Debt investments can have a maturity of up to 15 years, equity investments can be tailored to the needs of the various phases of the project;
  - The fund may (co-) invest as part of a syndicate and participate through risk sharing with a local bank.

- With the ACE program completed in 1991, a separate fund for nature, EU Actions for Nature (Council Regulation 3907/91, known as ACNAT), was adopted. This was designed to help support the implementation of the newly adopted Habitats Directive in May 1992, at a time when the EU was expanding its competence in the field of habitat conservation. ACNAT's intention was that actions for bird species and sites would continue to receive support in the context of the Birds Directive and, in addition, funds would be made available for the conservation of other threatened species and habitats.
  At the event, however, ACNAT was quickly replaced by the adoption of a new comprehensive environmental fund that targeted five main priority fields. With this fund, and its first-phase budget of ECU 400 million, LIFE I was born (Council Regulation 1973/92).
  The LIFE program (https://cinea.ec.europa.eu/life/about-life_en) is the EU's funding instrument for environment and climate action. Created in 1992, it has co-financed thousands of projects.
  The European Commission proposes to increase the LIFE program budget to €5.4 billion between 2021 and 2027. The details of the next LIFE regulation, the multi-annual work program and the related calls for proposals are still under discussion. The new LIFE program will cover the following areas: Nature and biodiversity, Circular economy and quality of life, Mitigation and adaptation to climate change, Clean energy transition.
- The Connecting Europe Facility (CEF) (https://ec.europa.eu/energy/funding-and-contracts/eu-funding-possibilities-in-the-energy-sector_en) is the funding instrument for EU to boost energy, transport and digital infrastructure.
  In 2018, the CEF was renewed for 2021-2027 with a budget of €42.3 billion to support investments in energy (€8.7 billion), transport (€30.6 billion) and digital (€3 billion). This represents an increase of 47% compared to 2014-2020, see the CEF fact sheet "EU budget for the future" for more information.
  Every two years, the European Commission draws up a list of projects of common EU interest (PIC) that can apply for funding from the CEF.
- Calls for projects are being updated on the website: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/home

VII. Conclcusions

In an age of artificial intelligence, the implementation of a smart meter that benefits from this type of technology is only related to the question "When?", and this implementation will become a reality sooner or later. The setbacks and advances of this implementation depend on the legislation adopted and the way in which consumer literacy, in terms of energy, is carried out. A thorough clarification must also be made to consumers, in terms of the data collected by the energy distribution companies, so that the consumer feel secure when providing their data. This security involves the use of a data transformation, when these are transmitted to the service provider. This transformation can be, for example, the elimination of the specific location where the data was collected, passing the data providers to "see" the data in terms of regions (for example, a group of buildings) thus not being able to carry out a house-to-house control . In other words, when transmitting data in both directions, there must be an encoder that protects consumers.

When it comes to saving energy and reducing the carbon footprint, consumers have to be "trained" and informed to become active consumers in relation to smart meters. The mere implementation of smart meters, unless accompanied by Appropriate educational measures will not make any difference in cost or efficient use of energy.

Acknowledgments

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