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Internet of Energy: state of the art and scenarios at European level

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Introduction

The energy industry worldwide is currently facing significant challenges. Firstly, growing global demand for energy led to scarcity of fossil fuels and therefore to sharp energy price increases. At the same time, the capacity of the atmosphere to absorb CO_2 is also exhausted. This creates considerable efforts for active climate protection and an efficient use of energy.

Secondly, an enhanced use of renewable energies is resulting into efforts towards their integration into the electricity grid, both on the basis of an increasingly decentralized and a still existing central supply structure. This requires a much higher degree of flexibility in terms of voltage holding and efficient load flow control than is provided in the current system.

Thirdly, changing regulatory environment imposed new requirements on the data interconnection between energy systems. Due to decentralization of power generation, transmission and distribution, different actors along the value chain communicate and interact with each other through shared interfaces. New regulations on standardization, metering, and consumption transparency also generate large volumes of data that need to be processed.

Finally, latest technological developments cannot be ignored anymore. Innovative demand response solutions, smart meters, energy-saving technologies capture the energy markets and are being increasingly used by both energy suppliers and consumers. All these factors require conversion to an intelligent and efficient supply system, which is networked through information and communication technologies – the so-called Internet of Energy (short IoE).

IoE is a cross-sector topic connected to the Internet of Things (IoT), communication systems, but also to the smart grid and low carbon technologies. It is relevant for the Industry 4.0 strategies as well as for the Energy Strategy 2050. So, the AIOTI, the European Alliance of IoT Innovation promoted by the European Commission, has a specific Working Group on Smart Energy and several other on IoE connected topics to boost the diffusion of this innovative technology in enterprises. However, although the IoT technologies are quickly growing, the IoE development is slower than expected. Lacking awareness of IoE technologies and a missing picture of what is the state of the art of IoE worldwide are among the reasons hampering the diffusion of the IoE in related sectors.

With this report, an overview of the existing and upcoming IoE technologies, use cases, applications, and related business models in Europe should be provided. A specific focus will lay on presenting IoE state of the art in countries Italy, Spain, Germany, Greece, Portugal, and Lithuania. The report has been created within the framework of the Erasmus+ project 'Internet of Energy – Education and Qualification', which seeks to support professionals from IT and energy sectors in using and managing IoE technologies and applications. Nine project partners from Italy, Spain, Germany, Greece, Portugal, and Lithuania will jointly create training courses in IoE and offer them as open educational resources. The findings of this report will be, on the one hand, adamant for designing these training programs, and, on the other hand, be an aid for professionals interested to learn more about the IoE world.

1. Internet of Energy across the globe

One might have heard the term Internet of Energy, but what exactly does it mean and what problems does it solve? Let's take a look at what the experts and researchers think about the IoE!

1.1 What is the Internet of Energy?

For the first time, the term 'Internet of Energy', or 'Energy Internet', was introduced by the American macro-economic forecaster Jeremy Rifkin in his book 'Third Industrial Revolution' in 2011 (1). He anticipated that millions of people would produce their own renewable energy in their households and factories and share green electricity in an 'Energy Internet' like the information was generated and shared via the web. Thus, IoE referred to an internet-style solution for electricity based on bidirectional information and power flow (2) and could be considered the extension of a Smart Grid.

It is noteworthy to highlight the difference between IoE and Smart Grid – terms that might be used synonymously. Whilst Smart Grid focuses only on the intelligent electricity distribution infrastructure relying heavily on reliable high-speed communication networks for monitoring and control, IoE encompasses the whole range of energy demands including electricity, heating, gas and mobility (3).

Leading researchers of the Europe's ARTEMIS[1] project dedicated to electric mobility also noticed the bidirectional nature of the IoE and defined it as "a network infrastructure based on standard and interoperable communication transceivers, gateways and protocols that allow a real-time balance between the local and the global generation and storage capability with the energy demand, also allowing high level of consumer awareness and involvement" (4). Furthermore, Vermesan et al. highlighted the capability of the new Internet-based infrastructure to fully deploy distributed energy sources for achieving a reliable, flexible, resilient, efficient and cost-effective power supply network.

Zhou et al. viewed the IoE from the business perspective and emphasized the core feature of IoE as "[...] the openness, interaction, equality, sharing and personalization in the whole process of energy production and consumption". In this context, energy "[...] is becoming a technological tool, a support platform and even a generalized resource, which can transform the life style of individuals and the business operation process of enterprises. Therefore, the innovation of energy system is fundamentally the innovation of management concepts and service models" (5).

Leading technology market research and staffing solution companies such as Beecham Research Limited BRL (6), NES Global Talent (7) define the IoE through the disruptive information and communication technologies (first of all, Internet of Things IoT, followed by the cloud and the Internet) that affects the entire energy supply chain towards shifting traditional energy paradigms, from the centralized energy generation and storage and one-directional power flow to the distributed energy systems, from the energy consumers to the energy prosumers that are enabled to generate and manage power on their own. IoE is understood therefore as the intelligent ICT-based interconnection of all components of the energy system, such as energy generation plants, transmission and distribution systems operators, consumer devices, and users with the purpose to ensure sustainable energy production and intelligent consumption.

[1] http://www.artemis-ioe.eu/

The impact of IoT on the energy sector is huge, many areas – from the power generation to the consumption in the households and in commercial buildings – are affected. Figure 1 graphically illustrates the emerging IoE world and produced impact as follows (6):

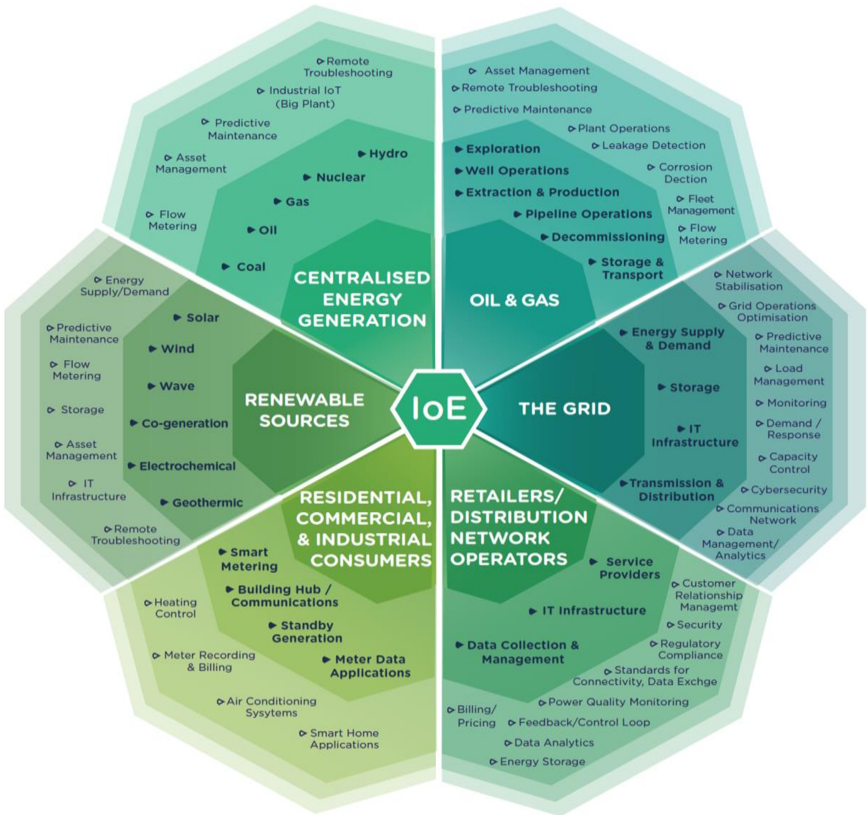

Fig. 1: Internet of Energy world (6)

This is to provide a brief overview of the new phenomenon called IoE. To deeper immerse into the IoE world, it is worth having a closer look at the IoE architecture.

1.2 Architecture of the Internet of Energy

According to Kafle et al., IoE architecture refers to the communication structure and represents both the energy and information exchange between various sources and loads, such as renewable energies, distributed energy storage, plug-in vehicles, residential and industrial consumers, etc. (8). These communication processes are managed and monitored via the Internet. The general principle is that energy and information flows are directed from the sources to the loads like the information flow in the Internet. Internet of Things (IoT) is considered the potential infrastructure to support the two-way communication.

Figure 2 shows these interconnections as follows:

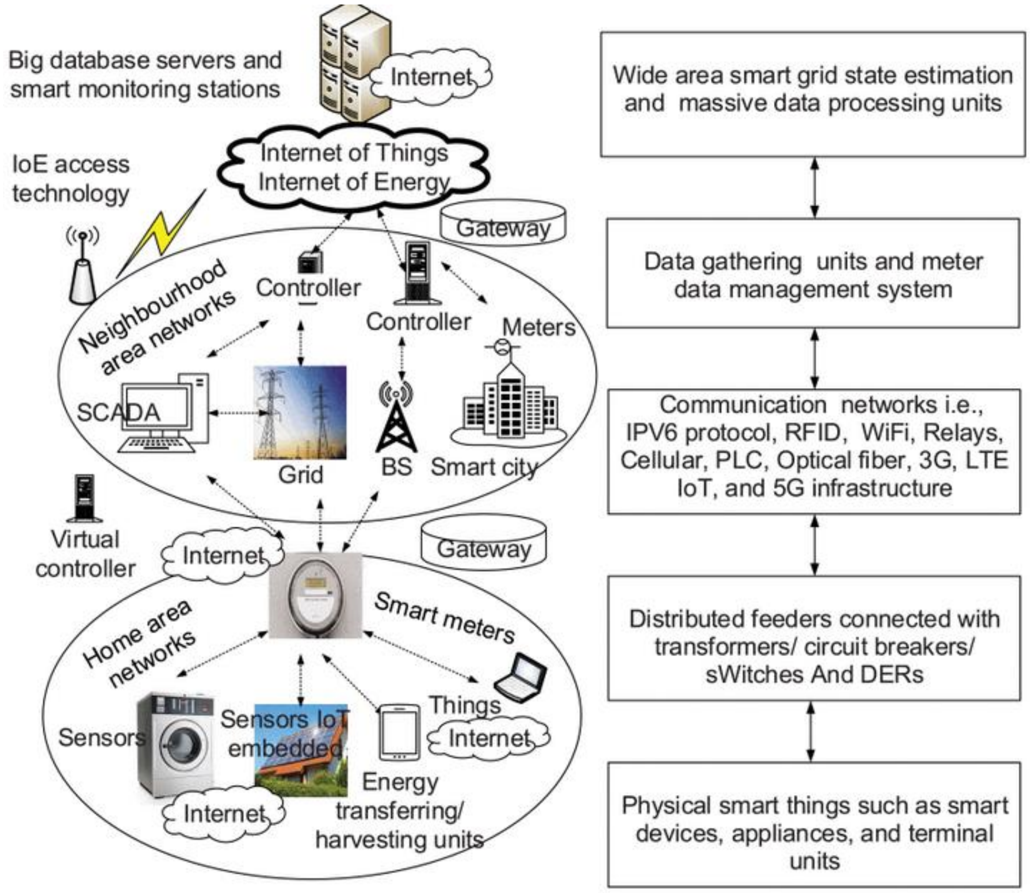

Fig. 2: Overall architecture of the IoE communication network (9)

As can be seen from the figure 2, the control center can receive the data from the various points and transmit them through the IoT networks. The IoT network also assures the connectivity of the physical smart things. Therefore, the IoE communication infrastructure supports the big data transmission and processing by providing two-way communication between them. Such a communication network is the key to monitor and control the physical objects at anytime and anyplace.

Another vision of the IoE architecture based on the state-of-art technologies and use cases has been proposed by Zhou et al. (10). They refer to the Smart Grid Architecture Model (SGAM) of the European Commission (11), the Local Area Grid concept (3), the FREEDOM system (12), and the Framework for Smart Grid Interoperability (13). As Figure 3 shows, the IoE architecture is composed of six layers:

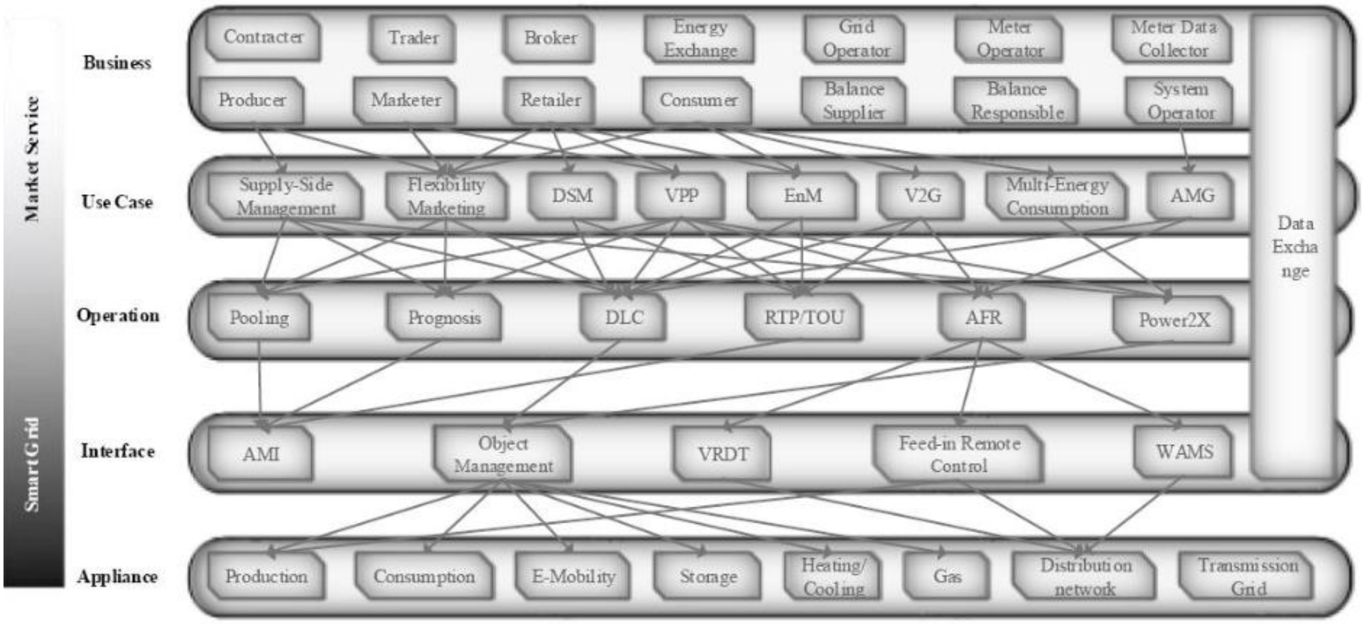

Fig. 3: Architecture of the Internet of Energy (10)

The six layers from the Figure 3 are represented – from top to bottom – through Business Layer, Use Case Layer, Operation Layer, Communication Layer, Interface Layer and Appliance Layer. Communication layer (Data Exchange) represents the communication channel from the Business Layer through to the Interface Layer. The Appliance Layer needs an interface to communicate with other layers so that it is not connected to the Data Exchange.

A part of Operation Layer, the Interface Layer and the Appliance Layer frame the Smart Grid whilst Business Layer, Use Case Layer and another part of Operation Layer compose market (energy) services. Following Zhou et al., the IoE can be understood as a combination of Smart Grid and energy services.

Each layer encompasses different components and allocated roles as follows:

A. Business Layer

Business layer results from the liberalization of energy market and handling energy as a service and/or product. Various roles and agents emerge, which can be categorized into:

- energy trading: refers to the energy production, exchange, purchase (Retailer), consumption as well as grid maintenance (Grid Operator);
- real-time balance between supply and demand: stable power system operation, supply of reserve energy (Balance Supplier), management of the balancing groups (Balance Responsible);
- distributed energy trading: execution of energy transactions (Trader), exchange of trading information between buyers and sellers (Broker), energy sale on behalf of small energy producers (Marketer), provision of financing and/or operation and maintenance of energy facilities (Contractor);
- data acquisition and information transfer for Smart Meter devices: installation and maintenance of physical meters (Meter Operator), meter reading (Meter Data Collector).

It should be stressed that the energy market segmentation continues, so that new roles appear such as Billing Agent, Tariff Management, Contract Switching Service. Moreover, a market agent can simultaneously play different roles (i.e. Grid Operator can additionally act as Meter Operator).

B. Use Case Layer

Use Case Layer represents various transaction and interaction modalities between market roles in the Business Layer. They can also be seen as business models:

- **Supply-side management (SSM)**: refers to the bunch of actions taken to ensure the generation, transmission and distribution of energy efficiently;
- **Flexibility marketing**: opportunity for Balance Responsible, Retailers, or Producers to turn unused electricity generation capacities into extra revenues;
- **Demand-side management (DSM):** means the planning and implementation of activities designed to influence customer uses of electricity in ways that will produce desired changes in the utility's load shape (14). The use case DSM can be realized in the Operation Layer through Real-Time Pricing (RTP)/Time of Use (TOU) and Direct Load Control (DLC);
- **Virtual power plant (VPP):** A VPP is a network of decentralized, medium-scale power generating units such as Combined Heat and Power (CHP) units, wind farms and solar parks as well as flexible power consumers and batteries. The VPP aims at relieving the load on the grid by smoothly integrating a high number of renewable energy units into existing energy systems. The interconnected units of the VPP are dispatched through the central control room but they remain independent in their operation and ownership. By networking all participating units through a remote control unit, it establishes a data transfer between the central control system and the participating units. The central control system is then able to monitor, forecast, and dispatch the networked units (15).
- **Vehicle to grid (V2G):** A concept that enables plug-in electric vehicles to operate as distributed energy storage by providing demand-response services to the power grid. The batteries in parked vehicles can be used to let electricity flow from the car to the distribution network and back. The V2G philosophy is similar to that of stationary energy storage, but the cars themselves play the role of energy storage units. They are able to contribute to the stability of the grid, for example by providing the electricity necessary to compensate for a disturbance. At the same time, they contribute to increasing the share of renewable energies in overall electricity consumption. V2G can be realized in three ways in the Operation Layer: Direct Load Control, RTP/TOU or Automatic Local Frequency Regulation.
- **Energy management (EnM)**: EnM is already implemented worldwide. According to ISO 50001, EnM is defined as “Set of interrelated or interacting elements of an organization to establish energy policy and objectives and to achieve those objectives” (16). This term covers both the technical resources and the organizational and information structures required for implementing Energy Management systems. EnM helps to save energy through monitoring, controlling and conserving energy in a building, organization or process and should therefore be treated in the context of the IoE. EnM may employ Direct Load Control and Power-to-X in the Operation Layer.
- **Multi-energy consumption**: within the multi-energy systems (MES) electricity, heat, cooling, fuels, transport and so on optimally interact with each other to increase technical, economic and environmental performance (17). Such systems can be a key for the decarbonization of the energy sector, thus coping with MES is of high relevance within the IoE concept.
- **Autonomous microgrid (AMG)**: AMG is a system that is autonomously operated depending on the grid and internal load condition, without operator’s intervention (18). AMG can be realized in various degrees, from real-time monitoring, fault diagnose and self-healing, to automatic

frequency and voltage regulation, transformer control to integration of DSM and communication between AMGs.

C. Operation Layer

Functions under the Operation Layer are needed to fulfill Use Cases as described above. The most relevant operations here can be listed as follows:

- **Pooling**: As energy generation becomes more fragmented due to distributed energy and the emerging use cases of DSM, VPP and Flexibility Marketing, Pooling is to aggregate dispersed energy, capacity, availability, flexibility or the demands of them to achieve economies of scale.
- **Prognosis**: Energy supply and demand prognoses caused by the intermittent renewable energy supply are crucial for System Operator to plan grid operation mode. Suppliers, Retailers, Aggregators and Traders also need prognosis to deduct energy prices. System Operator and Grid Operator rely on prognosis of network condition to schedule maintenance.
- **Direct load control (DLC):** DLC technology allows utilities to switch specific household appliances such as air conditioners, water heaters, swimming pool pumps on and off during peak periods. DLC programs in household have been vastly applied in the US while in Europe the development of DLC is moderate due to regulatory barriers (19).
- **Real-time pricing (RTP)/time of use (TOU):** RTP and TOU represent pricing strategies where energy price changes over time to reflect the supply and demand balance. The difference is only that RTP gives consumers information about the actual energy cost at any given time while TOU only varies between a few fixed price levels during a few fixed time periods. In this manner, consumers are motivated to shift load from peak time to valley time.
- **Automatic frequency regulation (AFR)**: AFR's task is to automatically provide capacity within 0 to 30 seconds to stabilize the frequency of the power grid. Nowadays, due to the rising renewable power sources but decreasing spinning reserve provided by the generators, technologies such as battery storage, V2G, Direct Load Control (20), or aluminum and Chlor-Alkali production (21) are applied to provide AFR.
- **Power-to-X:** Power-to-X stands for various energy forms, which emerge through transforming the electricity that cannot be consumed at the time of its generation, such as Power-to-Gas, Power-to-Fuel, Power-to-Chemical, Power-to-Power, Power-to-Mobility, Power-to-Heat. An interesting environmental comparison of different Power-to-X was made in 2014, showing that the highest reduction of global warming is achieved by Power-to-Heat via heat pump with hot water storage, and Power-to-Mobility, followed by Power-to-Power. The lowest CO_2 mitigation cost is realized by Power-to-Power (22).

D. Interface Layer

Functions in the Operation Layer are translated to commands and signals, which go to the Appliance Layer through the Interface Layer. In turn, the data from the appliances are collected by the Interface Layer and sent to the Function Layer. The relevant technologies of the Interface Layer are as follows:

- **Advanced metering infrastructure (AMI):** AMI means systems that measure, collect, control and analyze energy usage at the demand site and send the consumption data to utilities, network operators and customers themselves. An AMI system, as illustrated in Fig. 4, is composed of the following modules:

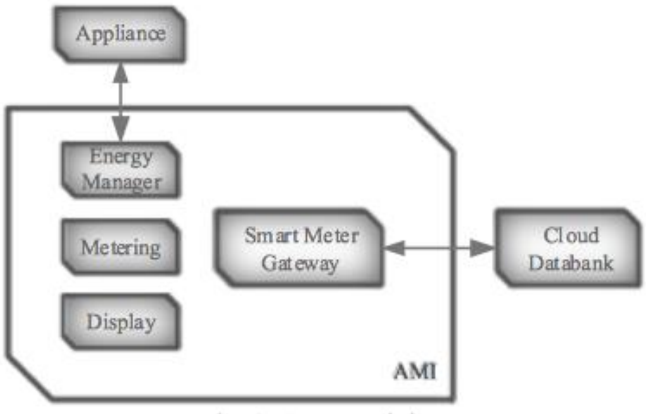

Fig. 4: AMI modules (10)

- Metering: registers energy consumption and production in a real-time and sends the data,
- Display: receives and processes the data, displays the analysis of energy consumption,
- Energy manager: receives RTP/TOU or is preprogrammed to conditionally generate control signals to appliances and monitor the status of appliances,
- Smart meter gateway: exchanges data and signals with externals and connects the components inside of AMI,
- Cloud databank: saves the historical data accessible to externals and customers.

Depending on data security settings and connection infrastructure, AMI structure can be easier or more complex. Various agents may benefit from the AMI, such as:

- Customers: due to the visualization of energy consumption, they may achieve energy and costs savings
- Utilities: savings of workforce costs for data registration, offering new value-added services (i.e. differentiated billing), improving the demand prognosis;
- System Operators: better knowing the network conditions.

AMI has been massively rolled out in Europe, the US and other countries. Among the limitations for the further spread of AMI, technical issues, data security and standardization, and investments can be named (23).

- **Wide area measurement system (WAMS)/ phase measurement unit (PMU):** WAMS is an advanced grid dynamic performance monitoring system incorporating multiple Phase Measurement Units (PMU) and Phasor Data Concentrators (PDC), together with information tools, Global Positioning System (GPS) and operation infrastructure. The purpose of deploying WAMS is data collection, sharing coordinated control actions at a high granularity and over a wide area, which makes the grid more efficient and reliable (24). The concept of WAMS was proposed in 1980s, and the first demonstration project was launched in 1995 in the US. However, WAMS finds its commercial use only over the last decade due to the trend of Smart Grid (25).
- **Feed-in remote control**: Through Feed-in Remote Control the renewable power plants can be controlled to reduce power generation or be totally switched off to prevent negative power prices. Feed-in Remote Control also makes possible a better integration of renewable powers into VPPs (26).

- **Voltage-regulated distribution transformers (VRDT):** VRDT automatically adjusts the transformation ratio so that the voltages of middle and low voltage grids are decoupled. This results into a full exploitation of existing transmission capacity and into the costs reduction of traditional grid reinforcement (27). VRDT applications are found mostly in Germany, where the rapid growth of distributed solar power already forced Grid Operators to either expand power lines or deploy VRDTs.
- **Object management:** an object-oriented program that checks the availability of the object and translates the command from Operation Layer into a set of signals of the control unit of a specific appliance.

E. Appliance Layer

The Appliance Layer embraces all the physical facilities (such as solar panels, wind turbines, coal power plant, hydro power plants, transmission grid, batteries, heat pumps) along the energy chain including energy production, conversion, transmission, distribution, storage and consumption. Energy flows in the Appliance Layer correspond to the trading flows in the Business Layer. Appliances are controlled through the Interface Layer by market roles in Business Layer in form of use cases and operations.

We believe, the proposed structure demonstrates a well-balanced overview of the most popular technologies, user cases, and market roles that form and coin the Internet of Energy. However, the IoE encompasses a wider range of technologies and applications, which can be explored by the interested audience of professionals by themselves!

1.3 Chances of the Internet of Energy

The consequences that the IoE brings along are manifold:

Firstly, the increased interconnection between all energy network agents allows the real-time data exchange and better synchronization and optimization of their processes. In this manner, the existent passive energy network is moving towards the market- and service-oriented decentral system. Moreover, a new information and communication infrastructure is emerging, which will eventually unify decentralized power sources into an intelligent multi-sourced distribution network (6).

Secondly, the IoE encourages the development of new and innovative energy services, such as optimization of energy consumption through Smart Meters, smart home monitoring through IoT-based consumer appliances, or support of electric vehicles through grid-to-vehicle-technology (G2V). This, in turn, leads to the increased opportunities for households, public bodies and small and medium-sized enterprises to balance their energy demand and therefore to reduce their energy costs by using energy at off-peak times. Thanks to Demand Side Response that enables SMEs and consumers to shift their energy demand in real-time, a secure and affordable power system can be ensured. In addition, the increasing integration of renewables into the grid will guarantee even more balance between energy supply and demand and bring additional benefits for households.

On the other hand, IoE facilitates the rise of so-called prosumers that stand for the active role of consumers who both produce and consume energy services. Consumers already became potential prosumers through installing a small-scale energy generation unit such as a solar panel on their rooftops. Moreover, produced power can be either used for own purposes or sold to the grid. In this manner, the energy supplier becomes an energy buyer. The prosumer may also store energy in a battery system or an electric vehicle, and is enabled to control power exports and imports by how he uses smart appliances in their households. From the technical point of view, this bidirectional communication and electricity transfer between the prosumer and supplier is facilitated by smart meters that – on the prosumer's site – visualize the prosumer's energy consumption and corresponding prices at different time intervals and therefore show potential areas for savings with a lower energy usage. This will allow the utilities to offer their clients tiered and dynamic pricing (TOU tariff) and ensure the accuracy of billing as it is the standard practice in the telecommunication branch.

The IoE may positively impact the industrial maintenance sector due to chances to remotely forecast and detect technical anomalies within the network. The so-called Predictive Maintenance, which is based on the IoT technology, relies on predicting equipment failures and preventing the occurrence of the technical malfunctions. In this manner, the frequency of the maintenance work as well as associated costs can be kept as low as possible.

1.4 IoE national policies

The IoE may also bring significant benefits at national levels helping countries manage energy demand and avoid blackouts in the future. Many countries have recognized potentials of this disruptive technology and started thinking over the corresponding rollout strategies. To name a few:

The United Kingdom: according to the estimations of Nicola Shaw, executive director of the National Grid in the UK, between 30%-50% of fluctuations in the grid in the UK could be solved by both households and enterprises adjusting their demand at peak time. The challenge for National Grid is, however, to attract more companies to adopt the demand side response technology (DSR) because many of them have not even heard of it (28).

China: In 2015, China established the Global Energy Internet and Interconnection (GEI) project as an extension of the Chinese Smart Grid to integrate renewable energy using information communicated through the Internet (29).

The United States: the Future Renewable Electric Energy Delivery and Management (FREEDM) Center funded by the National Science Foundation has created a new electricity delivery infrastructure with "plug-and-play" capability and an open-standard communication operating system features (30).

Japan: the Japanese Digital Grid Consortium (DGC), established in 2011, has proposed the concept of the Digital Grid based on an asynchronous, addressable digital grid router enabled to send discrete energy packets over existing transmission lines to any location using an IP address. In the DGC model the large synchronous grid is divided into smaller stand-alone cell grids connecting digital grid routers asynchronously (31).

European Union: According to Covrig et. al. (32), 459 projects on Smart Grid and Energy Internet (including Research and Development as well as Demonstration and Deployment projects), have been launched across EU and non-EU countries from 2002 to 2014. The related investments amounted to 3.15 billion €, 50% of which originated from France, United Kingdom, Germany and Spain. Denmark had the highest investment in this type of projects per capita. France and United Kingdom had the largest average budget per project. Germany had the highest cumulated number of projects and number of organizations involved. These projects were oriented towards a user-centric and output-focused energy production, transmission and consumption what corresponded to the wider concept of energy internet. The “E-Energy” project founded by the German government between 2008 and 2013 and announced by the Federal Chancellor Angela Merkel as beacon projects, directly aimed at creating Internet of Energy in six model regions through development of highly efficient and environmentally-sound ICT-based energy systems[2].

Following a European Commission directive issued by Brussels in 2006, each member state is committed to participate in the rollout of smart meters and to turn 80% of its legacy meter stock to smart by 2020. Each country may choose its own infrastructure model as well as act in line with the national legislation.

However, the implementation of the directive varies from country to country. A few countries are quite optimistic concerning the adoption of smart meter. So, on 1st of December 2018, France began its nationwide smart meter rollout. The goal is to achieve the benchmark of 95% digital meter deployment by 2020. French grid manager Electricité Réseau Distribution France (ERDF) will oversee the deployment of 28 million (80% from the overall 35 million meters in France) of the uniquely French smart meter - the Linky – and third-party access to metering data. The expected savings for households are determined between 5-10% (33).

A number of nations so far decided against a nation-wide deployment of smart meters. A lower uptake of smart meter is demonstrated also across the newer member states (34). Among the reasons that hamper the nationwide penetration of smart meters, a low awareness of population of this technology and heavy cybersecurity concerns of companies can be indicated.

1.5 The state of the art of IoE technologies across the globe

It should be noticed that at the time beacon IoE technologies are being developed and piloted in various research and development as well as deployment projects. Below a few outstanding technologies and corresponding projects are listed.

Vehicle-to-Grid (V2G): Japanese carmaker Nissan and multinational power company Enel launched in May 2016 a groundbreaking V2G project in the UK (35). The trial will work by installing and connecting one hundred V2G units at locations agreed by private and fleet owners of the Nissan LEAF and e-NV200 electric van. By giving Nissan electric vehicle (EV) owners the ability to plug their vehicles into the V2G system, owners will have the flexibility and power to sell stored energy from their vehicle battery back to the National Grid. This project will revolutionize how energy is supplied to the grid. Once scaled up, the V2G technology can become a game-changer for owners of Nissan EV in the UK as they become fully fledged and active participants in the UK energy market.

The similar project named Electric Vehicle-Smart Grid Interoperability Pilot has been initiated in 2016 by the French carmaker Renault together with the Dutch City of Utrecht and smart technology firms ElaadNL and LomboXnet. The partnership is developing a solar-powered EV charging network in Utrecht. The global aim is the implementation of smart grid solutions to reduce carbon emissions from the region’s power and transport sectors (36).

[2] S. more information about the E-Energy project in the chapter 2 of this report.

In the first step of the project, the carmaker supplied to the city about 150 EVs whilst ElaadNL and LomboXnet will install 1 000 solar-powered public charge hubs across the city for the EVs. During the second project phase, a vehicle-to-grid ecosystem will be deployed using the solar charging network to both recharge vehicles and feed energy stored in the vehicles of parked cars back into the grid.

Electric mobility: the ARTEMIS project thttp://www.artemis-ioe.eu/ consolidated 38 partner institutions across 10 European countries who jointly developed IoE solutions with the aim to create an electric mobility infrastructure and smart grid communications During the project lifetime (2011 – 2014), ARTEMIS partnership has developed hard-, soft- and middleware for seamless and secure connectivity and interoperability by connecting the Internet with energy grids. The project addressed reference designs and embedded systems architectures for highly efficient, innovative smart network systems regarding requirements of compatibility, networking, security, robustness, diagnosis, maintenance, integrated resource management, and self-organization.

Demand Side Response: Since 2016, global energy intelligence software firm Enernoc has been working with the Japan Institute of Applied Energy (IAE) for the rollout of a demand response programme. The partnership aims to demonstrate how transmission, distribution and system operators in the East Asian island nation can make use of demand response measures to ensure grid reliability and to avoid blackouts.

David Brewster, president of Enernoc, commented: "This new project is another step forward in the unprecedented electricity market reform occurring in Japan, and it will help cement the importance of demand-side management not only in Japan, but across the globe as well" (37). It should be noticed that Japanese utilities still suffer under the consequences of the East Japan earthquake and Tsunami in 2011. Thus, the partnership promises reliable solutions for the grid stabilization.

1.6 Challenges for the Internet of Energy

As previously mentioned, the massive rollout of IoE policies and strategies occurs with significant delays that are caused by various challenges. Kafle et al. (8) categorize the main challenges when transition to the IoE as follows:

A. Technical challenges

First of all, the IoE is expected to grow to a very complex network, which will integrate embedded systems such as smart grid, distributed renewables, sensors and require decentralized real-time monitoring and controlling as well as management of big data sets from various devices. In addition, the intermittent nature of renewable generation and the variability of loads makes achieving a robust intelligent energy management system quite challenging (30). Thus, ensuring a continuous energy supply for critical loads remains a serious challenge, which might be tackled through an effective demand-side management. Another challenge will be the regulation of the voltage and frequency of the grid within strict standards for networking smart grid components (e.g. IEC 61850, and IEEE standard including C37.1, 1379, 1547, and 1646, which are themselves quite complex (38).

B. Data privacy and cybersecurity challenges

Deploying the Internet for smart grid communications means opening up the infrastructure of utilities for the risks related to hacking and interference. Thus, cybersecurity concerns represent one of the

biggest threats within the IoE concept. The three high-level cybersecurity objectives for performance are: i) timely and reliable access to and use of information, ii) the integrity of communicated information, and iii) confidentiality of personal privacy and proprietary information (39).
In the past, there have been some serious cases of cyberattacks on the grid. The most dangerous malware attack was in Bushehr nuclear power plant (Iran) attacking SCADA system, which was exploited to monitor and control an electrical network (40). Attacks targeting power generation equipment, distribution and control stations could result in dramatic black outs or infrastructure damages.
For combating this type of challenges, experts suggest authentication, integrity protection, and encryption (41).

C. Business Model challenges

Traditional grid business models are based on large centralized generators and utility companies with a big market share from generation to the consumer premises. The shifting energy paradigm encourages, as previously described, development of new business models and services, which, however, cannot be fully adopted yet due to technical reasons: the IoE infrastructure and regulatory framework are still in its infancy. Deregulation and transformation of today's energy market are a key challenge for achieving future service-oriented energy market (42).

In the next chapters of this report, we collected a more differentiated overview from the selected Europe's countries concerning the IoE state of play, notably, Germany, Greece, Italy, Lithuania, Portugal, and Spain. The selection of these countries is explained through the participation of their representative institutions in the Erasmus+ project Internet of Energy – Education and Qualification, which the present report forms an integral part of.

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2. Internet of Energy in GERMANY

2.1 Awareness of IoE in Germany

The term Internet of Energy appeared in Germany for the first time at the level of the Federal Ministry of Economic Affairs and Energy (German abbreviation: BMWI) in 2008. At the time, German energy supply sector faced serious challenges related to the climate change, rapid growth in energy demand, and dwindling natural resources accompanied by an explosive development of disruptive technologies (such as Internet of Things IoT and Cloud Computing). In addition, technical elements of the energy infrastructure had to be replaced with new generation, transmission, and user components. So, power plants generating almost 50% of the output in Germany were about end of their technical lifetimes. During the same period, extensive renovations had to be undertaken across almost one third of German households towards installing new energy-saving technology and communication devices (1).

It has been recognized at the political level that firstly, politics and industries must work hand in hand and secondly, the gap between the energy sector and information and communication technology (ICT) must be filled to secure an economically- and environmentally-sound power supply for public sector and private households. Thus, the objective was set to create an “Internet of Energy” - a comprehensive digital network, which intelligently monitors, controls and regulates the electricity system.

This vision has been realized through an ambitious national programme E-Energy (2) that has been introduced in 2008 by the BMWI jointly with the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, and ended in 2013. The programme aimed at developing new, decentralised energy market solutions of tomorrow, and testing these new approaches in real-life scenarios across six selected pilot German regions. Figure 5 visualizes the geographical location of these projects:

Fig. 5: E-Energy projects and their geographical location across Germany (3).

The E-Energy programme led to the development of new ICT products, processes and services which helped improve energy efficiency, secure power supply, and mitigate climate change. The E-Energy programme also demonstrated that there was potential for new business models and qualification in an emerging field at the crossroads between the energy and ICT industries. Below the six projects of the E-Energy program will be presented in detail.

Moreover, IoE has been established as research phenomenon. In 2007, the Federation of German Industries (German: Bundesverband der deutschen Industrie e.V. BDI) established the working group "ICT for future energy markets" that has been renamed to "BDI Initiative Internet of Energy" in 2009[3]. The working group consists of representatives from research and industry sector who jointly elaborate solutions to successfully overcome the energy transition. The rationale of their activities is the awareness of the outstanding role of ICT that can resolve existing problems towards building the future intelligent energy landscape – the Internet of Energy (German: Internet der Energie). Specific topics of such a smart energy transition are different generation plants, transmission and distribution grids, storage as well as considerations on the future electricity market design, but also the question of the legal framework including the data protection issue.

The main goal of the BDI Initiative IoE is to design concepts for Germany that provide a roadmap for the transition to an Internet of Energy. This should be achieved through ensuring fast and secure communication between all market participants, process automation, and enabling new business models. The results of all these activities are recommendations for actions directed at the government, policy makers, and business leaders in Germany.

The current efforts of the BDI Initiative IoE focus on building the appropriate ICT infrastructure for the sustainable market design. The decentralization of energy generation and energy supply through renewable energies and combined heat and power plants, leads to increasing supply volatility and consequent bottlenecks in the regional networks. Flexibilities in production, storage and consumption will be the core features of the new energy system. Precise data is the prerequisite for exploiting the potential of such flexibilities at the network and market level, maintaining system and network stability and enabling an efficient market.

To date, three groundbreaking papers have been published by the BDI Initiative IoE as follows:

- IKT für Energiemärkte der Zukunft – Die Energiewirtschaft auf dem Weg ins Internetzeitalter, 12/2008;
- Auf dem Weg zum Internet der Energie – Der Wettbewerb allein wird es nicht richten, 05/2011;
- Impulse für eine smarte Energiewende – Handlungsempfehlungen für ein IKT- gestütztes Stromnetz der Zukunft, 10/2013.

2.2. Research and development projects on IoE in Germany

As previously stated, the six R&D projects under E-Energy Federal programme had mostly impacted the energy industry in Germany as they created and tested an integrated data and energy network with completely new structures and functions. Therefore, it is noteworthy to demonstrate them in the scope of this report.

[3] http://www.bdi-ide.de/

eTelligence – model region of Cuxhaven[4]

The aim of the eTelligence project was to implement concepts for the energy supply network of tomorrow. In particular, a complex control system has been created and tested to balance fluctuating wind, solar, biogas and CHP plants power and integrate it into the grid. The test region Cuxhaven was selected for the project implementation due to a large share of its energy needs that were covered by renewables. The crux of the project was a regional electricity marketplace that brought all market participants together, such as producers, consumers with shiftable loads, energy service providers and grid operators. In addition, two cold storage depots, a waste water treatment plant, the Cuxhaven municipal swimming pool, a wind farm, a block-type thermal power station were involved in the project assisting in the compensation of deviations in the power generation.
Many technical steps were needed to complete the eTelligence scenario resp. to interlink project partners via ICT. Advanced Metering Management System was deployed at around 100 local network stations in Cuxhaven. 650 private households were equipped with Smart Meters. Electricity producers and consumers have been merged to form a virtual power plant.

To ensure smooth communication with small generation plants, a reference architecture and associated software tools have been developed. In addition, various aspects of security were analyzed and threat scenarios were simulated based on international standards. In this manner, an important contribution to the interoperability and international standardization was made.

Among the results, eTelligence demonstrated that especially thermal energy systems, such as cold storage depots and block-type thermal power stations, can be used very effectively as energy storage facilities, achieving savings of up to six percent of their normal electricity costs. When sufficient wind is available, the cold storage depot lowers its temperature, creating a cold buffer for itself. When electricity prices are high, the cooling units are switched off. The cold store can however be further operated through the cold buffer for a few days, thereby reducing its electricity demand and related costs.
As part of the integration of the decentralized generation and larger consumption plants, plant types were further developed, so that a standardized plug-and-play connection of consumption and production of flexibilities became possible. In the long term, these plug-and-play interfaces will facilitate the uptake of new power producers and consumers into the system.

Besides, the conscious and environment-friendly use of electricity of consumers has increased due to introducing time-variable power tariff that allowed achieving significant shifts in electricity consumption. The power was used primarily when sufficient energy from renewable sources was available. On average, each consumer saved about 100 euros in electricity costs in the test year - on the one hand, by identifying energy guzzlers in the household, on the other hand, by using cheap electricity that resulted from the oversupply. Project participants demonstrated that each individual was enabled and motivated to contribute to the energy transition. 70 percent of the respondents said they regularly monitored their power consumption, 20 percent even several times a week.

Project partners:

- EWE AG (project coordinator)
- BTC AG
- OFFIS e.V.

[4] https://www.digitale-technologien.de/DT/Redaktion/DE/Downloads/Factsheets/factsheet-etelligence.pdf;jsessionid=45A11B5C16D7171FC39C692447A6639B?__blob=publicationFile&v=2

- Energy & meteo systems GmbH
- Fraunhofer-Verbund Energie
- Öko-Institut e.V.

eTelligence products:

- eTelligence-App and EWE trio smart box: Feedback system for consumers (Developer: EWE)
- Advanced Metering Management System: Connection, reading and creation of time series for smart meters and network sensors (Developer: BTC)
- EWE Power Smart Load Manager for business consumers (developer: EWE)
- Bonus and Malus Events: Innovative tariffs based on consumption and time (developer: EWE)
- Forecasting software (Developer: Energy & meteo systems GmbH)

Website: www.etelligence.de

Standards and patents: Open Source implementation of the standard 61850 (Energy & meteo systems, Fraunhofer ISE, OFFIS)

e-DEMA: Development of decentralized networked energy systems towards the E-Energy marketplace of the future[5]

The aim of the E-DeMa project in the Rhine-Ruhr model region was the conception of ICT-based solutions that enabled the intelligent use of all available resources as well as the optimization and integration of the entire electricity supply system. E-DeMa is considered the overarching concept that not only presented technical solutions, but also dealt with the opportunities of implementing these solutions in today's market situation. At the heart of the e-DEMA was the creation of E-DeMa marketplace that empowered previously passive consumers to participate more actively in the energy market in the sense of prosumers.

As part of E-DeMa, 13 micro-cogeneration units (micro CHPs) were installed for the field test, which could be switched on – when needed – as decentralized small producers and be aggregated into tradeable production quantities via the marketplace. In addition, nearly 700 households were equipped with ICT gateways (I and II) that allowed consumers to actively participate in the E-DeMa marketplace (i.e., to decide each month on which of E-DeMa tariff models they would be charged, or to aggregate and sell flexibilities).

Furthermore, about 600 households were equipped with smart electricity, gas, and water meters. A few customers also got home appliances such as dishwashers, washing machines and dryers to test how these devices could be controlled via smart measuring systems. In this manner, households were always kept informed about their consumption behavior and could adapt their energy consumption to the supply of renewable energies.

[5] https://www.digitale-technologien.de/DT/Redaktion/DE/Downloads/Factsheets/factsheet-e-dema.pdf;jsessionid=45A11B5C16D7171FC39C692447A6639B?__blob=publicationFile&v=2

Due to collecting the counter values , the consumption of integrated households could be recorded and displayed every 15 minutes. Already in a simple time-variable tariff, very active customers have shifted 8,7 percent of their consumption into the favorable tariff times.

From a functional point of view, the E-DeMa marketplace is a contract-based, market-supporting coordination mechanism that fosters all phases of contracting between suppliers and consumers, as well as B2B processes. During the field test only private households were integrated into the infrastructure. However, all solutions can also be deployed by commercial and industrial customers.

Project participants:

- RWE Energy AG (project coordinator)
- Stadtwerke Krefeld AG
- Siemens AG
- ef.ruhr GmbH
- Miele & Cie. KG
- Prosyst Software GmbH

Website: www.e-dema.com

e-DEMA products:

- Marketplace system (Siemens)
- ICT gateway 2: communication and control system incl. MPRM system as operating environment (Siemens, Prosyst)
- Innovative tariff products (RWE, Stadtwerke Krefeld, Technical University of Dortmund)
- Android-based app: displaying and processing new tariff products (University of Applied Sciences Dortmund, Stadtwerke Krefeld)
- Network control system: recording and forecasting (Siemens)
- Aggregator control system: management of consumption and generation plants (Siemens)
- Meter data management systems (Siemens and RWE)
- Multi-metering systems in the gas and water sector for connecting the division meters via M-Bus (Stadtwerke Krefeld)

e-DEMA simulations:

- Simulation models for the analysis of single and group load cycles of households and commercial and industrial customers; Scaling the results to different scenarios (Technical University of Dortmund, University of Duisburg-Essen, Ruhr University Bochum)
- Simulation and evaluation of communication technologies for Smart Metering and Demand-Side Management (RWE, Stadtwerke Krefeld)

MEREGIO: Minimum Emission Region[6]

MeRegio research project aimed at integrating the state-of-art ICT in the entire energy value chain to meet the demands for the highly-efficient decentralized energy systems. This has been achieved

[6] https://www.digitale-technologien.de/DT/Redaktion/DE/Downloads/Factsheets/factsheet-meregio.pdf;jsessionid=45A11B5C16D7171FC39C692447A6639B?__blob=publicationFile&v=2

through creating links between the physical and the trading level. The Göppingen and Freiamt/Ettenheim areas near Freiburg offered themselves as model regions.

Around 1000 commercial and private customers from the both communities were interconnected to form a "network of the future": they received smart meters, the MeRegioCockpit, and smart power traffic lights. The smart meter continuously sent the electricity consumption data of pilot customers directly to EnBW's (project partner) central billing system. This, in turn, sent the analyzed data about the energy consumption via Internet to the MeRegio Cockpit that could be displayed on the PC of each participant.

In addition, the customers were informed about the current tariffs and the development of electricity prices within the next 24 hours with the smart traffic light, which was also available as an app for the iPod. Red light meant a high electricity price, yellow - a medium tariff, and green light signalized the most favorable electricity price.

Piece by piece, the test persons were also provided with new smart home appliances such as freezer or dishwasher, which were controlled by a special control box and worked with low priced electricity. Later on, a battery system was additionally installed which stored self-generated electricity or cheap energy from the grid and then released it again when electricity prices were high. In this manner, a prototype of Smart Home has been created that demonstrated how the interplay between smart electricity meter, PV system and heat pump could work and positively change everyday lives.

The coordination of decentralized energy supply, energy demand and new services had many advantages: both electricity customers and decentralized producers operated as independent energy managers. They were enabled to control their consumption and thus the electricity costs. The energy companies also benefitted from the permanent data exchange, as they could better manage the grids (i.e. avoiding energy bottlenecks) and more efficiently operate their power plants. In this way, the MeRegio model also contributed to the environment protection: renewable energies were better integrated into the power grid, energy efficiency has increased, and CO2 emissions were significantly reduced. At certain times, load shifts of up to 20 percent (on average 7 to 15 percent) were measured. With only 1 percent increase in energy efficiency, test persons could spare about 20 tons of carbon dioxide per year.

However, MeRegio has also revealed some challenges, such as missing technical potentials in households and businesses and the still low awareness for such solutions. Although the willingness to participate in the project was very high, both the low technical maturity and the high rate of production ("just-in-time") often did not allow load shifts.

Participants:

- EnBW Energie Baden-Württemberg AG (project coordinator)
- ABB AG
- IBM Deutschland GmbH
- SAP AG
- Systemplan GmbH
- University of Karlsruhe (TH)

Website: www.meregio.de

Pilot products:

- MeRegio control box (EnBW)
- MeRegio App (EnBW)
- Power Submeter (Systemplan GmbH)
- Smart power traffic light (EnBW)
- Network Manager (ABB)
- CORE Platform (IBM)
- Marketplace (SAP)

Moma - Energy organism for the intelligent distribution of decentrally generated energy[7]

The key objective of the moma project (Mannheim model city in the Rhine-Neckar metropolitan region) was to develop a multi-disciplinary approach that allowed the integration of renewable and decentralized energy into the urban distribution grid. This has been accomplished through creating an open ICT-based platform equipped with a broadband powerline infrastructure integrating the various components. For the first time, an entire energy system architecture similar to a natural cell structure was developed that enabled a multispeed solution for the greatest possible use of renewable energy sources as well as the integration of energy storages. The cellular network architecture meets the needs for mastering the complexity of growing diversity and interconnectivity. The energy cells can be formed by buildings, city districts, municipalities and regions as self-optimizing energy cycles, which are (cross-)regionally interconnected and thus form a kind of energy organism. In addition, smart grid-based business models and incentive systems were systematically investigated and implemented.

The moma architecture initially consisted of several buildings connected to the distribution network, which were called object cells. About 200 of these object cells were grouped together to a distribution network encompassing agent structures for the grid and market support. Approximately 300 moma distribution networks were the components of a system cell. A CORE platform was deployed for integration and connection of the network cells to ensure the entire network management. In addition, the CORE platform linked the local market mechanisms via the marketplace of energy in the system cell with overarching energy markets. IP-based communication within and between cells happened via the broadband powerline. This system architecture also enabled Security by Design. Thus, a failure in a distribution network cell did not necessarily affect the overall system, so that the security of supply has increased.

To guarantee the management of the object cells, new control devices and mechanisms were tested in 671 households. Above all, the development and installation of the software Energiebutler that built the interface between the energy management, the other cells and the available devices with flexibility potentials within the object cell, was the central component of the optimization within the moma cell structure. Energiebutler helped customers align their electricity consumption with the variable prices at the energy market. Moreover, this software controlled consumer devices and decided independently whether a device had to be switched on or off (based on the current electricity price).

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[7] https://www.digitale-technologien.de/DT/Redaktion/DE/Downloads/Factsheets/factsheet-modellstadt-mannheim.pdf;jsessionid=45A11B5C16D7171FC39C692447A6639B?__blob=publicationFile&v=2

The field tests showed a high acceptance of the dynamic tariff among the customers: households reduced their electricity consumption on average to 11%.

Project partners:

- MVV Energie AG (project coordinator)
- DREWAG – Stadtwerke Dresden GmbH
- IBM Deutschland GmbH
- PPC Power PLUS Communications AG
- PSE Papendorf Software Engineering GmbH
- University Duisburg-Essen
- ISET – Association at the University of Kassel e.V.
- ifeu Heidelberg GmbH
- IZES GmbH

Website: www.modellstadt-mannheim.de

Pilot products:

- Communication network Broadband Powerline (PPC)
- Smart Meter Gateway as the basis for data acquisition and protection (PPC)
- Energy Management Gateway as a bidirectional communication interface to consumption/generation units in the property (MVV Energie, Fraunhofer IWES, PSE)
- Moma app (MVV Energie)
- Energiebutler software (MVV Energie, Fraunhofer IWES, PSE)
- OGEMA platform (OGEMA alliance, Fraunhofer IWES, MVV Energie)

Standards and patents:

- Patent on voting procedures in network cells with vending machines (MVV Energie)
- OGEMA platform (OGEMA alliance, Fraunhofer IWES, MVV Energie)

RegModHarz – Renewable energy from Harz[8]

The main objective of the regionally focused RegModHarz project was to foster the technical and economic development of renewable energies and their integration into everyday life of the region Harz. To this end, project partners implemented a virtual power plant VPP that encompassed a big variety of consumers, producers and storage. The most important factor was to ensure the stability of the power network due to the highly volatile nature of renewable energy sources.

An extension of the IEC 61850 standard has been developed to allow a simple and secure plug-and-play connection of equipment to a control room. With this generic data model, an automated integration of systems into the energy management has been accomplished. During the full operation of the entire ICT architecture of the VPP in the summer of 2012, six different decentralized systems

[8] https://www.digitale-technologien.de/DT/Redaktion/DE/Downloads/Factsheets/factsheet-regmodharz.pdf;jsessionid=45A11B5C16D7171FC39C692447A6639B?__blob=publicationFile&v=2

(two photovoltaic systems, two wind turbines, a biogas plant and a fuel cell) optimized their generated energy quantities and offered them at the simulated EPEX day-ahead and intraday markets. Within 14 days, the VPP in the Harz region was able to put to the market 3.3 GWh of electricity from the plants and achieved a turnover of 250,000 € according to a simulation based on EPEX data from 2008. Also the created ICT infrastructure has shown itself to be stable and secure.

Another achievement of the project was the "Regional Renewable Energy Tariff" that allowed consumers in the Harz region to obtain regional electricity from renewable energy sources such as wind, sun or biogas. The tariff aimed at minimizing the residual loads within the region so that customers could actively contribute to the balancing of production and consumption. The tariff was automatically processed by energy management systems and smart appliances. Besides, regional electricity in Harz region is considered the instrument for customer loyalty and identification with the domestic energy supply structure. In this manner, the acceptance of decentralized generation units has increased. An online platform also provided an opportunity to analyze and obtain information about the tariff and about the current, past and future production of renewable electricity.

RegModHarz also demonstrated that short-term wind power forecasting could increase profits when direct marketing of renewable energies. The flexible use of biogas plants could contribute to balancing the fluctuating production of solar and wind energy.

Finally, RegModHarz project incorporated the Phasor Measurement Units (PMU) to improve network monitoring. A total of 10 PMUs were installed in four local subnetworks of E.ON Avacon AG. In addition, a data storage system for storing measured data as well as an online-application for the second-by-second display of selected PMU variables were programmed and put into operation.

The functioning of the entire network was analyzed in detail during the field test over the first half of 2012. It has been proved that local energy producers were indeed enabled to bring their strengths and potentials into a smart grid using the created uniform communication interface. The RegModHarz empowered the system owner to offer his energy services to the Smart Grid. Conversely, the Grid got the opportunity to use these services and to optimally integrate the variability of the systems into the grid operations. This created the added value on both sides.

Participants:

- Cube Engineering GmbH
- envia Mitteldeutsche Energie AG
- envia Verteilnetz GmbH
- E.ON Avacon AG
- Fraunhofer-Institut für Fabrikbetrieb und -automatisierung IFF
- Halberstadtwerke GmbH
- Harz Regenerativ Druiberg e.V.
- HSN Magdeburg GmbH
- University of Kassel IEE Rationelle Energiewandlung
- in.power GmbH
- ISET – Association at the University of Kassel e.V.
- District Harz
- Otto-von-Guericke-University Magdeburg
- RegenerativKraftwerk Harz GmbH & Co KG
- Siemens AG

- Stadtwerke Blankenburg GmbH
- Stadtwerke Wernigerode GmbH
- Stadtwerke Quedlinburg GmbH
- Vattenfall Europe Transmission GmbH

Pilot products:

- PowerBridge (Siemens)
- energyPRO forecasting system (Cube Engineering, EMS International, Otto von Guericke University Magdeburg)
- Control room (Fraunhofer IWES)
- OGEMA platform (Fraunhofer IWES)

Standards and patents: Setting up communication services and data models to IEC 61850 (Siemens)

Website: www.regmodharz.de

Smart Watts[9]

The global aim of the Smart Watts project was to create an unbundling information and control model for the energy system, which was enabled to promptly provide the market players with the actual production and consumption data. As a result, a cross-cutting control and optimization of the energy portfolio (so-called end-to-end optimization) followed via the intelligent supply management. In addition to the conventional methods of portfolio management, the balancing was achieved by direct influencing production and consumption. This allowed an optimal exploitation of the available renewable energies as well as tackling fluctuations when their generation.

In particular, Smart Watts developed the smart kilowatt hour, which became a major factor at a decentralized energy market. In a smart home, the smart kilowatt hour motivated the consumers through flexible pricing to shift their energy consumption (manually or automatically) into favorable periods while maintaining the same level of comfort. The incentive-based system specifically influenced feed-in, consumption, supply and demand. The price for energy production and consumption was dynamically generated according to pre-given rules and sent to the respective terminals. The consumption data collected by means of smart meters formed the basis for variable tariffs and were billed and made transparent with a flexible billing and reporting system. This can be used to design services that stimulate energy-saving behavior.

The necessary connection of the households with the information and control systems was ensured via the open EEBus standard. The corresponding data could be automatically processed by smart sockets and home appliances. A special iOS-based app with various functions (including feedback and control) provided customers with detailed information about their power consumption and user behavior.
The interaction between different Smart Watts modules was tested in the model region Aachen. A total of almost 300 households were divided into three groups and integrated in the field test infrastructure. The first few months of the field test clearly showed that integrated automated solutions guaranteed the most reliable load shifts. At low priced tariff zones, the energy consumption increases of almost ten

[9] https://www.digitale-technologien.de/DT/Redaktion/DE/Downloads/Factsheets/factsheet-smart-watts.pdf;jsessionid=45A11B5C16D7171FC39C692447A6639B?__blob=publicationFile&v=2

percent were indicated by means of smart devices. Conversely, consumption reductions of up to five percent at expensive tariff zones were registered.

The EEBus as part of the Smart Watts project has meanwhile written a remarkable success story and has already been celebrated as a pioneering achievement for the energy transition. The key to success was its role as an interpreter: the EEBus described and made possible the use of existing communication standards for different actors - energy suppliers, grid, producers, consumers, whose integration in the context of the energy transition was becoming increasingly important, and therefore allowed the exchange of applications and services. This increased the comfort and efficiency of the interaction. At the Hannover Messe 2012, the EEBus Association was founded, which now embraces major energy suppliers such as E.ON, leading network technology manufacturers such as ABB or white goods such as Miele or BSH, and many other key smart grid players. The EEBus Association continues to grow and is steadily gaining influence. Thus, the breakthrough of the standard has become tangible.

Participants:

- utilicount GmbH
- Soptim AG
- Research institute for rationalisation at the RWTH Aachen
- PSI Büsing & Buchwald GmbH
- Kellendonk Elektronik GmbH
- Stadtwerke Aachen AG

Pilot products:

- EEBus smart sockets (Kellendonk)
- EEBus Bridge (Kellendonk)
- EEBus Stack (Kellendonk)
- Innovative tariffs (Stawag)
- Smart Portfolio Management (PSI)
- Smart Forecasting (PSI)
- Smart Balancing (PSI)
- Smart Accounting (PSI)
- Smart Information & Advice (PSI)
- Gateway basis software
- Data center
- Smart Market as trading platform for the Smart kilowatt hour (SOPTIM AG)

Standards and patents:

- EEBus for the description of the efficient use of existing communication standards enabling the cross-cutting communication amongst all network (Kellendonk Elektronik)
- Security Token for the energy sector (Energy Name Service ENS)

These flagship projects demonstrated the great benefits of the Internet of Energy along the entire value chain, from generation to end consumers. Moreover, these projects can be considered best practices in the field of IoE as they facilitated the development of further ICT-based models and solutions for the energy industry and the uptake of IoE into the dialogue with political decision makers and general public. The project results have been an integral part of the energy transition in Germany and provided a fundament for many subsequent projects that built on the know-how gained.

2.3. Overview of the established IoE technologies and scenarios in Germany

Smart Metering:

Starting from 2017, new smart meters were required by the German law for large consumers with a consumption of more than 10,000 kilowatt hours per year. In 2020, the next wave of installations in households is due. However, there were significant delays in the nationwide rollout of smart meters because of lack of mature and certified Smart Meter Gateways (SMGW).
The SMGW is considered the key technology for digitizing the energy sector and guaranteeing data protection and security at the highest level. The SMGW provides grid operators, electricity suppliers, and consumers with the needed information about the power generation and consumption and lays the foundation for the intelligent and secure network of tomorrow.

By the end of December 2018, the Federal Office for Information Security (German: das Bundesamt für Informationssicherheit BSI) has issued the first certificate based on the protection profile for the Smart Meter Gateway, which was developed by Power Plus Communications AG (PPC) in cooperation with OpenLimit SignCubes AG[10]. In addition to the proof of compliance with the safety requirements in the Smart Meter Gateway, the certification process also considered the manufacturing and development processes as well as the delivery routes of the devices. With the certification of the Smart Meter Gateway, the first IT security label has been awarded at the same time.

At the request of the customer, the installation of the first certified devices is already possible. The so-called "mandatory rollout" begins when at least three independent companies offer smart metering systems on the market that have successfully passed the certification process and meet the legal requirements.
There are currently eight other smart meter gateway manufacturers in the BSI certification process.

Network technology and network control:

STATCOM (static synchronous compensator): STATCOM is the converter for a modern system for grid stabilization in the SVC PLUS series developed by Siemens[11]. About two-thirds of the globally-installed STATCOM systems with modular multilevel power conversion technology are Siemens-listed.

The increasing importance of the STATCOM technology goes hand in hand with the new requirements of the power grid. The volatile feed-in and the growing distance between power generation and consumption make the grid more susceptible to fluctuations. STATCOM systems stabilize these fluctuations by picking up or feeding in voltage-assisted reactive power as required. Based on the technology of conventional reactive power compensators, Siemens has developed further innovative solutions, such as the SVC PLUS FS frequency stabilizer or the STATCOM mobile, which stabilize the grid and close gaps in energy networks worldwide.

[10] https://www.bsi.bund.de/DE/Themen/DigitaleGesellschaft/SmartMeter/SmartMeterGateway/Zertifikate24Msbg/zertifikate24MsbG_node.html
[11] http://50komma2.de/ww/2019/07/08/siemens-uebergibt-100-statcom-anlage-an-amprion/

Decentralized power systems:

They are increasingly considered not only a challenge for the power grid, but also a way to stabilize it. They can take on tasks that have so far been performed mainly by large, centralized power plants. The distribution grid operator Bayernwerk Netz GmbH, Consolinno Energy GmbH and the transmission system operator TenneT TSO GmbH have shown in a successful test how it is technically possible to use combined heat and power plants (CHP systems), heat pumps or biogas plants for grid stabilization[12]. A thermal load shift in a decentralized CHP plant could help to stabilize the power grid.

The novelty was that the artificial intelligence was used for process controlling, so that the plant could independently determine its flexibility potential. The potential of the individual plants could be aggregated by means of swarm intelligence or communicated directly and continuously to the network operator in a time span of 36 hours up to 20 minutes before the provision of the service.

In Bavaria alone, there are several thousand CHP plants, heat pumps and biogas plants. Nationwide, there are many thousands more. They can increase the flexibility of the energy system and thus make a contribution to the secure and decentralized energy transition in Bavaria and Germany.

e-mobility:

Electromobility is considered the core component of a sustainable future strategy in the mobility sector in Germany and is being currently supported by the Federal state. In 2010, the National Platform for Electro-Mobility was launched that brings together the activities of the various branches and the research community in the field of e-vehicles (4). Not only innovative engines are promoted but also reliable infrastructure (charging points) and well-trained experts who can deal with highly complex technologies. 500 million euros were allocated to promote electro-mobility. The goal was to make Germany a leading market for electro-mobility in the long term, and by 2020 to get one million electric vehicles onto German roads.

In this scenario, the market for electromobility is developing rapidly and poses new challenges for network operators, local authorities and the housing industry. Studies predict that electric cars in Germany can reach at least 15 percent of car traffic by 2030 (5). This requires a well-developed charging infrastructure.

In this regard, two main scenarios are promoted: public and private charging stations. The technology to be used behind both solutions is Internet of Things (IoT) and Blockchain.

Public charging stations: Thanks to IoT technologies, innovative services can be implemented in many places that simplify and promote the development and operation of smart infrastructures for the implementation of e-mobility concepts. Smart Parking, for example, is an IoT use case that is being implemented in many German cities and that also allows effective management of the available charging infrastructure. In Trier, i.e., ZENNER International GmbH & Co. KG has recently realized such a project with the municipal utilities[13]. When parking spaces are being monitored, the Smart Parking System not only recognizes the number of free and occupied parking spaces, but also differentiates between normal parking spaces, disabled parking spaces and e-charging stations. Via the website of energy providers, the citizens have access to the information and can directly access free e-charging stations. In addition, it can be seen whether an occupied charging station is actually used or it is merely

[12] https://www.tscnet.eu/tag/digitalisation/
[13] http://50komma2.de/ww/2019/05/16/iot-und-full-services-zenner-unterstuetzt-bei-realisierung-und-betrieb-von-e-ladestationen/

blocked by an illegally parked vehicle. The status data of the parking areas are transferred to the backend system via IoT gateways. The information about the occupancy status of the charging stations can then be made available to the citizen via an app. The Long Range Wide Area Network (LoRaWAN) radio technology was used to transfer sensor information locally. In Hamburg, too, LoRaWAN is to be used to monitor parking spaces with charging stations for electric vehicles.

Private charging stations can still be seen within the future IoE scenarios, which are presented below.

2.4. Future IoE scenarios, technologies, and business models

The future development towards an Internet of Energy in Germany involves complex relationships between different areas and applications. The classic value creation stages of the energy industry are becoming increasingly mixed, and new applications can no longer be assigned exclusively to one area.

Due to growth of decentralized energy markets, which will determine the energy industry of tomorrow, the Blockchain technology might be a promising solution to guarantee the smooth data exchange between generation plants, grids and storage facilities. A blockchain is a growing file that contains all the transactions of all involved actors. This file is not stored on a central server, but on the computers of all participating actors. New transactions are added by consensus in an automated reconciliation process. The core features of the blockchain technology are the assurance of data sovereignty (usage control) and the direct interaction between (unknown) actors. No third-party company is needed what mitigates IT security risks. The distributed system architecture of the Blockchain harmonizes therefore perfectly with decentralized energy industry.

Nowadays, a number of German energy providers and start-ups are working on testing blockchain solutions such as Ethereum, Hyperledger, BigChain or Tendermint. They mostly aim at the optimization of energy industry processes such as billing, master data management, or change of electricity supplier. In this context, they speak in Germany about the following future IoE scenarios:

- **e-mobility**: The nationwide use of e-mobility requires a well-developed charging station infrastructure. A very decentralized distribution and a large number of different operators push today's billing methods to their limits. For example, the process of recognizing the user upon authorization at a charging station may currently be delayed due to a multitude of requests at different entities. By using a blockchain method, the consumer at a public charging station could be immediately recognized and accounted for the amount of electricity purchased. In this manner, the processing can be significantly speeded up. This leads both to a comfort gain for the customer, to a cost reduction for the provider as well as to a detailed billing of the actual electricity purchased. In addition, the customer controls his mobility data all the time. A current project for this is, for example, Share & Charge by Innogy and slock.it[14], in which the billing of the electricity purchased for electric cars is tracked and billed based on blockchains.

  On the other hand, public charging stations are just one component of the future charging infrastructure. According to experts, even most e-car holders will refuel their car at home or in service. Andrea Kraemer, Managing Director of Minol Messtechnik W. Lehmann GmbH & Co. KG, is convinced: "The home-based charging will become the most important component for

[14] https://shareandcharge.com/

enabling electromobility over a large area. A house without charging will be as unattractive in the near future as one without an Internet connection"[15].

This fact is also borne out by the new elite project ELBE (Electrify Buildings for EVs)[16]. As part of ELBE, more than 7,400 charging stations are to be subsidized on private land in Hamburg by the end of 2022. The goals are comprehensive support for the construction and operation of charging stations on buildings and on company premises in Hamburg as well as the further integration of emission-free traffic and the Hamburg real estate industry.

The topic of e-mobility has thus also arrived in the real estate industry. In the Minol ZENNER Group, this has been recognized, too, and, in response to the growing demand from building operators, solution packages are being developed to equip residential buildings with charging opportunities. In 2019, Minol Messtechnik W. Lehmann GmbH & Co. KG and its partner GP JOULE CONNECT plan to offer complete solutions for smart e-mobility in the real estate industry called "Minol Drive"[17]. The Minol Drive service package should include advice, planning, installation and operation of charging infrastructures, issuing and managing charge cards, a roaming offer to have your own charging stations listed as public, and an app that controls the entire charging process leaves. In addition, users can take advantage of additional offers such as green power, intelligent energy and load management, sharing offers for electric cars and e-bikes, and solutions for efficient fleet management.

In the future, participants are also expected to be able to make their private charging stations available to other e-car holders. Payment and billing will be done automatically via blockchain-based Smart Contracts.
Thus, electromobility strips the niche role and is on the way to becoming a megatrend in Germany. In this situation, technical solutions will be promoted needed that make e-mobility smart and comfortable.

- **energy trading and new services:** thanks to the tamper-proof distributed storage of data in a blockchain, certificates for renewable and regional power production, for example, can be documented in the blockchain at the early production stage. As a result, new products such as green and regional electricity can be developed, which are undoubtedly attributable to a source and not duplicable (6). In addition, certificates for tradeable emission or CO2 products are conceivable. Moreover, Blockchain technology promises direct and anonymous wholesale energy without the need to approach a marketplace or intermediary. This is due to the fact that the Blockchain allows trustworthy transactions between unknown actors. The expected benefits are cost reductions and speeding up the process.

- **decentralized generation**: Decentralized energy production will still be seen as a key factor in reducing CO2 emissions and increasing the energy efficiency. Innovative tenant electricity models based on the Landlord-to-Tenant Electricity Act (7) are expected to be intensively promoted at the Federal level. In this manner, supplying electricity to tenants will be made more attractive and profitable for landlords, whilst at the same tenants' electricity bills will be reduced. Landlord-to-tenant electricity supply therefore helps drive forward the expansion of

[15] http://50komma2.de/ww/2019/05/16/iot-und-full-services-zenner-unterstuetzt-bei-realisierung-und-betrieb-von-e-ladestationen/
[16] https://www.digital-energysolutions.de/en/7129-2/
[17] https://www.minol.de/drive.html

renewable energy across Germany. The potential is huge: estimates suggest that up to 3.8 million homes could be supplied with electricity from rooftop installations.
In the future, these microgrids and distribution grids are expected to turn into so-called transactive grids, in which network-specific requirements and restrictions will be taken into account even before trading (6).

By linking with blockchain technology, the conditions for transparent and efficient energy trading between a large number of participating systems and diverse players can be created. As a result, the efficiency of the entire energy system can be increased and customers will enjoy both cost benefits and opportunities for new business models. However, it's not just companies, users or IT infrastructures that are facing new challenges with blockchain technology, but the legal framework must also adapt to technological advancements.

The fact is: new block-chain-based business models and applications are currently emerging with great momentum. The maturity of Blockchain technology in terms of speed, energy consumption, IT security, reliability, governance, interoperability and cost-effectiveness is also rapidly evolving. However, it should be noted that currently almost all blockchain applications and projects are still far from having a high market penetration due to unsolved general contract, energy law or data protection issues.

Last but not least: those who wish to be regularly updated about the latest developments related to the IoE in Germany are recommended to subscribe to the e-newsletter of the German Platform for Smart Grids 50,2 http://50komma2.de/ww/ resp. to visit it. The platform informs about the news from German IoE developers and providers in the field of e-mobility, network control, energy storage and is therefore a perfect tool for monitoring of what is going on in the German energy sector.

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3. Internet of Energy in SPAIN

3.1. Awareness of IoE in Spain

The first reference found to the IoE concept was made by Estevez [1] citing Thomas Friedman, book and documentary author, a three-time Pulitzer Prize winner and columnist at the Times, New Yorker and Washington Magazine. Estevez publishes articles in a specialized news website called "EcoIntenligencia".

The definition provided by Estevez is the following: "IoE refers to the foundations of Smart Grids whose main idea is the distribution of electricity from suppliers to consumers who use digital technology to save energy, reduce costs and increase reliability."

Fernandez, columnist at Euskadinnova also introduced the IoE concept but citing Jeremy Rifkin, the chairman of the Foundation on Economic Trends and advisor to the European Parliament:

"Rifkin draws a parallel with the transformation of the consumption and production of content on the Net. Like the centralized and hierarchical model of information, with the mainstream media, it has been replaced in large part through channels of horizontal creation and distribution on the Internet. Information technologies can favor the construction of distributed energy networks, unseating the model of large power plants. Rifkin's theory is based on several pillars, the commitment to renewables and the use of buildings as mini-power plants, capable of generating the energy they need and distributing the surplus. Storage, through hydrogen and network distribution managed through the Internet are also the basis of this energy revolution.

The current economic crisis is linked to the price of a barrel, and for Rifkin the only way out is to look for alternatives to oil. The Internet of Energy is not only based on extending the use of renewable energies, but replacing the current centralized model with small nodes that generate interconnected energy in a horizontal network where surpluses are distributed. This scenario is linked to the new collaborative economy that emerged with the Internet, where intermediaries are eliminated and people or small collectives (such as a block of neighbors or an office building, in this case) can become producers, using the possibilities of Internet for distribution." [2].

On the other hand, Jorge García Robles [3] also provides a definition to IoE:

"Internet of Energy (IoE) consists of the use of automated and intelligent infrastructure that regulates, programs and updates the functions of different sources of electric power, particularly sustainable ones. IoE works from the storage of data and programmed algorithms that quantify information, analyze variables and make intelligent decisions in the field of the use of electric power. IoE's intelligent technology controls the process of obtaining, distributing and supplying electric power, where the sources of the same and the devices that use it interact together." [3].

Many corporate publications (blogs, news…) have been published about IoE since 2012. This fact shows the awareness among Spanish companies of the IoE benefits. For example, Indra, one of the most important technology companies from Spain, has been working on this topic at least since 2008. They foresee the following benefits in the use of IoE:

"IoE will allow having the capacity to efficiently produce, store and use energy, balancing supply and demand through the cognitive use of the Internet of Energy, which will harmonize the electricity network through the processing of data, information and knowledge through the Internet" [4]. DEMAG company exactly copies the same IoE definition and benefits from Indra [5]. The main technologies that Indra foresee as the core of IoE are:

- Systems and platforms for the management and control of energy networks from production to distribution;
- European standard for monitoring Smart Energy Grids: smart meters and managers of energy demand in buildings;
- Systems for the optimization of the recharge and the autonomy of electric vehicles.

SMILICS technologies develops and manufactures wireless solutions for energy metering and control. They think that IoE offers energy efficiency, sustainability and technology always at the service of people [6].

Red Eléctrica, the sole transmission agent and operator of the Spanish electricity system, has also been working for many years on smart grids, energy storage and electric vehicles. An example of this interest is Grid2030, a multi-year innovation collaborative program where Red Eléctrica de España and InnoEnergy together explore radically new socio-economic or technical innovations in the power transmission industry [7].

3.2. Overview of the existing IoE technologies and applications in Spain

Smart Grids [8]

The development of smart grids in Spain will require an investment of €10,200 million over the next 10 years to generate intrinsic benefits of between 2 and 3.5 times the investment (€19,000 – 36,000 million). The deployment of smart grids will support the sustainable growth of the economy and promote global leadership of the Spanish technology sector as it facilitates the integration of new applications in the electrical system and improves overall system efficiency.

Undertaking and leading the transformation of the electric system with smart grids can improve the gross domestic product of Spain by between +0.20% and +0.35%, or between €2,300 and €3,800 million. This is due to factors such as developing the Spanish technological and electrical sector, employment generation, reduced energy imports and increased productivity thanks to an improvement in the quality of supply.

The development of smart grids will generate between 40,000 and 50,000 jobs in Spain, of which 20,000 are predicted to be directly related to the sector and 20,000 – 30,000 indirectly related. Indirect jobs include high value-added activities such as the manufacture of electrical and communications equipment; assembly, field installation and subsequent maintenance; and the development of energy management companies.

Meanwhile, Spain's energy dependence can be reduced by 5.3% by 2020, due to increased energy efficiency and efficiency of the electrical system, along with increased integration of renewable energy and electric vehicles. For the same reasons, CO_2 emissions can be decreased by 3.7% by 2020.

Smart grids will additionally support the goal of a global leadership position for Spain in the technology sector. Globally, and in the coming years, major investments are expected in smart grid technologies. Specifically, it is estimated that by 2020, investment in smart grids worldwide will be around €90,000 million. Spanish technology companies could capture a portion of this potential market (between €1,200 and 2,000 million per annum) in those areas favourable to the sale of Spanish products.

Spanish companies have proven to be a reference point in the management of power grids, with a cost efficiency more than double the European average and continuous improvement of service quality (improvement of 8% annually since 2006). The smart grid will allow Spanish companies to develop new business opportunities outside Spain and play an active role in the reconfiguration of the European and global energy sectors.

The smart grids will facilitate the effective integration of new applications and generate efficiencies for the electrical system. Specifically, the network will be more automated; distributed energy resources will be effectively integrated, increasing customer participation in the system; flexible management of distributed generation; and integration of new agents such as storage or electric vehicles will be accomplished.

These new applications could generate efficiencies and profits for the electricity system of between €1,100 and €1,800 million annually as a result of increased reliability and supply quality, greater efficiency of operation and maintenance of the system, more energy efficiency, optimized use and longer life of the assets, and a flattened demand curve.

Additionally, smart grids are a necessary condition for meeting the objectives of planned deployment of renewable energy by 2020 and the effective integration of other applications in the system, such as electric vehicles, which will contribute to a value of over €3,000 million annually and create more than 200,000 jobs.

Electric Vehicles

Electric vehicles hold significant potential for increasing energy security, reducing carbon emissions, and improving local air quality. Transportation accounts for about one-fifth of global energy use, and passenger vehicles account for about ten percent of energy-related carbon dioxide emissions. With the rapid rise in personal vehicle ownership around the globe, demand for fuel will continue to increase along with carbon emissions unless there is a shift in transportation [9].

Promoting electric vehicles is an alternative to reduce and limit them move towards the sustainability of the automobile sector. In a short period of time, world car manufacturers have built, marketed and sold a million electric vehicles, and a million drivers got used to these new low carbon advanced technologies. Comparatively, this figure represents approximately the average annual sales of conventional vehicles in Spain. The main problem is the battery autonomy, since its maximum range does not exceed 250 km, a restriction that limits the trip. Spain belongs to the group of countries which have longest trip average around 80 km. Then the problem is how to understand electric mobility, for that the types and modes of charging, the types of electric vehicles, and the available charging systems all interact with one another in the charging systems for electric vehicles [10].

Smart metering [11]

Smart metering allows reading electricity consumption and carrying out operations remotely through the development of a state-of-the-art communications system between smart meters that replace traditional electricity meters, and the electricity company.

The smart meter is the main element of the smart metering system. Its installation involves a great change in customer relations. Spanish and European legislation promotes the implementation of meters, which contribute to an active role of consumers in the electricity market and to efficiency in the end use of energy. In order to comply with this legislation, Endesa is developing a plan to replace all meters for customers with contracted power up to 15 kW, i.e., domestic supply.

With the implementation of the new hourly readings, bill estimates can be eliminated and customers now have new tools to improve their energy efficiency and detailed information about their consumption.

The implementation of these smart meters is also a huge step forward in the fight against electricity fraud and improving the safety of installations, given that these devices are equipped with sophisticated anti-fraud mechanisms that help to identify possible manipulations via alarms and alerts that are recorded by the remote management system, which also sends an alert if an installation is at risk of being tampered with or any other neighboring ones.

There are a few Spanish companies offering solutions for Smart Metering. SMILICS Technologies designs and manufactures current sensors and wireless electric meters [6].

A similar product is offered by Libelium's Waspmote platform [12]. It includes a current sensor that enables very high reliability monitoring of 6 parameters for electricity & water supply, logistics and industrial automation.

Figures 1 – 2: Smart Metering Waspmote Plug & Sense! model. Examples of application with the current clamp sensor [12].

Sensing, monitoring and actuating systems are expected to play a key role in measuring residential and commercial energy consumption. Smart meters will be deployed in large numbers if smart grids are to deliver anticipated benefits such as reduced greenhouse gas emissions, greater inclusion of renewable energy sources, and improved reliability. Presently, there are already over 50 million smart meters installed in the U.S. The European Union is aiming to replace at least 80% of conventional meters with smart meters by 2020. Leading nations in Asia, such as South Korea and China, are also heavily committed.

Other products of Libelium can also be applied to IoE by sending solar panels' performance data through the Internet in order to anticipate when to carry out maintenance actions or even remotely perform meter reading in the houses (known as Smart Grid) enabling a cheaper data acquisition for utilities and a more accurate billing for the user. On the other hand, there are applications aligned with energy saving, as is the case of Smart Lighting, which combines ambient and light sensors to know when to turn on or off the streetlights with the consequent energy savings. The same further applies to private households, where their energy consumption can be measured using sensors to check appliances' efficiency and look for savings. Finally, they can also use sensors for energy infrastructures perimeter security control [13].

Regarding electric companies, most of the Spanish companies, such as Union Fenosa, Endesa or Iberdrola are investing in the digitalization of their electric infrastructures. One example of this process is the use of smart meters.

3.3. IoE best practices and their adoption in Spain

Electric Vehicles

Endesa has taken part in the development of electric mobility solutions by fostering the development of fast charging. They have participated in the several projects related to this topic [9]:

- Vehicle to Grid (V2G): This system enables the electric connection and flow between the grid and the vehicle, so it can be charged but also act as a generator, producing electricity for households or feeding the grid.
- Fasto V2G: This is a bidirectional electric charger, capable of charging and discharging a vehicle depending on the requirements of the electrical system.
- Sunbatt: This project studies the possible second service life for batteries used in electric vehicles, to prevent them from becoming disposable products.
- Zeus: This project studies the feasibility of more efficient and economical urban electric buses. In this area, ULTRAFAST has been developed, a 400 kW charger for heavy vehicles. The first was installed in Barcelona in collaboration with Metropolitan Transports of Barcelona (TMB). This system enables 80% of a bus battery to be charged in just 5 minutes.
- Victoria Project (Vehicle Initiative Consortium for Transport Operation and Road Inductive Applications): This project was launched in 2015 together with a consortium of another four companies and three research organizations for the development of the first dynamic inductive charging lane for electric vehicles in Spain. The aim is to charge the vehicle while it is moving.
- CIRVE (Fast charging points located along the Iberian EU Corridors): An European project with the participation of 8 institutions with the aim of deploying a network of 40 fast charging points in urban and peri-urban areas and boosting the existence of these infrastructures in Spain.
- PALOMA (Prototype For Alternative Operation Of Mobility Assets): This project aimed at the integration of a new fast charging system for electric buses and the analysis of its impact on the electric distribution grid. The proposal is financed by the CDTI via the FEDER-INNTERCONECTA 2016 Programme and it will be developed in Malaga.
- ZEM2ALL (Zero Emission Mobility to All): The largest electric mobility demonstration project in Spain that was implemented together with Mitsubishi over four years. The project enabled assessing the impact in terms of contaminating emission levels and energy consumption within a community. Over the period in which the project took place, 4.6 million kilometers were covered with zero

emissions and over 100,000 vehicle charging services were carried out which prevented the emission into the atmosphere of 330 TN of CO2.

Smart metering [11]

Endesa and Enel have jointly developed a smart metering system based on Enel's tried and tested solutions and the experience provided by Endesa. Endesa has adapted it to its business requirements and to Spanish regulations. The technology developed by Enel is now used in more than 33 million meters worldwide and its efficiency has made it a global benchmark. Endesa is developing a plan to replace all meters for customers with contracted power up to 15 kW, i.e., domestic supply.

Endesa is the leading and pioneering company in smart metering and currently has the largest number of smart meters installed nationwide. Its system has been in operation since October 2010. Endesa's remote management plan not only involves installing meters but also hubs in the substations.

Endesa's smart metering system offers many advantages:

- Remote meter reading;
- Billing based on real readings, avoiding estimate bills;
- All operations concerning supply (connections, disconnections, power or rate modifications, etc.) are performed remotely;
- Remote operations are performed within 24 hours in most cases;
- Incidents are detected and identified faster;
- Better information on energy consumption, encouraging energy saving and efficiency.

The new meters are:

- Smarter by facilitating remote consumption readings and operations;
- More flexible because contracted rates can be adapted to consumption habits;
- More efficient by providing energy consumption to contribute to saving and responsibly using energy.

InGRID Active Grid Management (AGM) [14]

Indra one of the leading global technology companies, is a leading provider of customized technology solutions in various fields such as transport and traffic, energy and industry and telecommunications. In recent years it has developed a number of products and services related to the incorporation of IOT into the energy field. Indra offers Advanced Services of Energy Management, based on IoT, for Home, Buildings and Industry.

Indra offers a comprehensive solution to manage, monitor and control the consumption, processes and events of a large number of points remotely and in real time. This powerful solution has been built on a robust and scalable architecture, being consistent with the needs of today's market,

IoT monitoring and control platform developed by Indra with Intel technology to facilitate a dynamic, proactive, distributed and intelligent operation of electricity networks. The solution opens the door for consumers to manage their energy use and actively participate in new business models that improve the reliability, efficiency and sustainability of the electricity system.

Developed products:

- IGEA: Powerful multi-sector GIS solution covering the integrated management of all network asset information;
- InGRID NDM: Network Development and Maintenance: Management and monitoring of all development work from definition to commissioning; and network maintenance. Tool for design support, technical analysis, budgeting and automatic calculation of construction material requirements (integration with ERP);
- InGRID DMS: Distribution Management System: DMS/WHO functionality. Provides all the information required for real-time network monitoring and operation, as well as incident management. Integrated with SCADA, AMI, graphic databases (GIS) and simulation environments;
- InGRID WFM: WorkForce Management: Allows the integration of field work with mobile devices and the automated and optimal management of own or outsourced equipment, through a real-time solution fully integrated with corporate systems;
- InGRID Power Analytics: a stand-alone tool that enables automatic scheduled execution of complex network analysis and real-time network control;
- iOTS: Operator Training System: the iOTS module is integrated into the InGRID Suite for real-time simulation of network response, aimed at operator training. It also offers event and fault simulation capabilities, as well as an instructor station through which the simulation can be directed;
- InGRID AGM: Active Grid Management;
- iSPEED: Integration platform for real-time data acquisition and processing, capable of handling large volumes of data from multiple field devices;
- InGRID DASHBOARD: Analysis and Summary of the situation of the distribution processes (KPIs).

3.4. Research and development projects on IoE in Spain

Energy IN TIME - Simulation-based control for Energy Efficiency building operation and maintenance

Project lifetime: 48 months (October 2013 - September 2017)
Project coordinator: ACCIONA (Spain)

Energy IN TIME (EiT) was an European project that went beyond existing building control techniques, developing an integrated control & operation approach that combined state-of-the-art modelling techniques with the development of an innovative simulation-based control technique with the overarching objective of automating the generation of optimal operational plans tailored to the actual building and users requirements. This approach allowed reducing system inefficiencies and contributing to improve building energy efficiency and comfort.

Energy IN TIME has been validated at existing non-residential buildings in different Europe's locations with different climates. The demonstration sites consisted of four buildings with different typologies and building uses, including an airport, offices and test labs, a commercial and office building, and a hotel. The variety of scenarios served as a "proof of concept" of the Energy IN TIME solution, in terms of validity and adaptability to different typologies, climate conditions and users behavior.

The project consortium was made up of 13 partners from 8 European countries:

- ACCIONA (Spain)
- ANA Aeroportos de Portugal (Portugal)

- CIRCE (Spain)
- Cork Institute for Technology (Ireland)
- Université de Lorraine (France)
- Centre Scientifique et Technique de Batiment (France)
- FUNIBER (Spain)
- Institutul de Cercetari Electrotehnice (Romania)
- Integrated Environmental Solutions (United Kingdom)
- STAM SRL (Italy)
- Universidad de Granada (Spain)
- United Technologies Research Center Ireland (Ireland)
- Caverion Suomi Oy (Finland)

Project website: https://www.energyintime.eu/summary/

GrowSmarter: transforming cities for a smart, sustainable Europe

Project lifetime: January 2015 - December 2019

GrowSmarter is an European project that has received €25 million in funding from the European Union's Horizon 2020 research and innovation programme. The project aims to apply a combination of technologies for energy saving, reducing environmental impact and improving quality of life in Smart City environments as a pilot, with the aim of making them replicable in other districts and cities in the future.
The cities chosen to lead this project were Barcelona, Stockholm and Cologne, which will act as "lighthouse cities" (Lighthouse), with the implementation of 12 solutions, in the field of energy rehabilitation of self-sufficient buildings and districts, integration of urban infrastructures and sustainable urban mobility.
The project will encourage the implementation of innovative solutions around several changes, especially in the energy sector, which will help to promote, in an integrated way, initiatives of various kinds with the intention of replicating in other cities in Europe. Barcelona, in particular will focus on how to use new technologies to become a Smart City and will develop projects in different fields. In the field of energy, the project plans to rehabilitate more than 20,000 m2 of residential and tertiary buildings. In the area of infrastructures, the development of a global platform at city level for the management of city infrastructures and data from different sources, which can be used to provide new services to citizens and businesses, should be highlighted. In the field of mobility, the aim is to achieve better traffic management and optimisation, as well as to implement infrastructures to promote vehicles powered by alternative fuels.

Consortium members: Partnership is composed of 36 partners combining a large variety of entities including town halls, professional groups, research centres, universities and companies from different fields: energy, transport, telecommunications and others.

Project website: http://www.grow-smarter.eu/home/

Bidelek 4.0

The Bidelek 4.0 project is part of the Basque Government's commitment to promoting the industrial and technological development of the energy networks of the future, in accordance with the

Industrialisation Plan approved by the Basque Parliament and the 3E2030 Energy Strategy, which aims to diversify energy sources and reduce the use of oil derivatives. This investment effort will serve as a driver for the development of the local industry through innovation and the design of future equipment and solutions and will enable Basque industry to remain a world technological benchmark.

The objectives of this initiative are:

- To ensure that the greater digitisation of electricity networks allows for the efficient integration of self-consumption and other distributed energy resources, providing new services to customers who are increasingly better informed and more aware of efficiency and sustainability;
- Show the way that will make the distribution networks the vehicle capable of achieving the transition to clean and sustainable energy;
- Demonstrate the functionality of new technological solutions that increase the quality of service and the added value of electricity for customers;
- To put into practice the evolution of the current electricity distributors towards their future role as Distribution System Operators;
- Maintain the technological leadership position of the Basque energy capital goods industry.

Consortium members: Basque Energy Board, Iberdrola and the Provincial Council of Bizkaia

Bidelek 4.0 is a local project, which will be developed in the Basque Country and will contribute to progress towards greater decarbonisation of society, whose main lever is the electrification of the economy.
More than 25 companies will participate in this innovative project, which will be a worldwide technological benchmark and will promote the Basque Country's capital goods and energy infrastructure industry.
Following the success of Bidelek Sareak, which demonstrated the value of smart meters and automated grids, Bidelek 4.0 will provide greater benefits for consumers and grid users.

Project website: not developed yet, a few information can be accessed under: https://www.iberdrola.com/sala-comunicacion/noticias/detalle/ente-vasco-energia-iberdrola-diputacion-foral-bizkaia-acuerdan-seguir-apostando-digitalizacion-electrica-bidelek-4-0-

SENSIBLE: Storage ENabled SustaInable Energy for BuiLdings and communitiEs

Project lifetime: January 2015 - June 2018
Funding: European Commission, H2020 programme.

Project aimed at the efficient integration of different storage devices (electrochemical, electro-mechanical, thermal) and energy vectors (electricity, gas) through advanced energy management systems in buildings and network operation (i.e. intelligent network management and demand response) through innovative ICT tools.
The SENSIBLE project clearly showed that the objectives of Europe 2030 can be achieved locally by the intelligent integration of existing small-scale storage technologies into the energy distribution grid, as well as into homes and commercial or industrial buildings.
The project has received funding from the
An important aspect of the project was how to connect local storage capacity to energy markets in a way that will lead to sustainable business models for small-scale storage deployment, especially in buildings and communities, that will be solved through an innovative ICT platform that provides

distributed communications, procurement and grid processing capabilities, based on the new concept of "Real Time Distributed Services".

The innovative project results were:

- development and demonstration of power electronic technologies that enabled the full set of storage functions;
- development of methods for safe storage integration into buildings and power networks;
- development and demonstration of advanced ICT tools for the control and management of distribution networks;
- development and demonstration of power and energy management in buildings and local communities;
- development and demonstration of locally-focused energy market services;
- definition of specifications enabling new distributed energy storage products, markets and businesses.

Consortium members: Coordinated by Siemens, the SENSIBLE project was composed of 14 partners ranging from different fields such as business, universities or technology centres. Business partners were Siemens, Indra, Adevice, Armines, EDP Labelec, EMPOWER, GPTech and K&S. Universities or technology centres were INESC TEC, Universidad de Sevilla, The University of Nottingham, Meadows Ozone Energy Services (MOZES), Technische Hochschule Nurnberg.

Project website: https://www.projectsensible.eu/

3.5. Future IoE scenarios, technologies, and business models

The application of IoT to energy is having a growing but moderate impact in Spain. The major electricity companies are leading the way in the introduction of Big Data and IoT in their production and distribution systems, especially for renewable energies. It is estimated [15] that the energy sector will undergo profound changes in the coming years and will evolve towards a new paradigm focused on the active customer, efficiency and environmental sustainability, as technological innovations are introduced throughout the energy ecosystem and its value chain. However, the digital integration of all processes and data is still a major challenge for the Spanish energy sector.

Current electricity systems are moving towards highly efficient and automated scenarios for electricity transmission and distribution networks, resulting in a resilient and interactive network of services, capable of controlling information flows and data exchange in real time. Distributed generation systems, such as renewables, microgeneration and power cells, will be particularly important [16].

Regarding business sectors, further progress in the implementation of IoE is expected in the following areas:

Smart homes, buildings and cities

In particular, it’s about the monitoring and tracking of consumption, changes in management models, increased and improved communication between users and systems.
New buildings will incorporate in facades, roofs and windows, sensors and active and passive systems to measure the building's energy consumption and its variations in real-time to act and minimise its consumption, as well as innovative lighting technologies, with efficient and low-cost components and

subsystems. Cities and public buildings will intelligently manage lighting, irrigation, transport systems using sensors and real-time information.

Mobility and transports

One of the sector that is going to experience a substantial improvement is the transport industry. Transport is currently the fourth largest sector in terms of IoT investments in Spain. The application of Internet of Things in the transport segment has a direct impact on the sector, transforming how information is collected, analyzed, consolidated and acted upon real-time availability for decision making. Optimizing routes and times, increased security or fuel efficiency are just some of the benefits that transport companies are looking for [17].

With regard to electric vehicles, Spain is one of the world's leading manufacturers of vehicles and the first in Europe and is uniquely positioned to be among the leading countries. According to Nissan estimates, Spain could become the leading European market for electric vehicles by 2020 [18]. In order to materialise this trend, the need for a greater deployment of the network of charging points is highlighted.

In addition, there will also be developments in the field of Vehicle-to-Grid (V2G) technology, which enables electric vehicles to be fully integrated into the electricity grid and to play an active role in electricity services. It also will offer the opportunity for an alternative source of income.

Renewable energy [19]

The extension of an intelligent, efficient and sustainable energy system will make it possible to make better use of renewable energy sources, in particular, hydroelectric, wind and solar energy.

In the field of wind energy, the incorporation of intelligent technology into Wind turbines, automatically controlled by IoE is expected to be promoted. An example might be the use of sensors to know when and how the turbines will operate based on weather prediction, wind speed and other parameters.

Regarding hydroelectric energy, some hydroelectric power plants are already incorporating IoE, through wireless sensors that collect, monitor and communicate the real state of a hydroelectric plant, thus allowing the proper functioning of the plants and preventing any unexpected contingency. IoE also detects climatic variations, as well as water velocity and flow, in order to know and diagnose the conditions and operating mode of the plant.

In the field of solar energy, IoE solutions are also being incorporated. For example, the incorporation of IoE to the solar cells, allows automatic monitoring with sensors that provide different types of information which allows to predict and measure the amount of energy.

Storage solutions

In the coming years, it is expected that there will be significant growth in the development of advanced storage technologies to guarantee network operation and electrical coverage, both for applications in transport and for storing electricity in buildings.

An example of the development in this field in Spain is that of the company MAGTEL which, together with other European companies, is working on an innovation project for the development of a new intelligent energy management and storage system. The project is called DRAGON (Hybrid Storage combining high power and energy densities and integration for smart grids) and is supported by the European Union's Eurostars Programme [20].

Spain's background

Spain is the fifth country in Europe investing in IoT [16], behind Germany, United Kingdom, France and Italy. According to estimates, the IoT market in Spain will exceed 24 billion by 2020. Economic instability and budgetary constraints in recent years have held back investment in this area. However, the economic recovery in the following years is expected to encourage public and private investment and the financing of relevant projects in this area.

The current Spanish energy scene [21] is characterised by: Spain's position as an energy island; a high dependence on external primary energy sources; the limitation of investment in renewable energies in recent years, excess generation capacity or the new regulation for regulated activities.

Important steps have already been taken with the massive deployment of smart meters, with the development of real-time sensors and tools to know the status of the network, but there is still a long way to go in the field of IoE in both public and private sectors.

At the business level, there is still a general lack of knowledge about the potential and developments of IoE, however, there is a clear difference between large and small companies. Most of the large energy companies are incorporating IoE solutions and leading their introduction in Spain, however, SMEs in general have greater difficulties in entering this market. While much of the business sector recognizes the important benefits of adopting IOT technologies for their businesses, it also recognizes that they encounter numerous difficulties in addressing related initiatives. The main barriers include initial costs, or problems related to security and privacy or lack of knowledge [22].

Large companies such as Iberdrola are undertaking a process of transformation of their plants. Through projects to digitize its infrastructure, such as the STAR [23] project (Sistema de Telegestión y Automatización de la Red), Iberdrola has deployed 10.6 million smart meters in Spain. With an overall investment of over 2000 million euros, the company has modernised more than 90% of its meter park and has adapted around 74,000 transformer stations throughout Spain, incorporating telemanagement, supervision and automation capabilities.

Other companies dedicated to the development and implementation of technological solutions are also participating in this market, such as Indra. At the same time, small engineering companies and specialized consulting firms are joining the ecosystem around the IoE in Spain. Finally, it notes that many of these companies, in particular the largest ones, are developing projects around the world and taking advantage of EU support to develop pilot and demonstration projects and to transform the electricity system and its assets.

In Spain, a far-reaching change in the regulatory framework is needed in the next decade as a critical factor in favouring the transition to the new model and taking advantage of the potential of the incorporation of technological developments into the electricity system throughout its entire value chain. The national government must renew and establish new commitments to support renewables and the incorporation of recent innovations in the electricity system, to help IoE take off.

Experts in the field [17], consider that in Spain it is necessary to implement measures to favouring the transition into a new model. Several types of actions such as:

- Actions related to regulation and normative;
- Actions to promote the development of the productive sector;
- Actions for the development of competitive products and services globally
- Actions for dissemination, education and social awareness

must be carried out in the coming years so that Spain can be positioned in a competitive position in this sector.

At the regulatory level, some initiatives of a partial nature are being carried out. However, there is no integrated or specific strategy to support the development of the internet of energy and its economic sector. Among others, the following actions stand out at the national level:

Recently, the Spanish Government has approved the Innovation Plan for Transport and Infrastructure 2017-2020 [24], which includes specific measures for the incorporation of intelligent technologies to promote energy generation, storage and distribution systems. the plan seeks to promote digitisation, the Internet of things, intermodality and energy transformation and the development Intelligent Platforms.

Throughout 2018, the Spanish government will launch VEA Plan to encourage the purchase of alternative energy vehicles and aid aimed at financing actions to support energy-efficient and sustainable mobility. Moreover, Spain will present in Brussels a plan to expand the Spanish network of charging infrastructure for electric vehicles which will represent an important step forward in alternative mobility [25].

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4. Internet of Energy in ITALY

4.1. Awareness of IoE in Italy

Although there is no technical documentation, issued by Italian companies, talking explicitly about IoE, the most of them seem to be well aware of the Smart Grid concept. Therefore, there should be a wise awareness towards smart grid future and so, being Internet of Energy defined also as the development of a Smart Grid 2.0 it might be assumed that the companies' knowledge about IoE is implicit in the concept of Smart Grid.

Moreover, some Italian companies (ENEL and FIAT) have been involved in the projects within the IoE framework, such as ARTEMIS project, which proposed a novel architecture and distributed embedded systems that implement the real-time interface between smart energy grid and a cloud of devices/loads at the edge that can be plugged and charged to any source of electric energy. Term IoE was therefore introduced and reflected accordingly.

Recently, Italian electric utility Enel together with German power provider Eon have traded electricity over a new market place, which uses blockchain technology, demonstrating that Italy is really in the vanguard in the IoE field [1]. In fact, the Internet of Energy technology also aims to further increase the intelligence and automation at the consumer level and provides a direct access to the energy services market. The full implementation of the Internet of Energy will allow for not only bidirectional communication and energy flow between the consumer and the energy provider, but also directly between consumers.

4.2. Overview of the existing IoE technologies and scenarios in Italy

There are different applications of IoE technologies in Italy. In this section, we are going to discuss about the application sectors related to some projects in the IoE framework showing some ongoing projects in each sector.

IoT devices for the integration of renewable energy in power grids

Renewable energy generators, such as solar and photovoltaic cells and wind turbines, are progressively integrated into today's power grid. They have recently attracted considerable attention in smart grid studies, due to climate changes and environmental pressures.

Power generation patterns of renewable energy sources (solar and wind), which are distributed over the grid, are intermittent in nature and dependent on location and climate, so they pose significant challenges for the predictability and reliability of the power supply.

Such problems are addressed using the seamless interoperability and connectivity provided by the IoE technology. Furthermore, the IoE technology uses sensors to collect real-time weather information, which help in forecasting energy availability in the near future (s. Figure 1). Actually, in Italy some system operators are installing smart sensor on high-medium voltage towers to collect weather information. The aim is to develop predictive models to facilitate the integration of weather-dependent renewable energy.

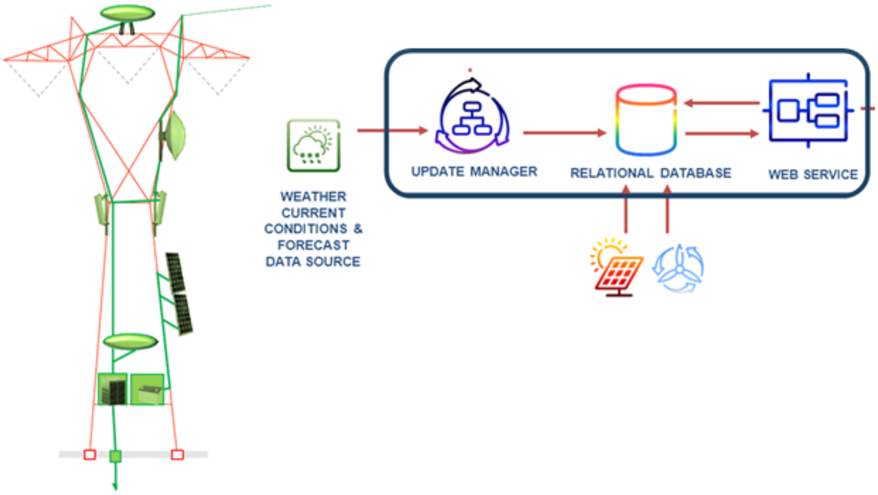

Fig. 1: Integration of IoT into the grid (SOURCE?)

IoT devices for transmission tower protection and maintenance

Another application of IoE concerns the transmission tower protection in order to enhance the safety of transmission towers from physical damage by plundering of components, natural disasters, unsafe construction and growing trees under the foundations. IoE technology can provide remote monitoring in addressing these security threats. The IoE-aided transmission tower protection system contains various sensors which generate early warnings of threats to high voltage transmission towers, enabling quick responses.

A pilot project is being studied by the Italian transmission system operator for electricity for the monitoring of the electrical infrastructure through smart sensor embedded on high voltage towers. The aim is to develop a system in which the sensors detect any threat, and send the relevant signals to a sink node. As can be seen from the figure 2, the sink node receives these signals from the sensors, processes them into data and transmits the data to a monitoring center. The transmission of the signal takes place through the optical fibre installed on power lines.

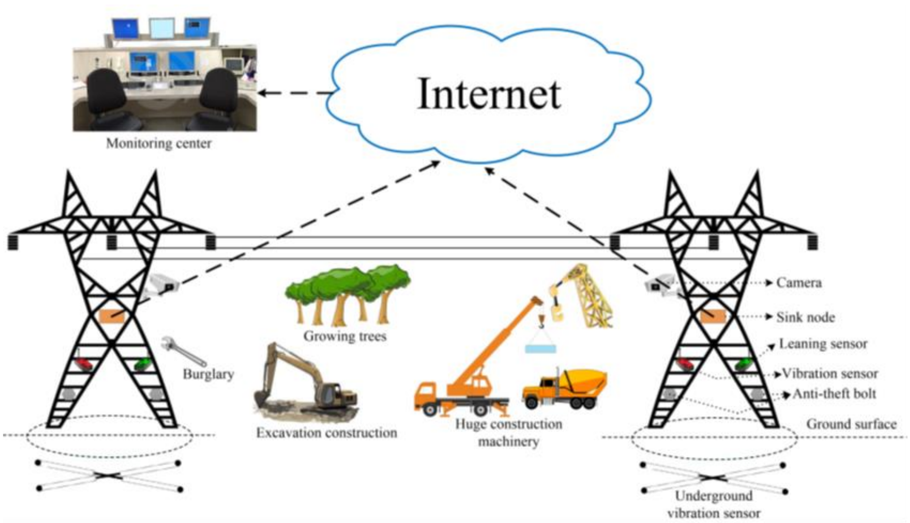

Fig. 2: Monitoring of the electrical infrastructure through smart sensor

Energy storage

One of the cutting-edge capacities of the Internet of Energy is the storage of energy for later use which is becoming a necessity for the full utilisation of the capabilities of renewable sources whose output is intrinsically variable and intermittent [2]. The growing increase in electricity generation plants using non-programmable renewable sources (NPRSs) have had an increasingly tangible impact on the dispatching of electricity and in general on the safe operation of the National Electricity System. Moreover, in many cases energy produced by renewable power plants cannot be used due to its stochastic nature. In this respect, Italy has identified energy storage as one of the possible solutions to the problem, planning the installation of new storage technologies connected to the National Electricity Transmission Grid in order to optimize generation from renewable sources and at the same time ensure increased security management of the Electricity System. The innovative nature of using such systems on the national transmission grid has led to a first experimental phase for the realization of two pilot projects, needed to test and validate the use of electro-chemical storage at the “utility-scale” level [3].

Electric vehicles as energy storage

Energy Hub, Energy Cloud and Energy Storage Cloud concepts constitute the basis of the Internet of Energy grid architecture. For such reason, the validation and assessment of the electro-chemical storage technologies is an important topic, in particular, for promoting the integration of electric vehicles into smart grids.

The Energy Hub combined charging stations, improved operating efficiencies and cost savings, accelerated fault finding and improved power quality as well as facilitated the integration of renewable and distributed generation sources in the city context using micro/nano grid deployments and cloud energy source distribution. Energy Storage Cloud allows the seamless integration of local and mobile energy storage (distributed energy banks to a standalone or part of the buildings/homes/parking/poles infrastructure, second-life battery packs, dynamically generated battery banks-fleet of vehicles connected when charging or when parking) into the Energy Cloud using the communication interface and moving towards energy as a service implementation.

Also in this sector, Italy has emerged as a leading country with its demonstrated technological potential in the field of electric mobility. An Italian distributor of electricity and the Italian Institute of Technology have teamed up on a corporate electric car sharing pilot with vehicle-to-grid (V2G) charging [4]. The project claims electric vehicle owners will be able to sell stored energy back to the grid at a profit. A battery-powered vehicle uses its excess rechargeable battery capacity to provide power to the electric grid in response to peak load demands. These vehicles can then be recharged during off-peak hours at cheaper rates while helping to absorb excess night time generation. Here the vehicles serve as a distributed battery storage system to buffer power.

This concept is visualized in the figure 3 as follows:

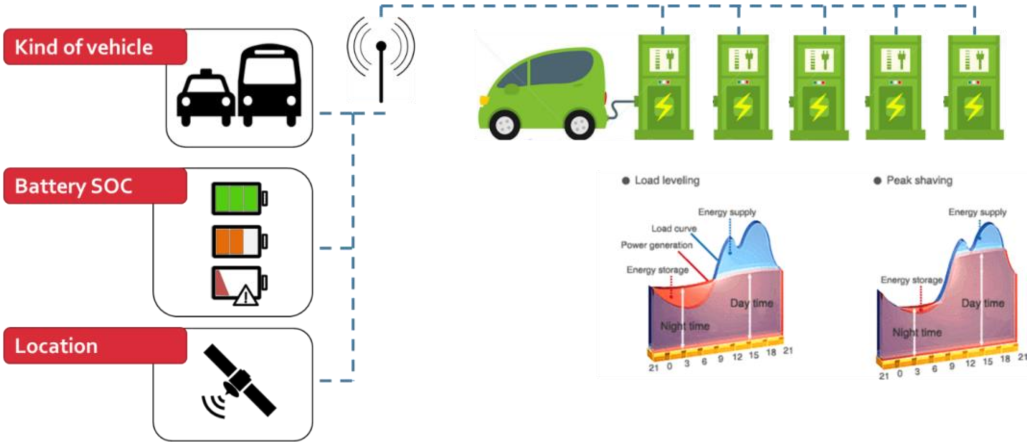

Fig. 3: V2G charging [4].

The concept allows V2G vehicles to provide power to help balance loads by charging at night when demand is low and sending power back to the grid when demand is high (peak shaving).

IoT Microgrid and Energy Blockchain

A microgrid is a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously. A microgrid connects to the grid at a point of common coupling that maintains voltage at the same level as the main grid unless there is some sort of problem on the grid or other reason to disconnect. A switch can separate the microgrid from the main grid automatically or manually, and it then functions as an island. A microgrid not only provides backup for the grid in case of emergencies, but can also be used to cut costs, or connect to a local resource that is too small or unreliable for traditional grid use. A microgrid allows communities to be more energy independent and, in some cases, more environmentally friendly.

Nowadays, about 300 micro-grid projects have been developed worldwide, adding up to a total capacity exceeding 1.5 gigawatts [5]. Italy also is active in the development of microgrid with project aimed at the development of a hybrid power plant that combines PV solar, wind power, Batteries for the Energy Storage System (BESS) and a diesel generator. It will be connected via an energy management system that will create an isolated micro-grid capable of providing 24 hours of continuous energy. The microgrid is equipped with communications platform, cloud, core and IoT software solutions to provide microgrid management, integrate communications for the industrial IoT and grid-control.

Concerning blockchain, the most interesting project is the Isernia Project, where Enel is developing its first smart grid in Italy. The project aims at providing a new approach for distributed generation by connecting and managing a renewable energy generation network and storage systems using ion lithium batteries, as well as by encouraging distributors and customers to play a new role as prosumers who produce and consume energy [5].

4.3. IoE best practices and their adoption in Italy

Smart Grid & Smart Island

The concept of smart grid is essential for the next step phase of Italy’s electrical distribution system. Smart Grid initiatives refer to developing electricity grids that may be connected to the electricity system or not, with the aim of an intelligent management of existing electrical resources both in terms of production and loading. E-Distribuzione, the primary Italian distribution system operator, is currently involved in numerous smart grid projects such as the PAN (Puglia Active Network) project. The project aims at the creation of an intelligent energy network and an innovative management of the distribution of electricity throughout the southern region. These innovations will have an important impact on the environment, leading to lower carbon dioxide emissions and limiting the need to build new cabins and lines.

The electricity transmission grid operator TERNA has developed the Smart Islands project, consisting of a strategy for a modern, intelligent, innovative, and high-tech future for islands which are not connected to the national electricity grid [6]. Terna together with IBM, have launched a project for the updating of the Giglio Island's electricity grid based on ICT solutions that integrate green sources, electricity storage and urban mobility in relation to the territory. Renewable sources, electricity storage systems, electric vehicles and high-tech solutions to manage "Active Demand" (that also involve water desalination) form a mix of innovative solutions that will make islands smart [7].

Smart Metering

Started in 2001, ENEL Telegestore is today the largest ever automated Metering Infrastructure deployment worldwide involving more than 30 million customers in Italy [8]. The key element of the smart metering evolution is the Power Line Communication Modem (PLCM) technology able to transmit data through the power line network.

Italian Regulatory Authority for Electricity Gas and Water (AEEGSI) has recently approved Enel's plan regarding the nationwide substitution of the old meters with new, "smarter" ones, called Open Meters. The new Open Meters will provide more detailed and frequent data exchange: clients will be able to interact with their providers in order to learn about their consumption rates in real time. ENEL chose PLC technology to transfer smart meter data to the nearest data concentrator and GSM technology to send the data to data centers [9].

In the following table, other Italian pilot projects on smart grid are briefly described [10].

Company	**Period**	**Investment**	**Description**
A.S.SE.M S.p.A	4/2011 12/2014	1.3 million €	Setup of devices and communication system on a primary substation providing for the exchange of information between the power grid and electricity generators from renewable energy sources.
A2A	1/2011 12/2014	0.8 million €	Intervention on a sector of power grid (about 100 km) involving active connected user to develop a smart grid prototype based on communication systems in order to maximize energy efficiency and the use of renewable energy systems connected to the grid.

A2A	1/2011 12/2014	1.2 million €	Intervention on different primary substations for the integration of renewable energy sources and for the power grid automation during both normal exercise and faults scenario.
ACEA Distribuzione	10/2010 12/2014	3.5 million €	Specific intervention on two primary substations for the power grid automation. Moreover, the project foresees the realization of storage system for the development of electric mobility.
ENEL Distribuzione	1/2012 12/2014	2.7 million €	Installing a control system on a primary substation for the monitoring of both active and passive power users.

4.4. Research and development projects on IoE in Italy

ADDRESS: Active Distribution network with full integration of Demand and distributed energy RESourceS

ADDRESS was an European Research, Development and Demonstration project (2008-2013) coordinated by the Italian company E-Distribuzione. It aimed to define, develop and demonstrate how demand response could make the consumption of millions of electricity customers more flexible for the benefits of the whole electricity system. The ADDRESS partners have designed a complete technical and commercial concept to support active demand: consumers can provide active demand by making their electricity consumption more flexible, since adequate devices (hardware and software) control the operations of selected home appliances, as well as local electricity generation and storage systems when relevant (prosumers) [11].

Project lifetime: 2008 - 2013

INERTIA: Integrating Active, Flexible and Responsive Tertiary Prosumers into a Smart Distribution Grid

INERTIA aimed at delivering an efficient Distribution Grid overlay control/management infrastructure that maximized the response capacity of the vast small commercial prosumer base (tertiary buildings, offices etc), presenting incentives and delivering benefits through their automated active participation in the energy market. The project introduced the Internet of Things principles to the Distribution Grid Control and Demand Side Management Operations. It provided an overlay network for coordination and active grid control, running on top of the existing grid and consisting of distributed and autonomous intelligent Commercial Prosumer Hubs [12].

The project has been funded under FP7 programme of the European Union.
Project lifetime: 2012 - 2015

4.5. Future IoE scenarios, technologies, and business models in Italy

The growth of the electric power production of electricity from renewable sources has implied important consequences and challenges for the Italian electrical network. Nowadays, renewable sources cover 27% of Italy's national energy consumption, with about 550,000 prosumers already connected to the network [13]. In Italy, such as in other European countries, the low predictability of renewable power sources has introduced new challenges for the management of a network that had been engineered and implemented according to the characteristics and requirements of a centralized generation model. Therefore, it is crucial to encourage the development of new technologies for the evolution of the country electrical network in order to improve sustainability, efficiency and security.

As showed in this report, thanks also to the found obtained through European projects, Italy has already started to adopt smart technologies at all the three phases of the electrical network, from transmission to consumption and user.

The primary areas of investment in Internet of Energy in Italy are integrated in the Smart Grid concept and include the integration of renewables, grid automation (primary and secondary substations) and operating centers. The key utility player in the smart grid arena in Italy is ENEL: with over $84.1 billion in revenues it is the largest utility in Italy and one of the biggest and most innovative worldwide. The company, the largest utility and the largest provider of electric energy in Italy, has recently announced a 300 million Euros project for installing, by 2022, 14,000 charging stations for electric vehicles. It has been estimated that developing an adequate recharging infrastructure in Milan would cost over $5.5 billion [14].

The table below summarizes a study [10] conducted by Milan's Politecnico University on potential investments in IoE key enabling technologies in Italy from 2012 to 2020, ranging from a minimum of $19.5 billion to a maximum of $78.2 billion.

TECHNOLOGIES	MARKET FORECAST UNTIL 2020	
	MINIMUM (MLN $)	MAXIMUM (MLN $)
Smart inverters	714.5	6,391,8
Asset optimization systems	521.8	782.7
Evolved Transmission Layer Systems	130	326.1
Distribution Layer Systems	6,500	10,435
Demand Response Management Systems	2	3.9
Evolved Advanced Metering Infrastructures	2,348	3,261.1
Home Management Systems	4,565.6	45,656
Storage Systems	5.217.8	9,131

(Source: www.energystrategy.it – Politecnico di Milano) exchange rate: USD 1 $ = EUR 0,75 €

Smart Inverter can interact with the grid preventing a photovoltaic system from going off-line when it doesn't have to. By doing so, they can actually make the grid more stable, by preventing the sudden deterioration of voltage and frequency. Nowadays, smart inverters have no penetration in the Italian market, because they can be adopted only by owners of plants powered by renewable sources in low tension. However, the studies conducted by Politecnico di Milano show that even in the least favorable scenario smart inverters have a considerable potential and are destined to play an important role in the Italian future electric scenario.

Regarding the smart meter market, currently about 32 million smart meters are installed in Italy, mainly as a result of the Telegestore remote management project, developed by the E-Distribuzione [15]. The great majority of the devices deployed in 2017 use powerline communication (PLC). Already in 2018, PLC smart meters' market is however expected to start to decline. Instead radio-based technologies like 4G cellular will increase their market shares [16].

Another key technology for the development of IoE in Europe is Home Management System (HMS), a home automation system that acts as an interface between the smart meter and the various appliances coordinating the management of the latter. To date, HMS are practically absent in Italy, mainly because of the lack of a communication standard which would regulate the exchange of information between the electrical network and the HMS. However, there is a growing interest in this solution. In fact, Italian electric operators are cooperating with telecommunications companies in order to define an open and standard protocol for internal communications between smart appliances, smart meters and the whole grid.

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5. Internet of Energy in PORTUGAL

5.1. Awareness of IoE in Portugal

The concept of 'Internet of Energy (IoE) is recent and, although it is gaining notoriety at EU level, in Portugal there is very limited information available.

In 2001, the Portuguese government launched a new energy policy instrument – the E4 Program (Energy efficiency and Endogenous Energies), consisting of a set of multiple, diversified measures aimed at promoting a consistent, integrated approach to energy supply and demand. By promoting energy efficiency and the use of renewable energy (endogenous) sources, the program sought to upgrade the competitiveness of the Portuguese economy and to modernize the country's social fabric, while preserving the environment by reducing gas emissions, especially the carbon dioxide (IEA, 2016). While from 2002-2007 the main priorities were focused on the introduction of natural gas (aiming at progressively replacing oil and coal in the energy balance) and liberalization of the energy market (by opening this former state-owned sector to competition and private investment), the emphasis shifted for the next 5 years was on energy efficiency (supply and demand sides) and use of endogenous (renewable) energy (IEA, 2016).

Renewable energy in Portugal was the source for 25.7% of energy consumption in 2013 (EUROSTAT, 2015). In 2014, 63% of Portugal's electricity needs were supplied by renewable sources (Garcia, 2014). In 2016, 58% of power produced in Portugal came from renewable sources, an increase against the previous year (50.4%), while renewable energy consumption represented 27.2% (early data) of total consumption (European Commission, 2017).

During February 2016, an equivalent to 95% of electricity consumed in Portugal was produced by renewable sources such as biomass, hydropower, wind power and solar power. A total of 4139 GWh was produced by these sources (Baptista, 2016). In May 2016, all of Portugal's electricity was produced renewably for a period of over four days, a landmark achievement for a modern European country (Nesten, 2016).

The renewable energy produced in Portugal fell from 55.5% of the total energy produced in 2016 to 41.8% in 2017, due to the drought of 2017, which severely affected the production of hydroelectricity (Carvallho, 2017). The sources of the renewable energy that was produced in Portugal in 2017 were Wind power with 21.6% of the total (up from 20.7% in 2016), Hydro power with 13.3% (down from 28.1% in 2016), Bioenergy with 5.1% (same as in 2016), Solar power with 1.6% (up from 1.4% in 2016), Geothermal energy with 0.4% (up from 0.3% in 2016) and a small amount of Wave power in the Azores. 24% of the energy produced in the Azores is geothermal (DGEG/MEc, 2018; Açores, 2018; Lusa, 2018).

Portugal committed to close all the country's coal producing facilities by 2030, making it almost completely reliant on renewable energy in the incoming years (Silva, 2018).

A new strategy emphasizing renewable energy and energy efficiency has focused efforts on meeting national and European energy policy objectives, as Portugal seeks also to lower investment costs and greater national competitiveness. The new strategy includes proposals to reinforce interconnections with transnational European electricity and natural gas networks, and measures to promote economic and environmental sustainability (IEA, 2016).

Following the economic crisis, Portugal was left with a substantial tariff deficit as retail electricity tariffs were set below costs, including subsidies to renewables. Portugal's plan to address the tariff deficit was the outcome of a negotiation process with industry stakeholders. Eliminating the tariff debt by 2020 is a significant challenge (IEA, 2016).

5.2. Overview of the existing IoE technologies and applications

Internet of Things (IoT)

The IoT is considered as the technology that is going to make an enormous difference, transforming all sectors of activity and the personal lives of its users in the coming years. The IoT market in Portugal has enormous growth potential, and the main industries and applications that can benefit include retail, healthcare, smart cities, and energy, among others (Hinchliffe, 2018).

While retail may be the most established IoT application, smart cities may have the most demand. Public infrastructures in Portugal can leverage IoT business models in different smart city domains such as smart transportation, smart grids, and utilities (Hinchliffe, 2018).

One different approach in which Portugal can be successful while leading with IoT for smart cities is in the development of hardware technology for devices that collect information and data for specific applications (Hinchliffe, 2018).

Esri Business Director in Portugal, Nuno Pereira, noted the exponential increase of the utilization and synergies between GIS and IoT sensors as a case of success, and it already exists nowadays as this arrangement is applied in the water sector in Portugal and it is helping to reduce losses, maintenance and planning costs (Hinchliffe, 2018).

In Portugal, there is a vast amount of projects inside the Open and Agile Smart Cities (OASC) network, from parking sensors to pedestrianized streets and accesses as well as smart lighting. For example, the report lists Águeda, a city located in Aveiro, as a very interesting case since it is develops many solutions in the arena of smart cities, especially pilot projects for the city, according to OASC task force representative Margarida Campolargo (Hinchliffe, 2018).

Águeda has a very interesting project concerning smart lighting. It detects if there are people in the street and increase or decrease light intensity. It can shut down certain areas remotely if a construction or repairing is required. There is no need to send a technician to the site. If a lightbulb stops working, it is possible to know which one it is. Overall, it is a very different dynamic from most other cities. Águeda, Lisbon and Porto are among the most involved cities when it comes to this kind of technology (Hinchliffe, 2018).

The use of sensors is a key component across many IoT applications and industries including all the above, as well as in energy. Since industrial companies need large amounts of energy in order to function, the cost of energy is one of the main concerns for most of the Portuguese industrial companies because it has a direct impact in the revenue and weakens the competitive power facing global concurrent industries with more inexpensive energy (Hinchliffe, 2018).

In order to improve the industry companies, there is also a need to identify clusters, access to credits at a reasonable price, raw materials and energy with amounts more similar to the rest of the Europe, with less bureaucracy and better judicial system (Hinchliffe, 2018).

On the domestic front, energy in houses can be managed and controlled through sensors; smart thermostats that detect when the owners are not in the house and regulate the temperature to conserve energy, for instance (Hinchliffe, 2018).

In Porto's energy sector, "the cost reduction made possible [by the IoT] will have more impact on public illumination, and in the water sector it will have more impact on irrigation. These are the sectors I would enumerate as the sectors more easy to tackle and more important," according to Porto Vice-Mayor and City Councillor for Innovation and Environment Filipe Araújo (Hinchliffe, 2018).

Smart Metering

Lisbon's district Parque das Nações was chosen by EDP Distribuição to pilot the project among around 100 customers, during 2017. The project is the result of a partnership between four other major companies: NOS, Huawei, Janz CE and U-Blox. The solution combines emerging technologies with the smart metering of electrical energy and the latest generation networks to oversee the electricity network (World's first operational NB-IoT smart meters in Portugal, 2017).

EDP Distribuição is using the technology for a pilot project as part of the Upgrid project of the Horizon 2020 Programme of the European Commission. The infrastructure network, using narrow band Internet of Things (NB-IoT) technology has been installed by NOS, based on Huawei's and Janz CE technology. Huawei and Janz CE designed and manufactured the new meter, using modules from u-blox. By doing so, NOS became the first operator in Portugal to test the 4.5G-IoT technology on its network infrastructure (World's first operational NB-IoT smart meters in Portugal, 2017).

The Upgrid project focuses on addressing the constraints and needs arising from poor observability of LV grid, local accumulation of distributed generation, risks and difficulties in managing the distribution network, aging infrastructure and social and environmental restrictions that inhibit the grid development. To be successful, Upgrid proposes an open, standardised and integral improvement of the LV grid. The project, led by Iberdrola Distribución, S.A.U, started in 2015 and ended in 2017 (World's first operational NB-IoT smart meters in Portugal, 2017).

NB-IoT, a low power wide area (LPWA) wireless technology, offers a number of benefits including a battery life of up to 10 years, a gain of 20dB over conventional GSM networks and support to more than 100,000 connections per cell (World's first operational NB-IoT smart meters in Portugal, 2017). Based on optimised and bi-directional communication, NB-IoT also helps to overcome challenges linked to the development of intelligent networks and smart energy. For instance, the automatic detection of power failures helps to improve response and restoration time, thereby improving customer satisfaction. This is especially helpful during storms when quicker detection is needed so that teams can be allocated to the areas more efficiently (World's first operational NB-IoT smart meters in Portugal, 2017).

NB-IoT supports online measurement of consumption, supporting various values per hour, and a range of energy events and statistics. In addition, demand response functionality is improved, enabling the installed capacity to be managed almost in real time. This function will go a long way in supporting the increase of electric vehicles and renewable energy. On a large scale, the solution will support a mature eco-system and technological evolution, achieved by perfecting its features and introducing new elements, in accordance with the requirements of the smart grid (World's first operational NB-IoT smart meters in Portugal, 2017).

Another benefit of NB-IoT is improving energy consumption efficiency. The district is already covered by NB-IoT and has been equipped with two NOS base stations, which provide NB-IoT coverage. Intelligent energy management in the homes of these customers, who will also play an active role in helping to improve their energy consumption efficiency, represents a relevant practical example for this technology. Manuel Ramalho Eanes, board director of NOS, says the project will help improve the efficiency of energy consumption in Portuguese homes. Energy efficiency is central to Portugal's energy strategy, according to the International Energy Agency (World's first operational NB-IoT smart meters in Portugal, 2017).

Smart Grid

EDP Distribuição (EDPD) is part of the EDP Group and Portugal's incumbent DSO (accounting for 97% of the market with more than 6 million customers). EDP Distribuição coordinates the Project InovGrid (http://www.inovgrid.pt/en) which entails a large-scale smart grid demonstration project in Évora (Portugal) and demonstrates Smart Grid concept by means of integrated management tools that (InovGrid, 2014):

- Improve service quality;
- Promote distribution network remote management;
- Reduce operating costs;
- Promote a more active role for customers/producers;
- Support new commercial services;
- Increase energy efficiency;
- Exploit the potential of distributed generation (DG);
- Enable the integration of electric vehicles charging network;
- Promote the environmental sustainability through the increase in energy efficiency;
- Foster the proliferation of micro-generation;
- Support the renewal of technologies and the improved exploitation of current capabilities.

The Portuguese city of Évora, with a population of 55 thousand and 1.307km2, was chosen to be the first Iberian Smart City – Évora InovCity – where an automated meter infrastructure was deployed. There are around 32 thousand electricity customers with an annual consumption of approximately 273GWh. Around 35.000 smart meters and 340 distribution transformer controllers (DTC´s) were installed to operation (InovGrid, 2014; Staff, 2017).

Regarding demand side management (DSM) functionalities, 3.550 facilities are fitted with demand response or energy efficient solutions, comprising different customer profiles, including residential, commercial and small industrial. The project also includes 70 V2G enabled EV charging points, 250 DG monitoring and control units and 2 primary distribution substations. A great number of stakeholders adopted new technologies and services, namely prosumers, universities, municipalities, subcontractors and service providers (InovGrid, 2014; Staff, 2017).

EDP believes that smart grids have the potential to contribute to the energy sector sustainability and InSmart goals namely by: increasing energy efficiency; reducing CO_2 emissions; reducing costs and increasing operational efficiency; integrating a large share of dispersed generation as well as electric vehicles; supporting the development of new energy services; and empowering customers to a more responsible and efficient energy use (InovGrid, 2014; Staff, 2017; Paulo Lúcio, 2011).

Being a distinctive project in the European landscape, the InovGrid project was chosen by the Joint Research Center (JRC) of the European Commission to be the support of the development of its

"Guidelines for Conducting a Cost-Benefit Analysis of Smart Grid Projects" [Report EUR 25246 EN], a comprehensive assessment framework of smart grid projects centered on a cost-benefit analysis (InovGrid, 2014).

InovGrid project aims at the development of InovCities, where intelligent network management, energy efficiency and renewable sources integration are key drivers. Évora was the first InovCity to be implemented within InovGrid project (Paulo Lúcio, 2011).

Electric Vehicles

The largest EV-related effort in Portugal, the MOBI.E electric mobility model was developed by INTELI, a Portuguese think tank, as a fully integrated and totally interoperable system of electric vehicle charging infrastructure, service providers, and intelligent electric grid management. The Portuguese Government and MOBI.E partners believe a global strategy and an electric mobility action plan are needed, and Portugal is poised to share its experiences. The MOBI.E smart integration between mobility and energy systems will result in using vehicles as a "decentralized mega-battery" that can store excess renewable energy for return to the grid during periods of high electricity demand and charge the vehicle batteries during periods of low demand when the electric grid is supplied by renewable energy. With a single card, a user may charge the battery of any electric vehicle at any charging point around the country with electricity supplied by any retailer (IEA-HEV, s.d.).

The MOBI.E's charging network is very concentrated in Portugal's biggest cities, Lisbon and Porto, and is composed mainly by slow 3,68 kW EVSEs. The more modern 22 kW EVSEs exist but are still very scarce. In August 2017, the 100 most used EVSEs were replaced by the new 22 kW EVSEs presenting two charging type 2 sockets, allowing a simultaneous charge of two electric cars. 202 new 22 kW EVSEs (404 type 2 sockets) were installed. This approach allows the MOBI.E charging network to be present in the whole country, within all its 308 municipalities, namely 278 in mainland Portugal and 30 in the autonomous regions of the Azores and Madeira. In the end of 2017 MOBI.E had installed 1.700 type 2 sockets and 50 DC fast chargers across Portugal, being the DC fast chargers mostly present at highway service stations (Lima, 2017).

To date, 10,000 new all-electric cars were purchased in Portugal. The main models are Fiat 500e, Nissan Leaf, Renault ZOE, BMW i3 and Tesla. Alongside with this, Portugal is joining BYD (www.byd.com) for order electric buses. So far, the Public Transportation Services of the Municipality of Coimbra has ordered eight 12m models from BYD with a delivery to be expected in early 2019 (Mironova, 2015).

The public transport company Carris from the Portuguese capital Lisbon has put out an open order for 15 electric buses and their charging infrastructure (Carris, 2016). Portuguese bus manufacturer CaetanoBus will be fighting for the contract. Some of their buses have already been tested in Lisbon, Port, Coimbra, Guimaraes and Braga. The bus was developed in cooperation with Siemens and engineers from the University of Porto. Carris is planning to acquire 460 electrified buses by 2021, 30 with an electric propulsion system. The city of Porto is also planning the purchase of 15 electric buses by 2019 (Mironova, 2015; Carris, 2016).

5.3. Future IoE scenarios in Portugal

The Portuguese energy policy of the first decade of 2000 was marked by significant investments in renewable energy sources. With the onset of the economic crisis and new policy orientations, the main documents of the energy strategy - the National Action Plan for Energy Efficiency and the National Plan of Action for Renewable Energies - have been revised in a logic of economic rationality and sustainability. Economic rationality forms the basis of the new energy model which results, on the one hand, from the combination between the adoption of energy efficiency measures and the use of energy from endogenous renewable sources and, on the other hand, from the reduction of the extra costs that burden prices of energy (Adene, s.d.).

Having in mind the targets for 2020, new goals have been considered and translated into very specific values for Portugal in terms of energy efficiency, with a general target of reducing primary energy consumption by 25% and a reduction of 30% in Public Administration. As regards the use of energy from renewable sources, Portugal is committed to a target of 31% of gross final consumption of energy and 10% of the transport sector by 2020. These objectives, which are drawn up in accordance with the European 20-20-20 targets, aim at simultaneously reducing the country's energy dependence and guaranteeing security of supply by promoting a balanced energy mix (Adene, s.d.).

As regards PNAER 2020, the plan foresees an 18% reduction in installed capacity in technologies based on renewable sources (RES), compared to the previous plan, with the share of renewable base electricity in the new PNAER to be higher (60% vs. 55%), as well as the overall target to be reached, which should be 34.5% (compared to the 31% target) and 11.3% for transport (Adene, s.d.).

March 2018 was a landmark month for the Portuguese renewable energy sector with production exceeding demand for the first time in nearly 40 years. Additionally, the country was powered solely by renewable energy for three days straight in mid-March. These impressive feats demonstrate that Portugal is well on its way to meeting its 2020 renewable energy targets. As part of the Europe 2020 strategy, the EU enacted legislation in 2009 which included a commitment to achieving a 20% reduction in greenhouse gas emissions from 1990 levels. Under this plan, each member state was obligated to set national targets for increasing the share of their country's total energy consumption accounted for by renewable energy. In Portugal's case, the 2020 target was set at 31%. In terms of gross final energy consumption, Portugal has the 7th highest percentage of the incorporation of renewable energy sources among the 28-member states. The country's bounty of natural resources and geographic location has enabled it to become a leader in the production of hydroelectric and wind power. These two sources alone made up 97% of electricity consumption in March. As a result, it is no doubt that Portugal will comfortably meet its 2020 renewable energy targets (Pirner, 2018).

The potential economic rewards of going green are also quite notable. Portuguese electricity prices are some of the highest in the European Union, due in part to the fact that power was generated from imported fossil fuels in years past. However, electricity prices will likely fall as a larger share of energy is produced domestically. This, in turn, will increase citizens' disposable income and reduce operating costs for businesses. Furthermore, the European Union estimates that achieving the 2020 renewable energy targets could result in the direct or indirect creation of 100,000 new jobs (Pirner, 2018).

Currently, electrical systems still maintain the functional structure adopted since the end of the 19th century, in which electric power is produced in distant places by large thermoelectric or hydroelectric power plants, being transported and distributed by electricity grids to consumers (Afonso & Monteiro, 2018). However, because of the high cost of these networks, in many cases it is not feasible to provide power where it is needed, which contributes around 1 billion people worldwide without access to electricity.

Given this scenario and considering that technologies in the field of electrotechnical engineering have evolved a lot in recent years, particularly in the area of power electronics, the energy sector is facing a profound paradigm shift, driven by the concept of electrical networks smart grids, aiming at efficient and high-quality infrastructures that are flexible and sustainable, integrating decentralized energy production from renewable sources (Afonso & Monteiro, 2018).

The integration of renewable energies at the macro level (large hydropower plants, wind farms or solar) and micro-generation alone represents a significant contribution to the sustainability of the energy sector and to the dissemination of smart grids and is also crucial so that populations in remote and poor places have access to electricity (Afonso & Monteiro, 2018).

In order to optimize the generation of energy from renewable sources, especially considering the intermittency associated with its production, in the future it will also be fundamental to combine flexible energy storage systems (reversible hydroelectric plants, which pump water to the reservoirs, batteries, fuel, etc.), allowing harmonization between production and consumption (Afonso & Monteiro, 2018).

Under the Paris Agreement, Portugal has committed itself to reducing greenhouse gas emissions by promoting policies to stop using fossil fuels by 2050, and to do so, it will be essential to invest in energy efficiency and rationality, in renewable energies, in storage systems and electric mobility, supported by smart grids (Afonso & Monteiro, 2018).

Considering the future prospects, Portugal can position itself as a relevant country in the development of innovative technological solutions with global application for the production and use of energy in a sustainable way, thus contributing to greater economic growth in the country. Several companies, institutions and universities in Portugal are working on the development of technologies for the sustainability of the energy sector and for future smart grids (Afonso & Monteiro, 2018).

Against this background, Smart grids are undoubtedly the future of electricity distribution in Portugal.

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6. Internet of Energy in GREECE

6.1. Awareness of IoE in Greece

A short overview of the energy supply in Greece informs us that the two most dominant fuels are oil and coal, while regarding more eco-friendly energy solutions natural gas was introduced in the 90s and raised sharply in 2011 before decreasing again in 2016. During the same year, coal production also dropped and so “the remaining energy production comes from renewable energy sources, of which biofuels and waste production accounts for the largest share, followed by solar, hydro, and wind” (1). Thus, it becomes clear that Greece has adopted a “cleaner” energy production and supply, aligning with the policies and measures that the European Union has put in place. However, there is not yet long-term energy strategy, but the country did participate in a 2050 energy roadmap in 2012, which will be described more in detail later (1).

In any case, it seems that knowledge and information is limited when it comes to IoE. It is possible there are companies of different sectors in the Greek region which are in the process of implementing this technology or shifting to a less fuel or coal or electricity-depended plan. However, currently it seems that there are not a lot of data on the matter. Nevertheless, energy and environment constitutes one of the eight priority arears of the Greek Strategy for Research and Innovation (2014-2020), which identified seven sectors while at the designing phase; 1) energy efficiency; 2) energy production from renewable sources; 3) energy technologies for agriculture and the environment (bio-based industry); 4) energy storage; 5) hydrogen and fuel cells; 6) technologies for smart grids; and 7) fossil fuel impact reduction. These sectors naturally include more sub-sectors and areas, each of them requiring extensive R&D in order to be implemented in the future (1).

6.2. IoE use cases and applications in Greece

Even though Internet of Energy is, as it seems, at an initial stage in Greece, there are already a lot of steps that have been taken and measures that have been implemented towards the development of “smart” cities, aiming not only to keep in line with the priorities set by the EU, but also, at the age of digitalization there are numerous ways by which everyday life can be facilitated and optimized.

Most of these initiatives that are already underway are based on the Internet of Things, which allows devices, through sensorisation, to connect via a main grid to the corresponding smart applications, without the need to create either wired or wireless networks. So, in 2018, the digital update of the Greek cities becomes a central policy for the country in order to achieve energy saving, service efficiency and rapid and transparent issue resolution. For this reason, the Greek Ministry of Digital Policy, Telecommunications and Media has designed a pilot program to be implemented in selected Municipalities, by utilizing the IoT technology.

The goal of this pilot action is to help citizens ameliorate their lives in a two-way manner, both a direct and indirect one. There is a great variety of possibilities and chances for that, with more and more presenting every day. One example would be the smart systems for parking, which solve in an effortless way, an everyday and constant challenge especially in the largest cities, by limiting the time required to find a parking spot; parking sensors which send data to a mobile application inform the drivers where to find a free parking spot (2).

Another more direct way of improvement daily life is the application of “smart” waste management; in other words, bins which operate via a wireless sensor sending data to a main network on the bin’s fullness. Then, via a mobile app, this data is sent to the driver of the waste collection vehicle, so the driver designs the route to take in order to empty the bins that are full and avoid those which are not. Also, it limits the phenomenon of overfilled bins especially in smaller neighborhoods. This sensor-operated bins result in fuel costs reduction as well as CO2 emission decrease. Therefore, a circular process is created which evidently leads to a cleaner atmosphere, a healthy environment and also an aesthetically pleasing result. These bins have been recently installed in strategic places in Larissa, a city of central Greece, as a pilot action. The city suffers from heavy heat during the summer months and the combination of unpleasant odors from the bins create a humid and uncomfortable environment. So, these bins, keeping waste below the surface of the earth, assist also in a lighter and cleaner atmosphere in the city (2).

Other initiatives to be taken in the Greek region, which the population will perceive in more indirect way as they will not drastically affect their everyday life, in the installation of smart light controllers on the street lamps. Via remote control, the light will turn off or on, based on demand and need, in other words based on whether there are any people around instead of just staying on until daytime. This way, energy saving can reach 20% and it can contribute to limiting energy waste. Similarly, installing smart meters on buildings can monitor their energy consumption and map their needs in energy and the ways in which these needs can be met with limited energy waste, e.g. motion sensor lights, temperature regulations in flats according to body temperatures of inhabitants and weather conditions etc. Also, these smart meters will be able to detect any waste or leak in energy and confine it (2).

Therefore, these afore-mentioned practices, and many more, are a priority for Greece in order for it to comply with the technological advancement set by the EU and create “smart” cities that are necessary for the battle against environmental degradation, traffic during peak hours and limited resources. So, this pilot project will be a sound investment towards a sustainable urban development though the technology and applications of IoT, and later IoE.

6.3. Future IoE scenarios in Greece

It has been proven challenging to find IoE future scenarios for Greece, because, as already stated, this new technology has not been yet fully introduced as a concept and a practice in Greece. However, as indicate above, in 2012, the Greek Ministry of Environment and Energy presented a National Energy Plan: Roadmap to 2050, designed by the National Committee for Energy Planning, which sets concrete goals for the future of energy in Greece such as:

- “develop a 60%-70% penetration of renewables in gross final energy consumption by 2050;
- stabilise energy consumption due to energy saving measures;
- relative increase electricity consumption due to electrification of transport and greater use of heat pumps in the residential and tertiary sectors;
- create a dominant share of electricity in short-distance passenger transport and an increase in the share of public transport enhance the energy efficiency of building stock and develop a high penetration of renewable energy sources in buildings;
- develop decentralized production units and smart grids” (2).

These goals have been based on the assumption that the economic recovery will be prompt and will give way to the country to develop in more specific ways as well as to participate in the vision of a digital Europe. However, a decrease in energy is being reported since 2008 which impedes progress in the field of energy efficiency or in energy infrastructures investments, so future scenarios can not be drawn as the energy field is not yet quite clear.

Nevertheless, Greece remains confident that the innovative Internet of Energy is not far behind.

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7. Internet of Energy in LITHUANIA

7.1. Awareness of IoE in Lithuania

Digitalization, Big data, Internet of Things, smart networks are becoming an integral part of the energy sector. Of course, even the most advanced technologies cannot replace electrons yet. However, alongside conventional energy, new unusual elements of information technology are emerging for energy. Technological change is driving the transformation of the energy business and the transition to the Internet of Energy, and Lithuanian energy providers are increasingly becoming aware of this challenge. According to D. Misiūnas, Chairman and CEO of Lietuvos Energija, in the future, energy infrastructure will be fully digitized. Power networks will allow big data analysis to maintain reliable supply in the event of major fluctuations in demand or supply, to communicate real-time price information, to be able to self-identify or prevent malfunctions (1).

Energy needs are constantly rising, and the smart specialization of Energy and Sustainable Environment in Lithuania poses such challenges:

- economical and efficient use of energy
- modernization of energy transmission and supply networks,
- diversification of energy sources,
- reducing the environmental impact of the energy industry.

To achieve these goals, more than just new technologies are needed. It is also important to evaluate changes in people's behavior (2).

Changes in the energy sector brought about by innovation have recently been drastic and have spanned all areas of the energy sector. There has been a revolution in renewable energy, with smart grid technologies providing comprehensive network monitoring and automated network recovery in the event of a failure. Smart meters have emerged to provide instant access to consumption information, and all of these data are used to create solutions for network management, energy trading, consumption management and household services. According to Andrius Adamonis, Business Development Manager of IT Services Company Tieto Lietuva, no cold fusion reactor in Lithuania might be built in Lithuania, but the country has many opportunities, strengths, and potentials, such as information technology and customer service solutions. With the digitalization of the energy sector, energy companies will be managing data arrays containing information on many aspects of energy production and consumption, which will provide a comprehensive picture of the energy service user (3).

D. Misiūnas recalls that the first light bulb in Lithuania was lit just 13 years after its invention. This event marked a new stage in Lithuanian energy history. Today, the country during new fundamental changes in the energy sector. Lithuania, as then, may once again be one of the leaders of change. This is a real opportunity, because the future of energy is not about resources or capital, but about innovation and talent. Lithuanian citizens just need to set an ambitious goal and pursue it consistently (1).

Also, Andrius Adamonis confirms that in order to attract innovation and good ideas to the Lithuanian energy sector, which has great potential, it is important to implement various ideas and business models and to seek cooperation between scientific institutions, talents, energy and information technology companies. Energy companies should look for ways to create in-house innovation labs where employees not only test existing products and solutions, but also attract researchers or startups to experiment together. Energy companies have a lot of "raw material" for experimentation and research in the form of data or even devices, but that data is private inside the companies. The data generated by the energy industry will be used to develop modern digital services. And scientists or just outside enthusiasts often have ideas and even funding, they just need real conditions and the help of energy professionals to test their ideas (3).

7.2. Overview of the existing IoE technologies and scenarios in Lithuania

Energy management

The most notable solutions in this area are:

- Heating, water and electricity network telemetry systems: Elsis TS UAB implemented the project during which the system control center equipment of Litgrid AB, the Lithuanian electricity transmission system operator, was upgraded. During the project implementation, the ELSIS TS installed a new Clarity LED3 Series video wall designed by "Planar Systems" consisting of 36 video cubes instead of the out-of-date operational video wall. Also, new working stations as well as electricity supply, uninterrupted supply and ventilation systems were installed for operators working 24/7. Installation of new technologies resulted in enhanced safety and reliability of the system control center.

  The video wall displays data not only from Lithuania, but also from surrounding power systems. Operators can monitor real-time volumes of electricity generated in power plants and windmills, operating electricity transmission lines as well as the ones disconnected for repair, transformer substations and switchgears, system frequency, import data, electricity demand and consumption. In 2016, when power links between Sweden and Poland start operating, the video wall will enable displaying data of Polish and Swedish power systems. The video wall serves as an information field which generalizes data. In the event of emergency, automated units transfer signals to the general system which processes information received not only from the Lithuanian electricity transmission network, but also from other power systems the Lithuanian power grid is connected to. Information displayed in one or more places helps make decisions more promptly and organize the system control activities more efficiently.
  Website: http://www.elsis.lt/en/litgrid-valdymo-centro-atnaujinimas-2/

- Controller for GAS consumption measuring: MPC-123 controller developed by the Lithuanian company Valsena is designed for GAS consumption measuring. It contains hermetic enclosure and internal batteries for uninterruptable work even on power failure. MPC-123 is created for data reading, archiving and analyzing in real time. Using GPRS/GSM controller secure sends saved data and reports to remote users. Controller supports most of protocols and interfaces (RS232, RS485, MBUS, Opto, Current loop, Analog and Discrete inputs), so it can be used with different brands and models of smart meters. Special "TRANSPARENT" data transfer protocol enables controllers to use with practically any device. On demand, the controller can be extended by Valsena programmers with specific features. For data exchange over GPRS/GSM any Serial interfaces, controller uses Modbus TCP/IP, Modbus RTU, IEC60870-5-104:2000, SNTP and other protocols.
  The clients are GAS, heat and watering suppliers, industry companies in EU, Ukraine, and Central Asia.
  Website: http://www.valsena.lt/lt/gaminiai/keitikliai/mpc-123.htm

- Alternative methods of remote metrological monitoring of electricity meters are being developed at the Faculty of Electrical and Electronics of Kaunas University of Technology for the purpose of monitoring the status of individual meters during operation rather than in a group.
  Website: https://www.etaplius.lt/ktu-profesorius-z-nakutis-daiktu-internetas-jau-ir-energetiniu-resursu-apskaitoje

Table below shows energy management solutions providers in Lithuania:

Company name	Turnover	Products	Employed
AXIS Industries	50-100 mln. Eu	>100k devices/year	>600
Elgama sistemos	1-2 mln. Eu	>100k devices/year	>20
IRTC	2-3 mln. Eu	<50k devices/year	>30
Sigmatelas	1-2 mln. Eu	<50k devices/year	>40
Valsena	<1 mln. Eu	<50k devices/year	>10
Elsis TS	5-10 mln.Eu	<50k devices/year	>40
Aedilis	3-5 mln. Eu	>50k devices/year	>60
Connecty	<100 Eu	>50k devices/year	4
BENCO	<1 mln. Eu	>50k devices/year	7

Table 1: Energy management solutions providers in Lithuania.

Presented companies are developing their products iteratively with minor focus on R&D. The cost of R&D and market reach of Lithuanian companies coupled with limited production capabilities puts them at a disadvantage and dissuades investment in such activities (5).

7.3. IoE best practices and their adoption in Lithuania

The general awareness of IoE in Lithuanian business is low and generated solutions, or its applications remain outside of mainstream business practices. The interest is expected to grow with the benefits of IoE becoming more apparent as technology matures and develops outside of Lithuania.

Energy resource trading system: Energy Resource Trading System (EIPS) is a project implemented by Tieto Lietuva at the end of 2011 under an agreement with the Lithuanian Energy Resources Exchange operator Baltpool. Baltpool is the operator of the Lithuanian Energy Resources Exchange, which has the right to organize trade in biofuel products.

The idea behind the system is to act as an online trading venue where energy companies can comfortably trade energy market products: long-term electricity contracts, gas, biofuels, etc. The system has to service about 300 companies and provide about 5,000 products (long-term electricity contracts, gas, biofuels, etc.).

The system includes both the portal for the marketing of energy products markets, as well as the reporting of the formation of reports, settlement execution, and the assessment of warranties for trade commitments of participants.

As a result, a lot of online shopping opportunities has been created, enabling buyers and sellers to electronically trade deals on the energy market. Participants, using the exchange trading system, could quickly and easily sell their products or purchase the desired product volume. "This project is the first for company, but our step in the energy sector of Lithuania is very important. Tieto Lietuva aims to become a strong player in this market, with the knowledge of Tieto's energy industry, our team's technological competence and ambition," - said Martynas Liberts, CEO of Tieto Lietuva (https://www.tieto.com/

“Litgrid” Electricity Distribution Project: Tieto Lietuva has developed a tool that automated the work of the electricity transmission system operator Litgrid. Thanks to the project implemented in February 2013, it is possible to transfer the collected data to the software more quickly and to predict the load on the grid and to ensure reliable electricity supply in the country.

The customer of this project was “Litgrid” Electricity Transmission System Operator. The company manages electricity flows in Lithuania and maintains a stable operation of the entire electricity system.

The main challenge in this project was to find out the rules for transmitting and measuring electricity in electricity networks and to develop a software tool that would automate the work of “Litgrid” employees. To achieve this goal, the researchers described formulas for calculating the voltage in the power transmission network nodes and programmed a tool that automated the work of “Litgrid” employees. The integration of the tool with other software used by Litgrid helps to monitor the loads on the Lithuanian power grid.

From now on, employees who monitor electric loads can move data collected more rapidly to other software and provide network load and ensure reliable power supply in the country.

“Lietuvos energija" transformation strategy LE 4.0.: “Lietuvos energija" has approved the digital transformation strategy LE 4.0 in order to create more convenient services for clients and increase operational efficiency. It aims to make the group of companies an organization that effectively employs advanced digital technologies in everyday work.
The strategy paper outlines six trends that underpin the digital transformation of Lietuvos Energija:

- Digital Solutions,
- Digital processes,
- Digital services,
- Digital relationship with the client,
- Digital assets,
- Digital work environment.

These orientations are aimed at increasing the value of the client by introducing intelligent services and creating more convenient service. A more flexible and efficient organization will allow to take into account the individual needs of each client and adapt to a rapidly changing environment. Thanks to the developed digital skills, employees of Lietuvos Energija will be able to use qualitative digital tools and implement new, efficient sharing of knowledge.

In order to successfully implement the Group's digital transformation, the strategy identifies three essential conditions:

- Reliable and real-time data access;
- Digital competence development;
- Fast IT function.

Ensuring these conditions will create preconditions for achieving the goals set in the strategy.

Digital transformation LE 4.0 will contribute to the strategic goal of Lietuvos Energija to double the value of the group by 2020. https://www.le.lt/index.php/atsakingas-verslas/skaitmenizacija/3514

7.4. Research and development projects on IoE in Lithuania

Analysis of promotion of measures for the use of renewable energy sources in electricity sector (Scientific paper, Andrius Stasiukynas, 2011)

Abstract. Based on a thorough examination of use of RES in the electricity sector, wind and biomass energy seem to have the greatest RES potential in the Lithuanian electricity sector. Use of hydro energy is bound by strict environmental norms that require an appropriate examination in order to be improved. Setting a green electricity feed-in tariff is considered the main measure to promote RES use in the Lithuanian electricity sector. The criteria for the feed-in tariff validity in Lithuania are not clearly identified and substantiated. Exploring the development of RES use, four key groups of obstacles have been identified. The review of various sources of information shows that the development in RES use in Lithuanian electricity sector is more oriented toward large corporate businesses than toward welfare of small businesses and household communities. It is important to note that full-function policy concerning RES use in households in general is not established. Municipalities should play a more important part in promotion of RES use for electricity production by creating decentralized municipal funds partially supported by the "Lithuania Environmental Investment Fund" and joint project implementation (according to the UNFCCC and the Kyoto Protocol provisions) for small RES projects.

Website: https://epubl.ktu.edu/object/elaba:16217255/

Smart grid development (Scientific paper, Virginijus Radziukynas, Arturas Klementavičius, 2016)

Abstract. The paper reviews the peculiarities of smart network development. The concept and vision of the smart grid as a modern smart grid is discussed, the aspects of the legal regulation of its implementation are reviewed, and pilot projects of smart grids dominate in the current stage of development. It is noted that the development of smart grids in Europe is now taking place as a natural process of technical progress and not as a mandatory policy. A general scheme for the development of smart grids, consisting of pilot and infrastructure projects, and its sources of financing shall be provided. Prospects for the use of smart technologies in Lithuanian transmission and distribution networks are reviewed. The benefits of smart grid development for electricity consumers, network operators, business and society have been examined. It is said that the Smart Specialization Program being implemented in Lithuania is promising and can effectively contribute to the coordination and strengthening of Lithuanian science and business efforts by implementing smart networks in Lithuania. It is concluded that more companies (in the field of high technology) will be established in Lithuania that will develop and produce "Lithuanian" smart grid/technology solutions and will contribute to the European Commission's recommendation to develop more higher value-added products.

Website:
https://s3platform.jrc.ec.europa.eu/documents/20182/195230/10.+Arturas+Klementavicius_LEI.pdf/48ca7a1c-086e-4d41-a759-bf1dfdd07c8f

Problems of integrated measurement systems in the context of employees competences (Scientific paper, Gediminas Bačkys, Renata Černeckienė, Birutė Dalmantienė, 2018)

Abstract. The adoption of energy efficiency measures is shifting the building installation industry towards green technologies, such as smart metering and home automation, bringing significant changes on workplace requirements and training. Electricians, apart from technical proficiency, require a combination of digital and environmental skills to respond to the installation, maintenance, and programming of smart metering and energy efficiency home automation systems. Although the adoption of energy measures for building installation is promoted under national and EU initiatives, the provision of relevant vocational education and training (VET) is insufficient in quality and quantity, fragmented and infrequent, not adequately addressing the needs of the sector. There is, thus, a clear challenge to increase the quality of VET provision for electricians to match their competences and skills with smart metering and home automation needs of a fast-changing market and to promote employability within the sector. The aim of the research is to analyze the opinion of employers of the energy sector in different European countries on the need for the employees ‘competences in smart metering and home automation.
Website: https://ojs.panko.lt/index.php/ARSP/article/view/64

Development of an Information System for Sustaining Energy Consumption in Smart Homes (Scientific paper, Evaldas Žulkas, Dalė Dzemydienė, 2017)

Abstract. Information systems play an important role in smart home management. They collect monitoring data for devices connected to a wireless network (e.g., sensors, lights, thermometers). Such systems are classified as complex modern electronic services management systems that can provide environmental management services in a smart home. However, for smart devices to be able to use energy efficiently, additional software modules are needed to make these devices more efficiently used. The purpose of our research work is to develop the functions of the information system, enabling the estimation of electrical energy consumption in the smart housing system and the use of forecasting data for controlling electricity costs
Website: http://www.journals.vu.lt/informacijos-mokslai/article/view/11396

Project: Smart energy accounting systems

(No. J05-LVPA-K-01-0017) - The project aims to implement R&D activities to develop a prototype of smart metering and metering device for smart energy metering systems and smart grids - high precision industrial electricity meter. New high precision industrial electricity meter smart grid development solutions perform network analysis, and so increase the quality of the smart grid. Smart metering systems and smart grids are directly related to increasing energy efficiency and security of supply and are currently the fastest growing segment of the energy transmission infrastructure market.

Website:https://www.esinvesticijos.lt/lt/paraiskos_ir_projektai/ismaniosios-energijos-apskaitos-sistemos

During the first period, a pilot project on automated metering enabling customers to save energy more efficiently was completed. As a result, the customers were no longer required to check their readings but were capable of reading them remotely.

Website: https://www.eso.lt/lt/apie-mus/vykdomi-projektai/ismanioji-apskaita

Workshop: Smart Energy Workshop at Hacker Games

The state-owned energy company group Lietuvos Energija, together with Versli Lietuva, offered for engineers, programmers, energetics and business developers the opportunity to create smart energy projects or prototypes over the weekend that could eventually become new products or businesses.

During "Hacker Games" over 250 engineers, programmers and designers has been created 41 developer, program, games, including a smart greenhouse, a mobile app to solve a suicide problem, a smart lantern for runners, and more

Website: https://ktu.edu/events/ismaniosios-energetikos-dirbtuves-renginyje-hacker-games/

Workshop: The smart energy hackathon was won by the unusual use of electric vehicles

During the Innovation and Technology Festival LOGIN held in Lithuania, Lietuvos Energija organized the fifth hackathon on energy innovation. The Special Commission selected the EV parity team as the winners of the Smart Energy hackathon, which proposed a solution to use electric car batteries to balance the power grid.
The two-day trial involved 10 teams that generated ideas to address the following energy challenges: aggregating and managing energy generation and consumption sources; education of energy consumers; promotion of productive consumers; system services using batteries for electric vehicles; charging solutions infrastructure for electric vehicles; Internet of Things and Big Data; optimization of network development; P2P Power Exchange Platform. Participants could also come up with their own theme or idea to contribute to the modernization of energy today.

Website:https://www.le.lt/index.php/naujienos/pranesimai-spaudai/login-2019-festivalis-ismanios-energetikos-hakatona-laimejo-neiprastas-elektromobiliu-panaudojimas-/5856

7.5. Future IoE scenarios, technologies, and business models

Lithuania has the most innovative economy of the Baltic states according to the Bloomberg Innovation Index. Aiming to create the ideal conditions for R&D and tech growth across the country, Lithuania builds on an already established technical industry and infrastructure. The state has identified several key sectors that it intends to focus its efforts and investments on:

- INVENTING new technologies, materials and practices;
- HEALTH technologies and biotechnology;
- Information and INTERNET technologies;
- FUTURE focus – sustainable technologies. (8)

The global Internet of Things (IoT) network is beginning to include a huge sector of energy meters, which is good news for consumers. (15)

Energy companies will change their profile by switching from seller to service provider. Not only will they ensure the reliability and convenience of energy supply, they will also offer more efficient consumer solutions, will enable the customer to earn the generated energy on the market.

The Lithuanian Energy Independence Strategy foresees that by 2050, Lithuania will only use renewables for electricity and heat production. True, this is not the only purpose that is believed to ensure lower prices for energy consumers and less polluting the environment. What changes are waiting for energy until 2050?

One of the trends is the energy digitization, intelligence, and the active involvement of energy users in the energy market. Until now, energy consumers were passive consumers who only knew how to turn on electricity and how to pay bills for energy that they were not able to influence, this has changed rapidly all the time. Consumers can not only choose different energy suppliers, but also actively react to changes in the energy market, when energy prices fluctuate not only for years, but also for the day, or even for an hour. (8)

More start-ups in smart energy sector. In Lithuania the number of energy-oriented start-ups has recently grown. A state-managed energy company group Lietuvos Energija (biggest energy company in the Baltic States) opened up a €5 million smart-energy-oriented venture capital fund that will invest into early stage start-ups. Its goal is to attract new ideas and external talents in the areas of smart grids, renewable resources, bioenergy, small generation, smart houses, large data and analytics, electronic services, as well as other energy-related solutions.

The fund intends to invest up to €1 million per year in start-ups. In the course of three years, the accelerator is expected to facilitate the development of at least 15 start-ups. In addition to funding, they are granted workspace at Vilnius Tech Park as well as access to a large network of experts and the infrastructure of Lietuvos Energija.(14)

Also, The Ministry of Energy of Lithuania is becoming the first ministry to join the largest Innovative Energy Innovation Network in Europe - InnoEnergy. It opens opportunities for Lithuania to co-operate with European energy sector leaders and become involved in a wide network of international investors, experts and innovators.

Energy Minister Žygimantas Vaičiūnas and Managing Director of InnoEnergy Central Europe Jakubas Mileris signed an agreement on cooperation in the field of development of energy innovations on May 15, 2018 in the final of the Power Up! Sustainable Energy Startup Competition in Vilnius.

Cooperation with InnoEnergy will include promotion of research, development of energy sector technologies and innovations, application of digital solutions in the field of energy, as well as export of Lithuanian energy products and competencies.

The established cooperation will allow Lithuanian energy sector participants to become involved in a wide network of international investors, experts and innovators and actively participate in programs that turn innovative ideas into products operating in the market.

InnoEnergy offers support to the expansion of European markets or additional financial assistance for the growth of small and medium-sized businesses in the energy sector. Larger companies could work with the most promising European energy starters and get funding for market entry innovations.

InnoEnergy also offers master and doctoral studies for future energy sector leaders, offers international programs, internships, and different ways of enrolling students in business projects. (9)

According to D. Misiūnas Chairman and CEO of the Board of JSC “Lietuvos energija”, digitization opens new global economy page, new one’s technology - the Internet of Things, great data, artificial intellect and so on. - Becomes the Axis of the Fourth Industrial Revolution still quite recent digitalization opportunities were exploited only in areas such as IT, media or finance sector. But lately, the key to digitization. We can also monitor developments in other areas. Energy is no exception. Its leaders are already preparing for a new digitization era IDC predicts that in 2019 about half of utilities suppliers more as 5 percent will invest in the introduction of new technologies. Based on Microsoft and Accenture Research, an energy company in the near in the future, its flow of investment from such traditional areas as infrastructure will turn to digital technology - the Internet of Things, great data, cloud computing, etc.

The main strategic directions of the Lithuanian energy policy development are energy security, competitiveness, green energy development and innovations.

Term Internet of Energy is not popular in Lithuania yet, but to leverage the functionality of smart meters and data communication infrastructure, Lithuanian researchers are looking at developing mechanisms for remote and uninterrupted meter monitoring. The development of smart metering, systems and innovative services for all types of energy accounting, covering electronics, electricity, metering, telecommunications, IT engineering, will be increasingly stimulated soon by global warming management, energy saving and the digitization of the EU energy sector.

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Conclusions

The present report on what is happening in the field of Internet of Energy (IoE) across and beyond Europe clearly shows that IoE is not Fata Morgana but an innovative ICT-based concept for the intelligent coordination and interconnection of all elements of the energy system including generation, distribution, transmission, storage and supply.

Among reasons that evoked emerging IoE, the transformation of the entire energy sector towards decarbonisation, digital transformation, and decentralization can be stated. These three global trends are radically changing the way the power is being generated, distributed, and consumed. As a natural result, the traditional energy landscape that was predominated by centrally-organized plants is disappearing. This leads to evolving new roles and behaviours of consumers, which are now called "prosumers" – those who produce and consume as well as sell and buy energy.

The need for the transformation of the energy sector has been realized worldwide at the political level. A number of countries developed and launched corresponding policies and programs aimed at integrating ICT-based innovative solutions in the energy industry.

IoE has been mostly implemented through disruptive information and communication technologies, such as Internet of Things (IoT), Cloud Computing, Big Data, Artificial Intelligence, and Blockchain. The penetration of the blockchain technology in the energy sector is, however, still quite low due to unsolved legal aspects.

Among established IoE solutions, Vehicle-to-Grid technology (V2G), innovative e-mobility concepts for charging infrastructure, Smart Metering, Predictive Maintenance, Smart Grids and microgrids can be named.

Different IoE concepts were successfully tested across the globe and achieved good results towards increasing energy efficiency, costs reducing, and decreasing CO2 emissions. These good practices form a fundament for future IoE scenarios as well as further research and development activities in this field.

It can be assumed that new business models will be created. In the future, power grid operators will increasingly act as information service providers and offer new services, such as energy management at the customer's premises. New agents will enter the market, such as operators of virtual power plants for balancing energy. By integrating (hybrid) electric vehicles adapted to the energy supply, it will also be possible to actively involve mobility sector in optimizing the energy networks. Consumer-oriented touch points will arise, such as demand response, building energy management (for commercial and industrial residents), electric vehicles charging management, and smart home management.

However, all these scenarios require substantial re-thinking of the electricity infrastructure, business models, regulations, and individual patterns of the energy consumption. Therefore, raising awareness of the general public of the IoE concept and its benefits seems to be a relevant component for cross-border rolling out of IoE.