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PEST Analysis of Smart Energy Grids: from the European Boom to the Incipient Emergence in Colombia

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Abstract

The electricity consumption in developed countries with high population concentration has grown significantly in recent years, contributing to the increase of global warming. This has driven the design and use of new alternative energy sources integrated into the conventional network allowing build intelligent energy networks (RIE) or smart grid (SG) for more efficient management of this precious resource. Therefore, the document proposes reviewing the state of the art of political, economic investments, technological development and their social and environmental impacts in 5 European countries with high levels of development, by applying the PEST analysis, which identifies the common characteristics and essential differences from the information available on the current situation of the SG serve as support comparative study with reality in these technologies in Colombia. As a final result is concluded that there is indeed an incipient development of RIE in Colombia, making it possible to apply the European experience for the construction of future short or medium term to encourage the implementation of projects and technologies described scenarios.

Keywords-Smart grids, energy conservation, sustainability, environment, automation, optimization, integration

1. Introduction

According to projections for increasing electricity consumption, power system repowering projects in Europe would involve more than € 100 billion in new investments that would integrate conventional networks with the growing number of Smart Grids or Smart grid [1] which correspond to system to distribute energy is defined as the integration of elements that allow the optimization of the energy production and distribution using automatic system that are able to ensure economic energy, sustainability, lower losses, high levels of quality, reliability, security and flexibility, integrating distributed system generation to the energy chain that can be renewable and cheaper or wasted in the case of non – renewable energy that is produced in the figures of cogeneration or self-generation [2]. According to this, currently the electrical system generates approximately 320 GW including renewable energy sources (FER) [3], a figure that will be exceeded by 2020 with a "production" capacity of 536 GW, representing a 57.6% increase over the year 2012 [1] [4], which means strengthening the integration of renewable energies in the European Union (EU) creating new high voltage lines with distributed generation, resulting in the immediate expansion of existing lines bringing a total length of 45,300 kilometers to 312,000 kilometers currently existing [1]. The extension of this extensive network with the penetration and massification of renewable energy in the region will contribute to the reduction of CO2 emissions to the environment, giving rise to a series of positive environmental impacts that have not yet been fully quantified because the construction of the systems of generation distributed with renewable sources is gradual in agreement with the policies and investment in each country.

Based on these aspects, the following study emerges as a response to the need to know the progress being made in Europe on Intelligent Energy Grids (RIEs) or Smart grid (SG) [5] , for which this document review and analyze the state of the art as an activity within the framework of the project "Integrating Sustainability and Energy Efficiency in Residential Electrical Installations in Barranquilla". The main objective of this project is to understand the concepts and applicability of alternative renewable sources in the EIR.

For this, the methodology that is applied is based on the analysis matrix PEST (Politics, Economy, Society and Technology), which is the description of the main laws, regulations or governmental regulations on the intelligent network the development of the same in the countries of Europe with the mayor according to the reports of entities such as the European Commission, IRENA [6] and the international energy agency with the most outstanding results and results of projects that lead these building policies worldwide and some data the most outstanding economic investments in the spectrum of these systems, relating these significant characteristics to the technological advances applied and their impact on society benefiting from environmental factors. The study is concluded to conclude about the topics analyzed and exposed from an integral point of view that becomes the baseline for the study of the RIE survey in Colombia.

Therefore, a study of the general to the specific is carried out, applying strategies related to the revision of the state of the art, understood as a set of activities aimed at the exploration or search of the current information that can be used for the achievement of objectives, knowing solutions to problems already solved in research projects or large-scale innovation, serving as a basis for a future study in Colombia of intelligent energy networks.

2. Methodology

2.1. Review of concepts: Smart Grid and intelligent management of electricity consumption

An "intelligent grid of energy (RIE)" or Smart grid (SG) is a power system that in addition to transporting the electrical energy generated by the generation equipment to each load installed with its respective controls, protections and other technical and operational characteristics, provides "two-way" interconnection between energy service providers and end-users being able to interact with the system by configuring energy consumption according to demand, achieving significant savings levels [1] [7] . Figure 1 illustrates this concept by easily distinguishing the "insertion" of telecommunication protocols in the electricity network where each user can intelligently control energy consumption and have knowledge of the variables that affect the generation system and its environment, thus achieving "Interact with the system in two directions."

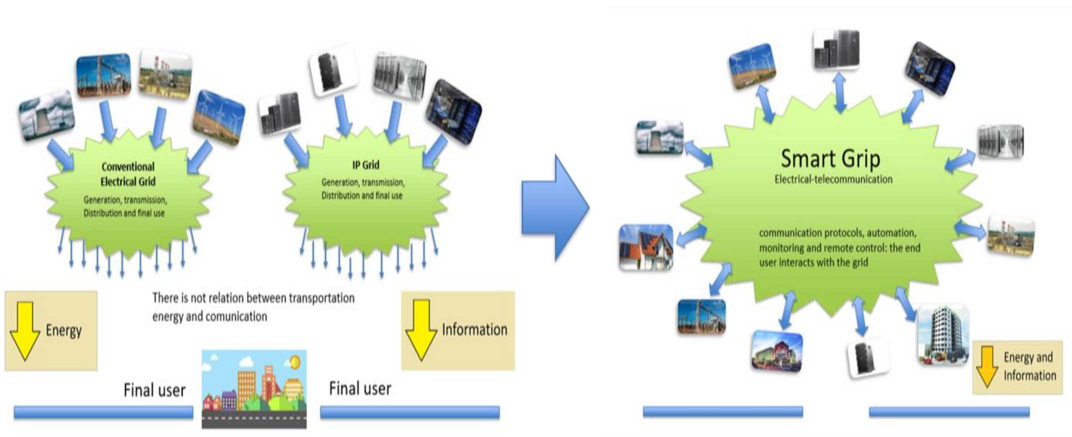

Figure 1. From the conventional model to the intelligent energy grid model [8].

The RIEs are based on the control of energy consumption in real time using sensors, time controllers, actuators and other equipment of the latest technology, which together with automatic network control systems allow to integrate all the elements in an automated system with the following objectives, among others [9]: To manage the intelligent demand of the energy by the consumers, to develop integrated systems of generation decentralized hybrids automated with renewable sources and technologies of storage of energy; to have autonomous systems of electric power generation and electrical systems in non-interconnected areas; to promote the development of the spectrum of the electricity market by diversifying the energy bag and to enable the penetration of the electric vehicle, adapting this type of mobile load as a dispersed device in the network.

A conceptual schematic of a "Smart City" [10] is formed in its essence by a set of modules intercommunicated with each other, which allows the actions described above, characterized by the presence of Energy Storage Systems (Smart Energy Storage), Lighting System (Smart lighting), Energy Management (Energy Management), Smart Building, Energy Generation Energy Generation, Informed Costumer and Electric Mobility among others ". The technological development of a Smart Grid project, according [11], implies a set of stages that allow to reach the final objective: stage 1 emphasizes the monitoring and control of the consumption of electrical energy; stage 2 corresponds to the design and construction of energy storage elements including electric vehicles and defining the storage equipment, consumers (end users) and generators and the last stage, defines the technical and operational protocols of the electric market within the microred and its relations with external markets. In this sense, much of the evolution of the current grid to a Smart grid will have its mainstay in the distribution network [12] [13], therefore, the market for the automation of the conventional energy network will have to evolve in the same way that this type of facilities or services will gain weight in the electricity grid of the future.

2.2. Components of a Smart Grid:

According to the above, the general structure of an RIE implies the existence of several components namely:

DER Distributed Power Generation Sources [14], (Distributed Energy Resource: These are energy generation and storage systems located at decentralized sites with a capacity of less than or equal to 15 MW. They conform the system of distributed generation, which have as main characteristic belong mainly to the end users and not to the companies providing the electric power service, in such a way that each customer can self-supply their demand according to the curve of daily load.

Advanced Measurement Infrastructure (AMI) (Advanced Meter Infrastructure) [15]: It is the smart meter system, interconnected by a set of communication networks and data management systems that allows two-way communication between utilities and customers or end users.

Advanced Distribution Automation (ADA) [16], **(Advanced Distribution Automation):** set of technologies that allow an electrical company to control and coordinate in real time the operation and operation of components, equipment and distribution devices remotely. Includes activities such as Control, Data Supervision and Acquisition (SCADA), Voltage and reactive power control, Fault locating (FL), Self Healing reconfiguration (FR), among others.

Communication Infrastructure, (COMM) [17]: is made up of the different communication devices with their respective protocols, to provide the connectivity that allows synchronization with all the components of the network interconnecting the DER, the AMI and the ADA, becoming the core of the Smart Grid. These functionalities and actions established as the "backbone" of the Smart grid, interact with the "modules" of input and output of the network including [18], among others not less important the Asset Management System, the Work Management System, the Interruption Management System, the Geographic Information Systems, the Energy Management Systems, the Demand Management System, the Management System of the Distribution, the Customer Information System, the Network Management System and the Data Control and Acquisition Systems.

Intelligent Power Meter, SMART METER: It is an electronic bidirectional electrical energy measurement device that incorporates the acquisition and processing of other variables such as water consumption, so that the measurement takes place in real time allowing consumers or end users and suppliers to know the information of the amount of power and energy consumed over time in accordance with the load profile and the energy prices in predetermined periods of time thus achieving the saving of money by adjusting the consumption according to the changes in supply and demand of the energy market according to the day-to-day regulatory restrictions, consumption curves and control, load limits, quality of service and fault management, among others [15], [3]. The general scheme of an intelligent meter contains the three essential systems corresponding to energy measurement; the memory and the main information device which is transformed into the advanced stage in the communications system [19]. In order to expand the operation, additional elements such as the power system, the calculation processor, the communications processor and the drive or control device.

3. Results and Discussion

There is no specific regulation for Smart Grids in each European country. In this vein, the European Standardization Organizations (CEN), CENELEC and ETSI, are responsible for fulfilling the mandates of the European Commission to establish norms, laws, directives or standards that facilitate the unification and homogenization regulation at European level, having as main incentive and impulse factors the will to create a European energy market by introducing the development of smart grids as an essential support for distributed generation [20]. These include those directives that essentially aim at a common short-term objective: according to Directive 2009/28 / EC of the European Commission for the year 2020, greenhouse gas emissions must be reduced by 20%, saving 20% of energy consumption by implementing strategies, plans and programs for the rational use of energy and greater energy efficiency and promoting the construction of non-conventional generation systems to ensure that 20% of electricity production comes from renewable energy [20].

Likewise, Directive 2009/72 / EC specifies the requirement for the implementation of smart meters by 80% in households by the year 2020 and Directives 2010/31 / EU and 2012/27 / EU legally address the strengthening of decentralized generation and the connection of smart meters especially in new buildings built after the entry into force of the aforementioned regulation.

From this legal and governmental momentum, the European Commission has created a set of mechanisms, such as the European Innovation Partnership on Smart Cities and Communities (EIP-SCC), for example, to stimulate the development of projects such as smart cities, which become a meeting space between cities, industry and citizens to improve life in the city through sustainable solutions. The fundamental objective of EIP-SCC is to establish strategic partnerships between cities and industry to develop future systems and infrastructures and to contribute to the definition of future actions in the area of intelligent cities, with characteristics different from conventional ones, guaranteeing a better quality of life and social improvement by promoting urban potential in sustainable development and the green economy as a hyper connected metropolis with zero emissions, productive self-sufficiency and human speed increase.

The PEST analysis of the Smart Grid in some European countries was developed in order to characterized their policies, economic investments and the use of advanced technology in the development and execution of smart grid projects with their social impacts are presented below, carrying out a general review of topics related to the transformation of the smart grid into conventional energy system as shown on Table 1.

Criteria	Italy	Spain	France	Colombia
Policies	The 2010 National Action Plan for Renewable Energy in Italy responds to Directive 2009/28 / EC of the European Commission and the Commission Decision of 30 June 2009 and promotes the use of energy from renewable sources through promotion, green certificates, incentives with rates of up to 1 MW (0.2 MW of wind energy), incentives for photovoltaic and solar thermal generation, priority dispatch to renewable energies, electrical connection in predetermined times, are of the procedures for authorization, monitoring and dissemination of information, mandatory inclusion of energy efficiency and energy savings in the context of all processes of generation and transmission to the end user.	The ORDER ITC / 3860/2007 defines the plan of replacement of conventional measurement equipment by smart meters. The order regulates that all accountants must be replaced before December 31, 2018. - The promotion of the use of energy from renewable sources is possible under specific regulations of the ministry of industry, energy and tourism applied in different regimes according to governmental energy policies. Aligned with European directives such as 2004/8 / EC and 2009/28 / EC which promote cogeneration aspects. - The proposed Royal Decree (RD), published on July 18, 2013, establishes the regulation of the administrative, technical and economic conditions for the modalities of electricity supply to self-consuming consumers, which will allow the change of centralized electricity production model to a model of distributed electricity generation.	The agency responsible for projects and monitoring of energy and environment management (ADEME) finances projects of demonstration of intelligent energy networks, whose objectives are to define the levels of integration of renewable resources, to structure related business models with the smart grid, define and create mechanisms and actions to meet the variable demand and prepare the different participants in the energy system before the eminent inclusion to the intelligent networks system with their respective impacts and effects.	- General principles of service according to Law 143 of 1994 that stipulates efficiency, quality, continuity, adaptability, neutrality, solidarity and equity. - In accordance with the general principles of URE in Colombia, Law 697 of 2001, "projects of a social, public interest and national convenience, fundamental to ensure the full and timely supply of energy, the competitiveness of the Colombian economy , consumer protection and the promotion of the use of non-conventional energies. - Institutional participation should favor the regulation of both electrical and communications technology through safety standards such as RETIE and efficiency such as RETILAP and RETIQ and general energy tariffs. - Law 1715 of May 13, 2014 "regulating the integration of non-conventional renewable energies into the national energy system" should be the driving force behind the development of large-scale renewable energy projects
Economic Aspects	220 million euros invested in demos and project development, 40 million euros invested in research and project deployment, 8.5% of total investment in Europe, 2.4 million euros on average per project, 140 million euros for the development of projects with own capital, 120 million euros for the development of projects with partner capital, 1 million euros on average per research project, 3.3 million euros on average per project demos and deployment	210 million euros invested in demos and project development, € 100 million invested in research and project deployment, 11.42% of total investment in Europe, 3.2 million euros on average per project, 150 million euros for the development of projects with own capital, 200 million euros for the development of projects with partner capital, 2.9 million euros on average per research project, 3.8 million euro on average for project demos and deployment	400 million euros invested in demos and project development, € 100 million invested in research and project deployment, 16.1% of total investment in Europe, 5 million euros on average per project, 200 million euros for the development of projects with own capital, 300 million euros for the development of projects with partner capital, 2.7 million euros on average per research project, 6.9 million euro on average per project demos and deployment	There is no detailed economic investment information on smart grid projects. As a national reference, the municipality of Medellin will allocate US $ 10 million in 2016 for technology transfer linked to Smart Grids. The initiative will add resources for ICT projects and energy for US $ 60 million, from the Science, Technology and Innovation FundSolar generation plan of 6,300 square meters that has 2,070 solar panels of silicon and supplies 24% of the energy demand of the warehouse success in Barranquilla represented in the requirements of lighting, refrigeration and air conditioners.
Technology	- Development and operation of web platforms and mobile applications for the monitoring, acquisition and storage of energy consumption data. - Development of intelligent control technology for the injection and bidirectional measurement of the energy delivered by the system to the users in Medium voltage. - Development and construction of fast energy storage systems with hydrogen without interfering or drastically modifying the operation of the conventional system for the efficient use of energy	Technically, several protocols related to substations of the national power system are applied, unlocking the IEC61850 automation systems and their integration with the network. It also complements this function with the application and creation of standards such as IEC60870-5, IEC60870-6, IEC61970, IEC61968, IEC61334, IEC62325, IEC62351, IEC61850. - OPEN protocols are applied to energy meters such as the DLMS / COSEM and Meters & More. - Currently the radio frequency and PLC (Power Line Carrier) are applied extensiamnete not to depend on external protocols. - AMI measurement systems can be implemented using technologies from satellites to computers of radioADE5169 (Analog Devices), AVR465 (Atmel), AS8268 (Austriamicro-sys), CS5463 (Cirrus Logic), MAXQ3183 (MAXIM), MCP3905 (Microchip), SA9904 (Sames), 71M6531F (Teridian).	Installation of measurement systems with intelligent meters and connectivity with WEB platforms for the control of demand by the end user. - Analysis of the peak loads of the demand curve and its influence on the sizing and configuration of the Smart grid. - Some of the most important projects are: PREMIO-Production Production, Enr et MDE, Intégrées et Optimisées, MODELEC: Optimiser la gestion des usages électriques résidentiels, OMERE (GE & IPERD): Optimisation et Maîtrise des Energies renouvelables et du réseau Electrique, ECOFFICES	- Execution of projects with different levels of advanced measurement infrastructure development with the adoption of models that ensure the interoperability of information systems and technologies: EPSA, ELECTRICARIBE, EMCALI, EPM, CODENSA and ESSA, among other companies. - EEB has a subsidiary dedicated exclusively to the development of the electrical component of mobility projects focused on the partial electrification of Transmilenio Phases I and II trunks. - CELSIA increased the efficiency of Flores II and III plants by moving from single cycles to combined cycles resulting in the reduction of emissions of about 500,000 tons of carbon dioxide per year. - Companies such as HMV and CELSIA have invested in small hydroelectric plants which to date represent about 700 MW installed. - The Hjepirachi wind farm is the only one in the country and serves as a study site.
Society	In 2000, Italy created and implemented the first project "Telegestore system" that allowed the installation of more than 25 million homes using smart meters connected through a communication line, which has allowed to manage more than 100 thousand transactions and 600 thousand daily readings [21]	Endesa has been working for years in the development and implementation of smart grids, smart grids, such as the project for the island of Hierro and other networks that are a cornerstone for the development of smart cities Smartcity Malaga and Smartcity Barcelona [22] Smartcity Málaga was the first smart city promoted by Endesa in 2009 in which 11 companies, 14 research centers and five official bodies participate, benefiting 300 industrial clients, 900 service companies and 12,000 domestic clients and which has become in reference to world-wide level as model of energy management in the big cities. The project will save 20% of energy consumption, which means avoiding the emission of 6,000 tonnes of CO_2 per year.	• Intelligent management of the electrical energy used inside the offices through which employees are active players in this methodology • Design of business models for the intelligent integration of energies from alternative sources and conventional system • Setting up of research and development spaces where new alternatives based on the sustainable use of solar energy are considered, leading to a high demand for energy research projects, especially in relation to generation with bulb turbines and Continuous Current power transmission.	• There are Non-Interconnected Zones that allow the construction and operation of hybrid generation systems and can use very variable renewable sources due to their scale and very high energy storage costs. • Electricity market players would increase with smart grids: Generators (new developers), Conveyors, Distributors, Consumers (industrial, commercial, residential and residential), System operator especially in isolated areas within the market in general, which would contribute to the development of more direct and indirect jobs.

4. Conclusion

The global outlook on the Smart grid market is favorable. This market has an average annual growth of 26% until 2017 [18]. The volume of this global market will increase from 23,970 M $ in 2010 to 125,150 M $ in 2017. Regarding the world development field, the largest investments are currently made in the United States and in the European Union (approximately 70% of the total). In contrast, by 2017, the weight of these regions will be reduced to 12% of the total, while developing countries, especially in Asia and Latin America, will become the largest market for such technology.

In Colombia, Colombia has renewable energy resources with a still incipient development: Biofuel, Wind (Wind), Geothermal, Solar and Biomass in coastal regions and in the interior of the country in non-interconnected areas that make it possible to build power plants which can withstand significant loads in energy consumption. Based on the PEST analysis, it is determined and concluded that the development and growth trend of smart grid in Europe cannot become a point of comparison with emerging economies such as Colombia, since the differences and gaps are clearly significant. It is therefore advisable that the broad scope provided by European Union directives and the achievements in countries that have implemented implementation and testing projects plus other research activities with universities and research centers serve as guidance for the development of strategies and methodology for executing smart grid projects in the country contextualizing them to the national reality.

It is also identified as a common feature of the PEST analysis that one of the main actors in the future of smart grids is the final domestic user, whose participation is active and must satisfy their expectations regarding the system, which will inevitably lead to changes in their habits. Consumption and its relation with the environment. Nevertheless, this also requires the redesign of the distribution / commercialization companies that must evolve from passive to proactive companies, suppliers of energy transport with standards of quality, support, connectivity, interaction with users through monitoring, control and information, actively managing networks and generating markets for additional services.

References

[1] Raquel S. Jorge, Edgar G. Hertwich, Grid infrastructure for renewable power in Europe: The environmental cost, *Energy*, **69** (2014), 760–768. https://doi.org/10.1016/j.energy.2014.03.072

[2] O. Adalberto and S. Jorge, Set of Elements, Parameters and Considerations to Get Successful Inclusion of the Smart Grids in Colombian Power Systems, *Revecitec*, **5** (2015), no. 2, 125–134.

[3] K. Sharma and L. M. Saini, Performance analysis of smart metering for smart grid : An overview, *Renew. Sustain. Energy Rev*, **49** (2015), 720–735. https://doi.org/10.1016/j.rser.2015.04.170

[4] A. A. Munshi and Y. A.-R. I. Mohamed, Big data framework for analytics in smart grids, *Electr. Power Syst. Res.*, **151** (2017), 369-380. https://doi.org/10.1016/j.epsr.2017.06.006

[5] R. Bayindir, I. Colak, G. Fulli and K. Demirtas, Smart grid technologies and applications, *Renew. Sustain. Energy Rev.*, **66** (2016), 499–516. https://doi.org/10.1016/j.rser.2016.08.002

[6] IRENA 'REmap 2030' report bodes well for renewables, *Renew. Energy Focus*, 15 (2014), no. 1, 8. https://doi.org/10.1016/s1755-0084(14)70008-0

[7] F. AlFaris, A. Juaidi and F. Manzano-Agugliaro, Intelligent homes' technologies to optimize the energy performance for the net zero energy home, *Energy Build.*, **153** (2017), 262–274. https://doi.org/10.1016/j.enbuild.2017.07.089

[8] P. Kolasa and M. Janowski, Study of possibilities to store energy virtually in a grid (VESS) with the use of smart metering, *Renew. Sustain. Energy Rev.*, **79** (2017), 1513–1517. https://doi.org/10.1016/j.rser.2017.06.101

[9] T. V. Tran, N. T. Dang and W. Y. Chung, Battery-free smart-sensor system for real-time indoor air quality monitoring, *Sensors Actuators, B Chem.*, **248** (2017), 930–939. https://doi.org/10.1016/j.snb.2017.01.198

[10] H. Ben Sta, Quality and the efficiency of data in 'Smart-Cities,' *Futur. Gener. Comput. Syst.*, **74** (2017), 409–416. https://doi.org/10.1016/j.future.2016.12.021

[11] F. Salazar, G. López, J.I. Morenoa, H. Amarísb, Paving the road toward Smart Grids through large-scale advanced metering infrastructures, *Electr. Power Syst. Res.*, **120** (2015), 194–205. https://doi.org/10.1016/j.epsr.2014.05.006

[12] Smart Grids: Sectores y actividades clave informe estratégico de la fundación para la sostenibilidad energética y ambiental.

[13] E. C. of Ontario, Annual energy conservation progress report, Vol. 1, 2010.

[14] G. Frederich, P. Dove, Integrating Distributed Energy Resources into the Smart Grid, Advantech Corporation, Industrial Automation Group, Vol. 1, 2010.

[15] E. Vuong, R. S. Kamel and A. S. Fung, Modelling and simulation of BIPV/T in EnergyPlus and TRNSYS, *Energy Procedia*, **78** (2015), 1883–1888. https://doi.org/10.1016/j.egypro.2015.11.354

[16] F. Zavoda, Advanced distribution automation (ADA) applications and power quality in Smart Grids, *2010 China International Conference on Electricity Distribution (CICED)*, 2010.

[17] Emilio Ancillotti, Raffaele Bruno, Marco Conti, The role of communication systems in smart grids: Architectures, technical solutions and research challenges, **36** (2013), 1665–1697. https://doi.org/10.1016/j.comcom.2013.09.004

[18] Salvador Ruiz-Romero, Antonio Colmenar-Santos, Francisco Mur-Pérez, África López-Rey, Integration of distributed generation in the power distribution network: The need for smart grid control systems, communication and equipment for a smart city Use cases, *Renew. Sustain. Energy Rev.*, **38** (2014), 223–234. https://doi.org/10.1016/j.rser.2014.05.082

[19] T. Month, Conquering Advanced Metering Cost and Risk, *Energy TT&DD*, 2015.

[20] M. Cotti, Experiencia italiana en los sistemas de gestión y certificación de productos en relación a la eficiencia energética, *Revista Electro Industria*.

[21] G. Dall'O, E. Bruni, A. Panza, L. Sarto and F. Khayatian, Evaluation of cities' smartness by means of indicators for small and medium cities and communities: A methodology for Northern Italy, *Sustain. Cities Soc.*, **34** (2017), 193–202. https://doi.org/10.1016/j.scs.2017.06.021

[22] D. Grimaldi and V. Fernandez, The alignment of University curricula with the building of a Smart City: A case study from Barcelona, *Technol. Forecast. Soc. Change*, **123** (2017), 298–306. https://doi.org/10.1016/j.techfore.2016.03.011

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