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Review

The "Smart" Concept from an Electrical Sustainability Viewpoint

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Abstract: Nowadays, there are many technological-intensive applications that claim to be "smart". From smartphones to the smart grid, people relate the word *smart* with technical novelty, automation, enabled communication, and service integration. There is indeed a gap between those smart technologies and their intended "intelligence"; this has arisen an indirect debate between works focusing on automation and mechatronics design and others pursuing a conceptual approach based on fulfilling determinate objectives. One last approach relates the said smartness to deep learning methodologies. In this work, it is attempted to explore both perspectives by providing an overview of recent works around energy usage toward *smart cities* and the *smart grid*, pointing out the main conceptual pillars upon which both approaches stand. Certainly, there are enabling technologies supporting the smart concept overall; thus, this work addresses them to characterize "smart" not from technological or conceptual one-sided viewpoints but from their common backbone. Therefore, the interested reader can find in this work an integrative conceptualization of the smart context, a literature review of recent advances, and a deep discussion of how enabling technologies and current technological trends based on energy consumption are shaping the ongoing efforts toward a sustainable future. More importantly, a new approach to define *smart* in the said context is elaborated far from the typical misunderstanding of technological nesting or mere usage of "advanced" digital technologies. Rather, smartness is addressed by the integrative objectives the application pursues, the objectives set by its users' intent, and the attained results in terms of public benefit.

Keywords: smart grids; smart cities; smart buildings; smart houses; smart devices

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1. Introduction

The UN states that "water, food, and energy form a *nexus* (The word "nexus" is used by the UN to describe an interdependence or synergy between water, energy, and food [1].) at the heart of sustainable development" [1], implying that those resources are inherently correlated and that their availability is critical to ensure society's well-being. It is not hard to see that energy, particularly electrical, powers most human activities and services, from agricultural pumping to hospitals and the internet. Undoubtedly, modern civilization deeply relies on electrical power, as the recent 2021 Texas power crisis made clear sharply. Apart from natural disasters and accidental faults, "pressure on the *nexus* is being driven by a rising global population, rapid urbanization, changing diets, and economic growth" [1].

It is clear that human "progress" consumes the same finite resources much needed to guarantee our safety [2]. A call for balancing such consumption to avoid resource exhaustion has taken form under the concept of *sustainability*. Generally speaking, a sustainable activity is such if it can be *sustained* indefinitely [3,4]. However, water and energy consumption keeps rising, as well as consumerism and the desire for comfort. Thus, the much-needed sustainable development seems stagnant on the side of human behavior, and a direct association between sustainability and technology has been established instead. Moreover, climate change and carbon emissions seem to monopolize the sustainability discourse, thus favoring a short-sighted individual understanding of the said *nexus* and a mostly passive approach toward sustainable behavior.

On the side of technological development, many efforts are pointing toward a more responsible consumption of resources. For instance, there are studies about hybrid machines in AC systems for smart grids [5], energy harvesting from alternative sources [6], optimization of productive processes [7,8], transport system electrification [9], recycling technologies [10,11], and overall automation is an example of how sustainability has been pursued. Regardless of the impact of each technology, here is where the "smart" concept comes to play, not without ambiguity. So then, what is a *smart* technology? How is the smart concept associated with sustainability?

From a simplistic perspective, *smart* seems to imply human-like behavior. However, a smartphone is so since it can transfer data in addition to voice and run software applications, not since it can reflect or reason. It is indeed in the different services (hardware and software) that the device adds beyond its *basic* capabilities where one normally would find the said smartness. Similarly, houses, buildings, and power grids are considered to be smart when they incorporate some sort of technology for parameter metering or remote control and when they are connected to digital services expanding the typical reach of their traditional counterparts. In short, smartness seems to refer to the way in which systems assist people in partially (or entirely) fulfilling requirements [12,13], such as comfort, security, and interaction with others.

Therefore, it is reasonable to state that smart technologies pursue sustainability, assisting people to be sustainable, which comes with a clear obstacle given in the subject's intention, interest, or understanding of sustainable development and the subject's context. Thus, technology cannot be sustainable by itself and requires knowledge, intent, and appropriate conditions to provide actual benefits. It is also preeminent to recognize that sustainable development must come from better use of energy and resources and not from generating a surplus to satisfy ever-growing demand. In this sense, it is necessary to stage the *smart* concept in such a way that it demarcates the planning, integration, and control of energy resources from a sustainability perspective. Therefore, in this work, the *smart* concept is discussed, analyzed, and reworked under that approach. As a result, a definition of smart is attempted from two perspectives, namely, by taking into account the elements typically found in "smart" proposals and then hierarchically, moving through the elements comprising smart cities and smart grids.

There are other studies addressing the meaning of the *smart* concept. For instance, in 2020, Raff et al. presented a framework to conceptually approach smart products [14]; however, the focus was mostly on consumers' perceptions rather than sustainability objectives. Similarly, full frameworks for manufacturing processes and product design have also been proposed, including smartness and sustainability as core metrics [15,16]; nonetheless, the smart concept is not a part of sustainability and is mostly associated with the control and communication capabilities of devices. There are other works that do address sustainability, addressing the smartness of homes and buildings, but not attempting an extension of the *smart* concept overall, but constraining the study's reach to specific energetic, societal, or economical factors [17,18]. Finally, there have also been efforts to address the *smart* concept by analyzing bibliometrics and keywords used in the literature that, in the end, offer a summative depiction listing characteristics and expectancies rather than providing an actual definition [19]. In this work, it is attempted to demarcate the meaning of the *smart* concept in the context of sustainability and energy generation, offering a new viewpoint which, however, will benefit from the previously cited reviews.

This work is distributed as follows. In Section 2, the meaning of the word "smart" is discussed based on four important foundations such as sensors, communication infrastructure, decision-making, and sustainability. The application of smart technologies focused on specific areas is discussed in Section 3, ranging from particular devices to more general devices and applications. A discussion of challenges and further research applied to state-of-the-art topics, such as energy management, autonomous vehicles, and security, is presented in Section 4. Finally, Section 5 presents the conclusion of this work.

2. Overview of the "Smart" Concept

The word *smart*, as a prefix to technologies and concepts, is used to distinguish its accompanying word with respect to its "non-intelligent" counterpart. However, it is usually unclear or subjective what the added value the smart formula brings or why the counterpart was considered to be non-smart. Usually, smart processes and devices do not justify their "smartness"; instead, the public becomes responsible for finding common ground among the smart-*stuff*, consenting to indefinite boundaries; even in the academic literature, "scholars seem to provide diverging perspectives that suit their research objectives" [14]. Moreover, the smart morpheme is often used lightly, only for newness or improvement. This section attempts to demarcate the said concept under the sustainability viewpoint associated with the electrical energy usage of *smart grids* and *smart-cities*.

In general, what characterizes a machine as *smart* varies among different authors. Some consider that the intelligence of a machine should be a reflection of human cognitive capacity, usually requiring high computational complexity. For other authors, the use of artificial intelligence or deep learning algorithms that solve specific tasks is enough to label systems as *smart*, even if cognition was not even aimed at. In any case, defining intelligence in terms of complexity is problematic because solving specific tasks without cognitive complexity may require greater computational load than providing "abstract" solutions [12,20].

In terms of sustainability, *smart* is often used as a shorthand to highlight the *active* participation of systems and people in the desire for an environmentally-friendly and cost-effective way of using energy and resources, and generating waste [21]. Thus, such smartness embraces almost any *enabling technology* or methodology addressing those objectives, indeed offering a broad, ambiguous framework. Further, smart technologies are expected to assist users [22]; thus, aside from sustainability concerns, the expected smartness implies improved comfort. Such contradictory goals rely on a common presumption: highly automated systems can accomplish both simultaneously. As a result, *smart* can be wrongly interpreted merely as "highly automated" and assumed to facilitate the *passive* role of users, hindering the much-needed awareness of and participation in sustainability objectives.

Furthermore, *smart* systems are usually represented hierarchically. *Smart* energy [23,24], is distributed by *smart* grids [25], comprising *smart* cities [3], where there are *smart* buildings [26] alongside *smart* houses [27–29], using *smart* meters [30,31], sending data through a *smart* infrastructure [32] for further *smart* planning [13]. Then again, there are objectives defining every *smart* instance, but it is tempting and straightforward to focus on *technological nesting* rather than on local, regional, and global sustainability objectives. Such a hierarchical approach is meant to reveal dependencies, communication needs, waste streams, etc., but it can be perceived as nothing more than a requirement for upgrading a system, using *smart*-stuff all the way through. Many of these assumptions rely on an analogy with highly-automated industry (recall the *automation pyramid* [33] which, by the way, was not dubbed *smart*). Automated measuring, actuation, control, analysis, and planning indeed help companies optimize their processes, but assuming that it is just a matter of adding technology is a shortsighted misunderstanding: clear objectives, sufficient means, and objective metrics are necessary.

Nowadays, there is a trend referred to as *smartification* implying the mentioned automation to achieve well-structured and orderly processes, aiming to prevent or reduce losses and accidents [34]. It is often agreed that *smartification* relies on four pillars: (i) the devices that allow data acquisition (sensors), (ii) the infrastructure that admits data transfer (e.g., the IoT), (iii) the server or repository where the database is backed up and processed (management system), and (iv) the decision-making routines that permit the process to become self-controlling (e.g., AI). Each of these stages intends systems and processes to be automated and efficient, providing them with a certain degree of intelligence from measured data when possible. In the same way, the automation pyramid is often aimed at maximizing profit; in the context of this work, the referred intelligence must match sustainability objectives, adding a transversal intent to all the pillars. The discussion so far is schematized in Figure 1. A sustainable approach must come from both technological development (smartification) and the active participation of users.

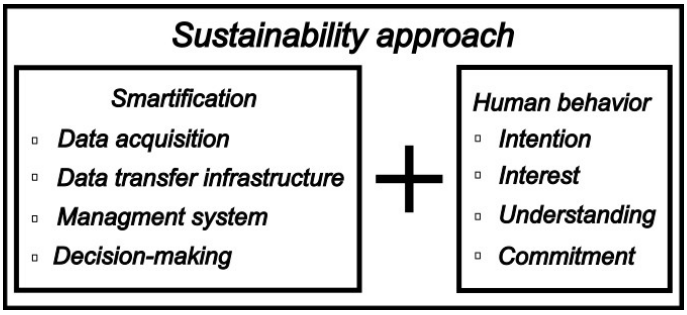

Figure 1. Smartification with a sustainability approach.

2.1. Sensors

Sensors are devices capable of capturing the process variables to depict the system's behavior in general and, more interestingly, to update automation systems to enable process feedback, control, and management. Sensing is not new; it has been used for centuries and is currently present in almost every imaginable industry, recently adding flexibility through wireless capabilities [35]. Over the years, sensors have been measuring a wide variety of physical variables and, more recently, even complex aspects like workers' psychological workload [36].

A more proper term to refer to *traditional* sensors is, perhaps, *transducers*. Such devices "translate" some variable of interest to an analog or digital electrical signal that could be later interpreted by a person or a machine. Currently, the term *smart sensors* refers to a single device incorporating a transducer, a processor, and a communication interface [36]. Again, the line between traditional and *smart* sensors is blurry as both acquire a physical variable, process it so that it can be scaled or interpreted in a more useful manner, and communicate the result through available means. It is from the added potential that digital processors and communication interfaces bring that the smartness of a smart sensor comes. Here, the keyword is *potential* since, as opposed to traditional sensors, smart sensors enable the incorporation of a myriad of services through software and local decision-making.

There is also a sense of smartness associated with the complexity (or abstractness) of the variable being measured. For instance, traffic, thermal comfort, and psychological workload are not directly measurable variables and comprise some degree of perception or interpretation. The sensors measuring such variables are actually basing their outputs on other directly measurable input variables (e.g., heart rate or even recorded video [34]) and following predefined routines, tested beforehand, to yield a "reasonable" quantitative output. The device is then labeled as smart as it *interprets* its context, which is a human-like behavior.

Thus, two main observations can be made here: first, a sensor is a device that puts out quantitative information from its surrounding media; second, the sensor's smartness relies on its capability to offer services through modifiable software or on the abstractness of the measured aspects. Therefore, the smartness is not in the sensing itself, and smart sensors are just integrated systems sharing a common casing, offering "intelligent" services thanks to their added processing and communicating capabilities.

Indeed, in 2018, Wang et al. compiled the different types of smart sensors, their applications, and some foreseeable future challenges. Sensing smartness is aimed, for instance, at consumer characterization, demand response program marketing, demand response implementation, power network connection verification, outage management, data compression, data privacy, and so forth [36]. There are also examples of smart sensors used in the electrical network infrastructure to minimize losses at the distribution stage and buildings [30,32,37]. In 2018, the works of Kumar et al. and in 2019, Buzau et al. also focused on electrical losses [31,38]. Finally, in 2021, Mohammadi et al. implemented smart sensors for electric vehicles in order to create a platform that allows real-time monitoring of vehicle flow, reliable information transmission systems based on IoT, energy storage systems, and artificial intelligence to promote the development of autonomous electric vehicles [39].

2.2. Communications Infrastructure

On the one hand, there is a need to link the measured data with the processing units and the actuators, which are more likely to be far from each other in an industrial setting. On the other hand, it is also necessary to store and analyze the data and confront it against overall outcomes. Every data-related interaction among the said elements is part of the communications infrastructure: the physical means through which the data is transferred, the monitoring devices that ensure data integrity, and the many interacting endpoints.

With the invention of the internet, data transfer was no longer limited to a local system but allowed for remote interaction. Currently, the communications infrastructure can also be seen hierarchically, ranging from local-area networks to satellite communications. However, satellite-related technologies and the internet are well-established commodities, and it is not usual to dub them *smart* in spite of being highly automated, multi-purpose enablers. In this case, even though the internet offers rather "smart" meshing, routing, and consistency-checking mechanisms, it is *typical* in the sense that people are already used to it and that its "smartness" is not in direct contact with the end user. However, there is a predominant and influential scheme normally linked to smartification: the *Internet of Things* (IoT).

The IoT concept mainly contemplates the intercommunication of a multitude of devices over a network [40]. A major conceptual difference with respect to the *typical* internet is that the IoT focuses on broadcasting devices rather than people-device interaction, leading to novel concepts such as Machine-to-Machine (M2M) communication [41]. Similarly, the IoT is associated with high densities of connected devices, sometimes requiring dedicated infrastructure, lightweight communication protocols (e.g., Sigfox and LoRa), and aiming to reduce signaling overhead overall. The interested reader can refer to the ISO/IEC 30118-5:2021 standard [42], where a common protocol for IoT operation is proposed to consolidate secure and interoperable operation. One can think of the IoT as devices autonomously broadcasting data to help in the fulfillment of an automation objective [37].

However, both the communication network and the subsequent storage systems do not make decisions beyond the security protocols dealing with cyber-attacks. It is true that the communication platform must guarantee data integrity in what is now known as the Head End System (HES) [43]. Still, the smartness is not in the infrastructure itself but in the ability that the IoT offers to automatically make a massive amount of data available for information or analysis purposes, such is the case of Marinakis [44] and Ram [24] who implemented the IoT with the aim of making efficient use of energy. It is clear that the IoT concept goes hand-in-hand with other modern concepts such as *sensor cloud*, and that its applicability ranges from factories to foreseen worldwide services [45]. It is usually agreed that the IoT concept could be the starting point for smart cities [46] in an attempt to achieve monitoring and automation of all city needs.

Therefore, the *smart* communication infrastructure has two main differences with respect to its typical counterpart: it is device-oriented and it is excessively dense, requiring communications efficiency. Thus, it is "smart" because it enables, for instance, M2M and can handle enormous amounts of data for further analysis. It is a network with one main objective: automation's efficient empowerment [46].

For example, Kumar et al. [38] and Liu et al. [47] proposed the usage of the IoT and smart sensing for efficient energy management in *smart* cities. Alternatively, Humayun et al. [27] proposed optimization schemes based on the IoT for energy consumption. A similar work focusing on intelligent building management was proposed by Marinakis [44], whereas Mohammadi et al. [48] focused on the communication platform for the improvement of services and comfort in a smart city. As mentioned above, Desai et al. [37] collected information on how the foundations for smart cities have been laid through the IoT.

2.3. Decision Making

The usage of data can take two paths. Typically, the acquired data is interpreted through stored routines and later presented to some users to help them make decisions; processing is intended to display data conveniently. This type of semi-automated system has been widely used, as mentioned by Krishnan et al. [49]. On the other hand, a system can command other devices automatically, based on parameters set beforehand and with the help of different technological approaches aiming to streamline processes and improve services [23,50].

However, while *smart* decision-making sounds directly related to the second path, it is unclear what the difference is against highly-automated alternatives, and it is hard to identify a decisive distinction among literature. Industrial automation has already availed *Manufacturing Execution and Systems* (MES) and *Enterprise Resource Planning* (ERP) systems, which enable processes to run almost or entirely, autonomously. Even financial and commercial services can be integrated into production processes. How are these *typical* alternatives not smart? Some recent discussions have focused on the collaboration of workers and machines as a sign of "modern" smartness [23]. However, once again, the concept of intelligence seems swayed toward mere automation.

Some authors classify typical decision-making as an already intelligent system [51] due to the fact that with the integration of sensors, control systems, communication infrastructure, data analysis, and decision-making, productivity has increased, accidents have been reduced, energy is used more efficiently, and the carbon footprint can be abated. However, could one say that *smartification* has already been fully attained? As stated before, it would be amiss to confer the *smart* label on technological nesting. A deeper look makes one see that smartness actually operates the other way around since such advanced tools are not smart by themselves but are rather part of a smart system, which became smart once integrated objectives were put forward: there is an integrative intent with complex reach. For instance, abating the carbon footprint is a complex matter requiring setting objectives beyond (but supported by) efficiency, profitability, waste management, etc. In this context, smartness seems to refer to an adaptation of industrial automation to other aspects and other objectives beyond profit [34], essentially dealing with non-repetitive environments.

Therefore, advanced technologies are enablers, and *smart* decision-making is also, as far as it can pursue complex objectives, adapt to changing conditions, and *learn* from experience. These are more than operative, repetitive tasks that can now be also automated. For instance, in 2018, Khan et al. provided a framework for the application of artificial intelligence that monitors, learns, and solves challenges around microgrid implementation [52].

It seems that a distinction is needed since there are two identifiable types of automation, one addressing repetitive tasks to obtain calculated benefits, orderly operation, and exhaustive monitoring, and another able to adapt and fulfill integrative objectives. In the same spirit, there is also a trend incorrectly dubbing any application of industrial automation outside industry walls "smart," hiding smartness behind technical proficiency. As said earlier, it is necessary to observe integrative objectives requiring some degree of adaptation.

2.4. Power Usage and the Smartification

With industry and government raising awareness about the responsible use of resources, sustainability is a topic that has gained prominence [53]. The growth of energy demand is an important issue because most of the resources needed for power generation currently come from finite sources [54]. Therefore, a tempting proposition is the migration to alternative sources or the joint use of alternative and fossil sources, as mentioned by Jannati et al. [55]. However, *smartification* does not depend only on technological progress or the ability to automate processes as discussed above, but on the integrative objectives being pursued. In this case, efficient and sustainable consumption and generation of power. Therefore, sustainability must be a driving axis of *smartification*. This concept of sustainability within the *smartification of things* implies a balance between comfort and the effective usage of resources [3].

In addition, it has been predicted that by 2030 more than 60 percent of the world's population will live in urban areas [46]. Energy procurement complexity will increase, so sustainable planning must be addressed as soon as possible. In terms of electricity generation, the prediction of electricity production in a power station is an important problem. The efficiency and profitability of a power plant rely on an adequate prediction of power consumption, as overproducing power is just as detrimental as not meeting user demand. Hence, how to use big data from smart meters to promote and improve the efficiency and sustainability of the electricity grid is a pressing issue [56]. Over the years, the concept of sustainability has taken various definitions, but all sources agree that a sustainable system must make efficient use of available resources.

In their turn, alternative energy sources put forward new challenges to solve. One of them is the synchronization between sources, typically referred to as *power sharing*. Since there may not be a centralized power generator regulating the electrical network, the different providers must be in constant communication and guarantee robustness even in disturbed conditions [13,57]. Efficient consumption of the generated energy, the reduction of losses during its transmission and distribution, and power quality are also issues to be addressed [58]. Additionally, power bi-directionality, active participation of consumers, *plug-n-play* integration, and grid resiliency, to name a few, are part of the objectives comprising another smart concept, *smart grids* [59,60].

It is clear that integrating new technologies does not only bring benefits but also challenges, contributing to this work's stand about *smartification*: integrating modern technologies into typical processes does not result in smart systems directly, and a holistic objective-driven approach is necessary to effectively evaluate, develop, and solve emerging challenges of "smart" solutions. Contrary to the discussed automation focusing on repetitive processes, it is clear that power procurement offers a variable environment that cannot be treated as a manufacturing plant. Thus, a *smart* approach is not necessarily coupled with novelty, technical proficiency, system autonomy, or orderly operation.

3. Hierarchical Application of Smart Technologies

Now that the *smartification* concept has been discussed and some of the typical misunderstandings have been considered, a hierarchical approach is taken in this section to present how the *smart* concept has been applied to different systems pertaining to energy procurement. By breaking down the *smartification* hierarchy, the *smart city* and *smart grid* concepts are then analyzed.

3.1. Smart Devices

There are currently several devices on the market that allow the interconnection with systems to fulfill monitoring and control tasks, e.g., devices such as smartphones, smartwatches, even smart bottles, and smart shoes, among others [61]. Those devices are intended to make users' lives efficient or comfortable by providing added-value features or services. These devices can be considered part of *smart cities* since they operate as information-gathering agents for subsequent management at higher hierarchical levels. Examples of this are smartphones when used as driving assistants: they enable the user to follow the best route, thus avoiding traffic and reducing pollutants and time waste. Clearly, there are many sensors and devices operating autonomously, without human intervention [62].

Such devices enable the automatic operation of other systems. For instance, lighting systems for isolated rooms monitored through the internet [63] or thermal comfort systems based on temperature regulation [64]. Additionally, security systems with surveillance cameras and motion detectors [65]. Together, they can bring enhanced comfort and safety in a domestic environment, i.e., a "smart home."

Although there is not a single definition for smart devices, all of them share common characteristics: they are interconnected digital apparatuses using some communications infrastructure such as the IoT. However, one can still make a further distinction. For instance, the ISO/IEC 30118-5:2021 standard [42] contrasts *simple* and *smart* devices in terms of "capabilities," in their turn dependent on how extensive use they make of the communication infrastructure. It is noteworthy that such a distinction is not clarified throughout the standard and seems to be directly associated with the devices' complexity.

Moreover, Raff et al. used four *archetypes* to depict smart products [14]. In their work, they identified smart products to be (i) *digital*, comprising hardware capable of computational processing and data management (software); (ii) *connected*, implying communication potential; (iii) *responsive*, entailing automatically reacting or adapting to input signals; and (iv) *intelligent*. This last archetype impedes a clear definition by enabling a recursive logic and relegates the first three archetypes to requirements rather than defining elements. The authors state that an "intelligent" product is capable of learning, anticipating, and acting independently; it uses powerful AI software, reasons, and makes its own decisions [14]. Other frameworks dealing with manufacturing processes and product design associate smartness directly with control and communication capabilities, which seem in line with the preceding approach [15,16].

It is clear that a proper definition of smart devices is not available from the current literature and that most defining attempts make use of subjective features or technical characteristics that are hard to generalize or match with everyday examples. However, besides the technically vague *intelligence* or *complexity*, it is clear that smart devices are digital, connected, and responsive. In terms of users' perception, smartness may come from the superior hierarchical application in which smart devices enable the experienced benefits or added services. To this end, smart homes, buildings, cities, and grids could offer such a perspective if assessed by focusing on their integrative objectives.

3.2. Smart Homes

Smart homes (domotics) are systems that integrate user comfort with security [66]. They allow remote monitoring and control but are also capable of "making decisions" or executing commands based on parameters established by the user. An example of user defaults could be to save energy [67,68]. In some smart home proposals, AI has been integrated to learn from users' behavior and provide a better experience using the provided interfaces [69], but as mentioned above, the integration of these technologies does not necessarily make the home smart.

Smart homes work with a focus on users and their comfort, but the same technology can be used to take advantage of energy savings and help reduce waste, which could contribute to sustainability [17]. Currently, with the inclusion of alternative energy sources, such as photovoltaic systems in homes, there are new challenges to solve, such as the injection of energy, taking care of the quality of the network and the supply at times with high demand peaks, among other issues [70]. Recently, Büyük et al. demarcated smart homes in terms of functionality: "the smart home's main function can be denoted as management and control of appliances to realize comfort or energy efficiency," they also focused on the need for analyzing the inhabitants' patterns for further optimization [17].

In this case, the intelligence of the houses is centered on satisfying the needs of the inhabitants, who decide how the smart home operates, perhaps leaving sustainability in a secondary role. As said before, it will mostly depend on the user's intent and context understanding, as there is a trade-off: embedded technologies can either maximize comfort or minimize power usage, depending on the adjusted set points or real-time decisions.

Now, smart houses are increasingly common, or at least houses with integrated alternative energy sources. A similar approach is also becoming relevant in the urban context of smartification: smart buildings.

3.3. Smart Buildings

Cities have grown to the point that housing complexes are becoming more common, and vertical offices are normal; hence, systems have been developed that help cover the basic needs of users within these buildings. The *smartification* of these structures is currently being sought from the very design steps or by adding technology to modernize existing buildings and the associated services. The concept of smart buildings aims to guarantee basic services while improving energy efficiency, security, and waste reduction, among others [26].

Currently, the *Building Information Modeling* (BIM) concept is transforming the way in which buildings are designed, built, and managed. Mainly, it encompasses sharing information among the construction or management team, together with data analysis and visualization for accompanying decision-making around the building's life cycle. A building can now be planned with sustainable objectives, aiming to increase safety during construction and subsequent maintenance, saving material, and planning the efficient use of resources [71–73]. Another concept that has become relevant is *Building Energy Modeling* (BEM), which uses mathematical models to simulate and predict the energy consumption of buildings, resulting in efficient designs. Together with these systems, AI-based algorithms also participate in the construction and management phases, e.g., using *Knowledge Discovery in Databases* (KDD), data mining, and deep learning systems to identify losses, clustering algorithms, and semi-supervised learning techniques [74].

During operation, smart buildings centralize decision-making, reducing the impact individual users may have, which is a major difference between smart houses and smart buildings because users do not have full control over the building setpoints. In smart buildings, sustainability is normally sought as a "collective" objective, whereas in smart houses, comfort and safety are usually paramount.

For a building to be considered *smart*, it must comply with at least [44]:

- Smart energy management
- Comfort of the inhabitants
- Response to natural disasters
- Waste treatment
- Sustainability

It can be seen that there are more objectives attached to the concept of smart buildings than to smart houses. There are two foreseeable reasons for that: buildings must usually comply with more strict regulations (public policy) involving resource usage, and building management is centralized, reducing the variability of the individual intent discussed above.

3.4. Smart Cities

When talking about smart cities, the issues to be dealt with are more complex than those in the hierarchy outlined above. Smart cities are dynamic; their processes occur concurrently and can be approached from different perspectives. Next, different appreciations of smart cities will be presented, according to the literature.

In 2022, Humayun et al. established that "a smart city is an evolution of a smart home that is an effort toward the automation of the whole city" [27]. Actually, in 2019, Chen et al. went further by defining a smart city as the joint work of automated homes and smart grids [75]. In addition, the definition that has been built throughout those years is the collection of several approaches to solve the needs of users based on the IoT to enhance the quality and efficiency of services and resources [52]. In 2014, Zanella et al. stated that the application of the IoT paradigm to an urban context was of particular interest since it responds to the strong impulse of many national governments to adopt solutions based on information and communication technologies in the management of public affairs, thus realizing the so-called concept of a smart city [76]. At the same time, Pitatzis introduced another concept related to smart cities that may cause confusion: "Ambient Intelligence" (AmI), which, like the IoT, is related to the sensing of systems [43].

Pitatzis used the term AmI to refer to applications that aim to animate the environment for the end user, that is, use user-centric technology. Finally, Muhammad proposed a data prioritization framework managed by the integration of artificial intelligence, IoT, database analytics, and experiments with evaluations of real-world installed systems [77]. Therefore, previous scenarios could be generated, and strategic planning could be carried out in view of an objective. In the same spirit, Szewczenko proposed the "smart aging" concept, implying that a smart city could enhance the lifestyle of the elderly by taking advantage of the technologies listed so far.

On the other hand, in 2018, Abdennahder et al. included "infrastructure" in their definition of a smart city, which, together with the combination of IoT, is envisioned to facilitate mobility, improve energy efficiency and conservation, air and water quality, identify problems to quickly provide solutions, offer rapid response to disasters, collect data to make better decisions and deploy resources effectively, as well as share data that allows collaboration between entities and between domains [57]. Similarly, in 2021, Javadinasab et al. mentioned that in a smart city, the infrastructure must self-diagnose, self-adapt, and self-heal during normal and extreme operating conditions [34]. It can be seen that, as objectives grow in complexity, definitions, and proposals tend to lie around complex requirements rather than specific technologies.

On the other hand, for Din et al. (2018), a smart city comprises information gathering, processing, and forwarding technologies that inspire the invention of tools for improving life quality [40]. Big data is a major player for some authors, as its manipulation has revolutionized the operation of many systems, which, together with energy efficiency and the IoT, lay the foundations of smart cities [51].

In addition, in 2020, Abbas also offered a definition, mentioning that the smart city is intended to tackle or minimize problems created by rapid urbanization and population growth, such as energy consumption, waste, and mobility, through the highest efficiency and resource optimization [46].

Konstantinou stated that smart cities must be oriented toward satisfying the needs and security of the citizens who inhabit them [78] (a lot like a smart home), an idea that Mohammadi also adopted by stating that the services that can be offered in a smart city must be optimized using the IoT and information sensing [48]. On the other hand, Mohamed proposed that the use of alternative energies in conjunction with electric vehicles would improve comfort. In that work, it is proposed a stochastic fuzzy-based framework based on cloud theory for optimal scheduling and management of those technologies [9].

On the electrical side, in 2022, Humayun presented a smart city as an interconnected system that must aim to reduce energy consumption [27]. Therefore, energy optimization is inevitable. Similarly, in 2021 Mahmud proposed a peer-to-peer structure with the intention of sharing the energy generated by alternative sources [25]. In 2021 too, Tantau agreed with this idea, considering a smart city as an example of how energy policies—their use or origin—shape the lives of citizens with the intention of improving them [79]. As a consequence, new business models have grown in large cities, using new technologies to improve living conditions. Because of this, in 2021, Tang mentioned that electric power had become an irreplaceable element when talking about the development of urban areas [80]. Others focused on the need for energy storage systems in urban areas to manage the collection of energy obtained from renewable electricity sources and to supply clean electricity products to consumers efficiently, which has gained relevance in recent years [81].

As Humayun stated, when defining "*smartification*" for a city, one of the problems to solve is energy optimization, from its generation, distribution, and consumption [27]. Therefore, some researchers have turned their efforts to this issue, such as the case of Javadinasab [34] and Martins [82], who proposed adopting innovative technologies in the quest to improve efficiency. Furthermore, Ullah offered a more detailed definition of smart cities focused on the efficiency of growing urbanization, energy consumption, maintaining a green environment, and improving the economic and living standards of its citizens [51].

Cities have always been centers of high population density, so the management of resources in them has been a topic of interest. Thus, intelligent planning that streamlines processes, supply chains, and waste streams is part of the development of smart cities, as Longo proposed [13]. Moreover, by collecting information from smart cities, Martins concluded that they were systems that go beyond the interconnection of buildings within a city since they had the potential to improve the management of energy resources [82]. In general, sustainability in smart cities implies optimizing energy consumption and managing its generation, prioritizing alternative sources. Tantau raised the idea that smart cities should be urban centers that provide high life quality to their inhabitants through optimal resource management [79]. In the same way, Humayun stated that sustainability in Smart Cities could be easily observed in road lights, public and private buildings, parks or parking lots, and in general, any system that consumes energy and could be made more efficient [27].

Interestingly, smart cities seem to be defined in the academic literature heterogeneously depending on specific viewpoints. There are definitions focusing on its modularity [83], its added potential to offer enhanced services [84], others mostly dealing with life quality [85], and, lastly, others dealing with resource usage management [86]. Usually, the works addressing smart cities cite the ISO 37120 standard [87]. However, such a document does not address smart cities but *sustainable cities and communities*. Indeed, the said standard proposes a list of indicators and themes that, in the end, build a framework to evaluate/plan the sustainable development of human settlements (for instance, the themes are economy, energy, finance, housing, population, and social conditions, transportation, and urban planning). The usual entailment of *smart* and *sustainable* cities supports the approach taken in this work, where smartness is attached to integrative sustainability objectives.

In 2014, Mosannenzadeh et al. conducted a literature review to find a definition of smart cities through keyword analysis [19]: "[a] Smart City is a sustainable and efficient city with high quality of life that aims to address urban challenges by application of information and communication technology in its infrastructure and services, the collaboration between its key stakeholders, integration of its main domains, and investment in social capital." The cited definition operates more like a framework where cities could be measured and compared in terms of life quality, collaboration, integration, and investment. However, there are persisting issues better suited to define smart cities in terms of objectives: sustainability, efficiency, and tackling urban challenges.

It is challenging to offer a definition that covers all perspectives and needs. However, sustainability does not exclude any, covering societal, economic, and technical aspects. Thus, briefly, smart cities seem to point toward sustainable development of urban environments. One should not try to define smart cities using their component parts or specifying the enhanced services to be provided. Rather, a smart city is a city with an integrative sustainable aim, where every operational and technological effort points to the sustenance of urban life. Table 1 shows a classification of the different works addressing smart cities.

Table 1. Different approaches to Smart City.

Classification	Approach	Supporting References
IoT	Information and communication technologies to enhance the quality and efficiency of services and resources.	[27,46,77] [52,75] [43,76]
Infrastructure	Intended to facilitate mobility, improve energy efficiency and conservation, air and water quality, and data sharing.	[34,57]
Data, processing, storage	Information gathering, processing, big data	[40,51]
Minimize problems	Minimize energy consumption and waste, through resource optimization	[46]
Life quality and services	Satisfying the needs and security of citizens, improve comfort	[9,48,78]
Energy storage	Manage the collection of energy from renewable energy sources, supply clean electricity products	[25,27,79] [80,81]
Efficiency	Adopt innovative technologies for energy optimization	[27,34] [51,82]
Sustainability	Optimizing energy consumption and managing its generation, prioritizing alternative sources	[13,79,82] [27,83,84] [85–87]

3.5. Smart Grids

As previously mentioned, the energy needed in cities is increasing, and conventional energy generators use finite and highly polluting sources [88]. Conventional power facilities and infrastructure already include sensors, protections, and diagnostic systems and rely on distributed communications. However, the inclusion of technology has been scheduled and slow, so automatic detection of specific problems or complete monitoring and decision-making in real-time throughout the entire infrastructure is not yet possible.

As a result, there are current efforts focused on the development of the so-called smart grids, which have been conceptually proposed to address the above-said issues. Different definitions of smart grid can be found in the literature, such as the one exposed in the work of El et al. (2018): a smart grid is a system comprising distributed and heterogeneous components to intelligently deliver electricity and meet environmental requirements by integrating renewable technologies [89]. Whereas for Chou (2019), smart grids are directly related to the ability to measure the energy behavior of buildings in such a way that energy consumption can be estimated in a grid [5]. However, in the literature, it has been mostly agreed that for a network to be considered *smart*, it must consider the integration of alternative energy sources, power bi-directionality, security, resilience, backward compatibility, and plug-and-play capabilities for integrating new systems [90].

From the side of alternative energy sources, their integration to the power grid, and mainly to the distribution network, is intended to reduce CO_2 emissions and transmission losses. Overall, they go hand in hand with the smart grid concept as they may enable the reduction of the carbon footprint of the power grid [75]. However, by adding alternative sources, new challenges for the network arise. Integration into the grid is not seamless from a technical viewpoint, and variability [91] forces the system to consider energy storage systems or to rely heavily on the main power bus abruptly. For instance, Akhter mentioned that the variable and non-controllable nature of solar irradiance causes critical issues in power systems, such as voltage fluctuation and the need for reactive power compensation and frequency regulation, impacting the grid's reliability and stability [54].

In this sense, the smart grid should allow the integration and management of alternative sources together with conventional ones. The generation of energy is ceasing to be unidirectional and driven by large utility companies. Rather, network users are currently becoming *prosumers* (producers and consumers), generating power using alternative sources. Therefore, smart grids are bi-directional by nature, in such a way that the end-user can use the conventional primary source, energy generator plants, or storage systems and interact with the grid to reduce the electric bill or even make a profit. For instance, Mbungu defines a smart grid as a novel electrical network that acts intelligently to accommodate clean energy, electric power management, grid modernization, and consumer participation in an energy-efficient manner, improving the traditional power grid [92].

It is important to highlight that such bi-directionality modifies the originally planned distribution grid, forcing old protections and devices to be replaced, and gives rise not only to technical issues but also to economic considerations since the electricity market could be open for everyone with an active connection and with enough investment capital. A traditional power grid is inadequate to overcome modern-day challenges addressed in a smart grid, so information and communication technologies have to be included [75]. With this scheme, it has been theorized that the cost (economic and environmental) of electricity generation could be reduced because systems would amend local problems that could not be managed from a distant centralized power plant. The patterns of energy consumption vary during the day, the season, the year, and the area. As Eseye mentioned, the total energy cost can be reduced significantly by applying the demand response concept in small-scale decentralized energy systems [91].

However, it is foreseeable that the integration of generators as individuals or associations (such as the *Virtual Power Plant* concept) would result in an increasingly stochastic panorama for all users, including the bigger energy providers, which, in the end, are expected to uphold the grid if suddenly necessary. In addition, with such a dynamic electricity market, it is possible to consider dynamic pricing and low-scale energy bidding, which could result in very complex interactions among prosumers and utilities. Thus, it has been considered that reducing the variability is a paramount objective for the smart grid, and *energy storage systems* are usually considered, mainly based on lithium batteries which are heavy pollutants. Indeed, it has also been proposed that storage systems could participate in the grid to take power when energy is cheap and release it whenever its cost rises, leading to a trading system where fair competition seems hard to attain. It can be seen that the smart grid is not a technology in itself but a platform to offer energy-related services and enable a very active energy market.

However, it would be impossible to operate as above-described without the instrumentation that allows the monitoring and management of the energy flow. Smart grids must be able to monitor every subsystem at the generation, transmission, distribution, and consumption levels and must be able to prevent or promptly correct any inconvenience that may arise. For example, Araujo proposed an infrastructure that includes wireless equipment for smart grids to enable exhaustive monitoring [93]. In his proposal, wireless sensors attached to the network are used, which allow the transfer of information using standardized communication protocols. In addition, Desai emphasized communication within the network, establishing that the smart grid integrates an electrical grid with information technologies for efficient power distribution and transmission between consumers and suppliers based on an *advanced metering infrastructure* (AMI) [37]. Clearly, the IoT is also a strong candidate for this end [94].

Another major challenge within a smart grid is security, which can be addressed from two viewpoints. First, accidents must be prevented, and power quality must be ensured; however, with the insertion of *distributed generating units* and active, automatic systems, grid manipulation, e.g., maintenance, could risk both. A scheduled disconnection may not remove power from some desired area; a preventive reconfiguration could result in heavy disturbances, or the detection of faults could be bypassed if grid parameters are not known precisely. Indeed, everyday operations would challenge local systems as the grid would be ever-varying. Monitoring and rapid response to different operating ranges and behaviors are important to avoid noise and power quality disturbances introduced by active, alternative power supplies [95]. On the other hand, heavy digitization and usage of telecommunications [96] make cybersecurity paramount for the effective and safe operation of a smart grid.

So far, it is clear that not only exhaustive measuring is required, but also automated systems that can tackle the overwhelming complexity and variability of the smart grid. The control systems must be able to act based on real-time data, forecasted scenarios, expected objectives (even economic ones), and sudden variations. They must also be able to react in an emergency situation and reduce the number of users without service. All those tasks are expected to be processed in parallel or simultaneously, in such a way that all problems are solved concurrently [91]. It can be seen that the smart grid concept implies complicated interactions, very ambitious objectives, and the need for exhaustive, advanced technological devices. It is noteworthy that the smart grid is, unlike smart buildings or smart homes, not an actual technology but rather a proposed platform, or conceptual architecture, where the said new services and objectives could be planned and assessed [90].

Briefly, in the *smartification* context, it is clear that the smart grid requires many of the already introduced *smart* technologies. However, it is not from its natural technological nesting that the smart grid takes its name. As presented above, the integration of alternative energy sources seems to push the need for bi-directionality and to enable prosumers, which in turn, requires exhaustive monitoring, a specialized communications infrastructure, and complex control systems. It can be seen that the main issue is that consumers are expected to interact actively with the grid, so the role of users is that of *electrical agents* performing variable consumption-storage-generation tasks, pursuing an integrative objective. This is opposed to the typical passive role that users have as energy consumers. Those users are also empowered to make decisions (or use a system to do so) depending on their intent, technical capabilities, enforced policy, and the developing electrical market. To integrate such intelligent users under the same power grid, it is necessary that the grid itself copes with such an intelligent operation. Therefore, the smart grid can be defined as a power grid architecture that enables and empowers *smart* users to actively interact with it. A smart home or a smart building is also an *electrical agent* that could participate in this scheme. Table 2 shows the different works in which the smart grid concept has been addressed. In its turn, Figure 2 shows a schematic view of a smart grid comprising several electrical agents empowered by smart devices.

Table 2. Different approaches to Smart Grid.

Classification	Approach	References
Alternative energy sources	Aimed to reduce CO_2 emissions and transmission losses	[5,88,89] [54,75,91]
Bi-directionality	Network users are both producers and consumers of energy	[75,91,92]
Instrumentation	Allow monitoring and management of the energy flow, to prevent or promptly correct any inconvenience that may arise	[37,93,94]
Security	Prevent accidents and ensure power quality	[95,96]
Decision-making	Control systems must be able to act based on real-time data, forecasted scenarios, expected objectives, and sudden variations	[91,94]

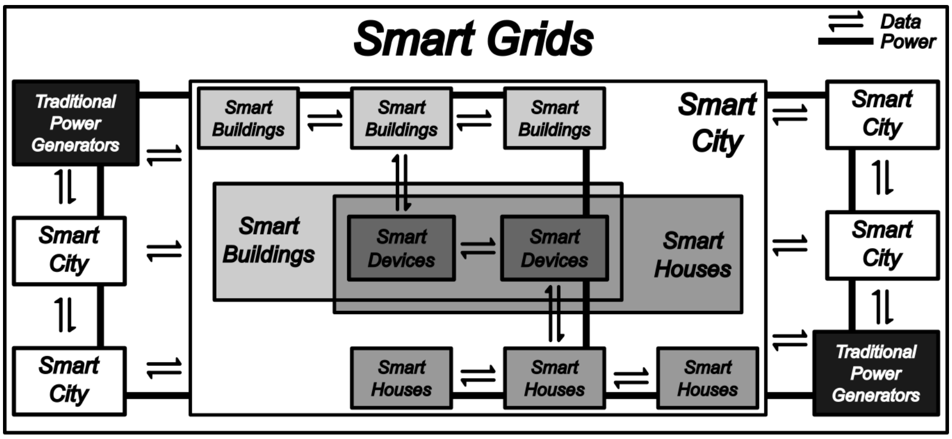

Figure 2. Systems smartification hierarchy.

4. Discussion

Technology is advancing by leaps and bounds, and people are readily involved, at least from the perspective of the consumer electronics market. Not long ago, terms such as smartphones or smart watches were coined and shaped users' expectations around how technology would satisfy their needs, contributing to their comfort and safety. In a similar manner, individuals can now install rooftop PV systems, monitor their household energy consumption, or install smart thermostats, and mostly endorse the application of new technologies as a means to attain a "green" future. However, the much-needed involvement and understanding of sustainability topics are hindered because, apparently, *smart* technology can automatically attain sustainability. Therefore, modern users are passive technology consumers in the same way as typical consumers are passively consuming energy.

Attaining a sustainable future using technology is paved with several challenges. Nowadays, "smart" devices are constantly launched, allowing their integration into other systems or platforms offering enhanced support services [14]. However, is *smartification* justifiable in the sustainability context?

Usually, a device's "smartness" goes hand in hand with computational power, storage autonomy, and communication capabilities. Different operating systems, updates, and compatibility issues make systems obsolete, promoting their early disposal and consumerism overall. Additionally, higher technical capabilities are associated with more energy consumption, the need for bigger batteries, or manufacturing processes favoring cost reduction rather than further recycling. Data processing also has infrastructural and environmental costs. Thus, on the side of consumer electronics, it is difficult to find a compelling scenario in which a passive user could attain smart objectives.

The biggest challenge is to convince society and cultivate an interest in sustainability matters. In the same spirit, public policy must also be adapted so that these systems can be developed, recycled, and disposed of adequately. Further, an effort must be made to ensure the installation of alternative sources or storage systems is beneficial overall.

On the other hand, cybersecurity is one of the challenges that arise when talking about *smartification*. Smart technologies and cloud storage and processing are usually accessible through the internet; therefore, they are vulnerable and must be protected. The interconnection among devices is as beneficial as it is risky due to the potential access to user information or the possibility of executing commands from unauthorized sources. Therefore, the protection of information and connected devices is a pressing issue [89]. Cybersecurity is paramount for industrial production processes, autonomous or remotely controlled systems, energization and comfort in buildings, food production systems, and even economic issues since they depend on the transfer of sensitive information. Currently, the flow of information through the Internet is one of the issues with particular relevance for the development of smart cities. Therefore, point-to-point encoding processes are currently being implemented. A practical example is autonomous vehicles requiring data processing with high computational cost and access to online databases in real-time in order to operate.

From an electrical viewpoint, *smartification* poses challenges at different levels. As presented before, power bi-directionality goes hand in hand with power quality and demands for a robust electric grid and its associated infrastructure. Indeed, it is also expected that new services and devices can be seamlessly integrated into the grid, changing the set points and considerations used during the grid's design phase. For example, electric vehicles are heavy mobile loads; ideally, the infrastructure should support charging at all times and places, also implying a large investment. As these vehicles become common in the market, their connection to the grid will represent a significant electrical load that will require the development of better technologies, such as ultra-fast chargers and efficient and environmentally-friendly storage systems, in addition to the fact that the connection of these systems will affect the power quality in the network. Clearly, to satisfactorily enable power exchange between electric vehicles and the power grid, a structured communication protocol is needed, increasing infrastructural requirements. The guidelines for communications during power exchange (*Vehicle to Grid (V2G)*) have been outlined in the ISO 15118 standard [97]. The interaction strategies have been referred to as "smart charging" because the charging process could be managed, e.g., to depend on the status of decentralized energy generation systems in smart homes [98].

Similarly, the integration of alternative sources such as solar panels or wind turbines, despite being mostly accepted worldwide, is still challenging for some countries using out-of-date grids and thermoelectric power plants. Investments are too high, and energy costs could be affected.

Similarly, even though distributed generation could support and supply the power grid, the current infrastructure is not prepared to receive energy from arbitrary locations. Likewise, the variability of alternative sources must be compensated using traditional generation facilities, for which electrical stress increases, or incorporating storage systems, whose typical battery-based approaches may be heavily pollutant. This area of opportunity has been studied by Jannati et al. (2017), who proposed a probabilistic distributed generation units planning model to determine technology type, capacity, and location of distributed generation units, while simultaneously allocating energy storage systems based on predetermined capacities [55].

Regarding energy storage systems, there are some major issues currently being discussed. The energy density of a battery involves the use of new materials, and the dis/charging processes could affect their overall performance and lifespan. There are many works addressing different battery storage operation strategies in an attempt to make good use of them, pushing toward increased lifespan [99,100]. The area of batteries and energy storage is extremely important since the storage and use of energy marks the limitations in the projects to be carried out [26,101]. In addition, batteries are heavily pollutant during manufacturing and disposal. Ineffective usage could imply a negative environmental balance. In order to make full use of storage systems, there are some works proposing interconnecting electric vehicles to the main grid as supporting devices, not only during charging cycles [102]. To facilitate the reader, the challenges in which work is being done regarding the smartification of the systems are presented in Table 3.

Table 3. Challenges that are currently important for smartification.

Approaches	Opportunities Areas	References
Human behavior	- The interest of society toward a sustainable future - Consumption habits and active users - Public policies such as recycling	[79,85] [2] [3]
Alternatives power generators	- Power quality - Infrastructure - Supply in low-generation situations - Management of the generated energy - Storage energy (batteries)	[26,58,101] [55,95,103] [81,104] [54,99] [95,100]
Electric vehicles	- In-vehicle energy storage - Ultra-fast charging system - Infrastructure of the electrical network - Data management in real-time - Decision-making systems	[9] [39] [98] [102] [105]
Cybersecurity	- Data protection during transfer - Data protection in the storage system - Point-to-point protection between devices	[65,89] [49] [106]

5. Conclusions

In this work, a thorough discussion around *smartification* was presented to provide a conceptual framework where smart cities and the smart grid could be defined from the energy sustainability viewpoint. A specific attempt to avoid misconceptions and reduce ambiguity was presented. In conclusion, the common ground between *smart* systems and devices was found in terms of added assistive services intended to empower users to attain some objective. Such increased potential is provided by programming and communication capabilities enabled by digital technologies. On the other hand, to properly define *smart* frameworks like smart cities or smart grids, it was necessary to distinguish between usual industrial automation, necessary for repetitive processes, and the automation required to face complex and ever-changing environments. Thus, those frameworks are not *smart* due to technological nesting, novelty, or service enhancement but because they intend to attain an integrative objective; for instance, a smart city is a city with an integrative sustainable aim, where every operational and technological effort points to the sustenance of urban life, whereas the smart grid is a power grid architecture that enables and empowers *smart* users to actively interact with it, as opposed to the typical passive role of consumers. Finally, some challenging topics that are becoming relevant for the future of smart cities were presented.

One major effort made throughout this work was to present users as major players in the desire for sustainability and as part of smart systems overall. For instance, smart devices and products do not have a clear distinction from other digital, connected, and responsive devices until they are incorporated into a higher-level structure with integrative objectives. Users' intent and understanding of sustainability objectives could guide technology toward the sought benefits because, in the end, even autonomous technology is as assistive or supportive as the set points established beforehand. Therefore, smart technologies must not be directly labeled as sustainable, and advanced technology must not be directly labeled as smart. Smartness comes from the *active* pursuit of desired results, empowered with the available technology.

In addition, it was confirmed that most of the works in the literature address specific issues and justify smartness from limited viewpoints or, on the other hand, provide a wider approach where ambiguity and subjectivity are hardly avoided. Even those review works addressing frameworks or concepts mostly offered lists of expectancies, qualitative indicators, and requirements that could not, in the words of the works' authors, fully grasp the entirety of proposed alternatives. It is then concluded here that the problem relies not upon the different approaches taken or on the authors' apparent shortsightedness but on the underlying uncertainty accompanying our own understanding of human intelligence, technology, and sustainability. It is here concluded that smartness should be aimed and weighed in terms of desired results. Moreover, due to the anticipated hardships risking human civilization, those results must be compelled by collective benefits, sustainability being a paramount concern.

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Abbreviations

The following abbreviations are used in this manuscript:

AC	Alternating Current
AI	Artificial Intelligence
AmI	Ambient Intelligence
AMI	Advanced Metering Infrastructure
BEM	Building Energy Modeling
BIM	Building Information Modeling
ERP	Enterprise Resource Planning

HES	Head End System
IoT	Internet of Things
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
KDD	Knowledge Discovery in Databases
M2M	machine-to-machine
MES	Manufacturing Execution and System
PV	Photovoltaic
UN	United Nations
V2G	Vehicle to Grid

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