Smart Energy for a Smart City

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Smart Energy is a key element of a Smart City concept and understanding the current state and prospective developments of Smart Energy approaches is essential for the effective and efficient energy supply for the needs of the exponentially growing energy demands of contemporary cities.

Keywords: Smart City ; Smart Energy ; urban development plans ; Poland

1. Introduction

Although there is no universally adopted definition of what a Smart City is and all the existing definitions require further clarifications [1], the significant majority of these definitions include the Smart Energy domain as one of main structural domains of the Smart City concept [1][2]. The importance of Smart Energy for a Smart City function is first of all based on the worldwide rapid growth of the cities and consequently the growing demand for an energy supply [2]. Another factor which determines the importance of energy is its tight interdependence with the successful development of the other Smart Cities structural domains: e.g., transportation and manufacturing [2]. In the worldwide sample of 20 Smart Cities, it was found that increase in the Smart Energy index by 25% doubles the overall Smart Economy index [1].

However, the increased need for a Smart Energy supply in a context of Smart Cities requires taking into consideration the spatial aspect of Smart Energy [2][3][4], as the Smart Energy provision leads to the increase of energy-specific land demand [3]. This is because a major aspect of Smart Energy sources (e.g., renewable sources) is that they emerge on and require every square meter of land surface, therefore, making the land an ultimate resource for the Smart Energy provision [3]. This makes the Smart City planning, Smart Energy planning, and spatial planning deeply interconnected and be perceived and analyzed not as separate parts, but as a progressive continuum [3][4], which will lead to the improvement of the quality of life and the overall socioeconomic development of the Smart City [3][4].

Despite the importance of the integrated research on Smart Cities, Smart Energy, and spatial planning, there is still a substantial gap in the analysis and systematization of the current state of knowledge on this issue [3], as the academic scholarship has mainly emphasized the energy supply component [5][6][7][8][9], leaving the spatial dimension aside. Only a few studies [10][11][12][13] have recently started the drift towards the research on the integrative interaction of urban policy, energy policy, and spatial planning.

Another important shortcoming is the predominant interest in developed countries as the object of the research and some oversight of advances in this area made by the transition economies from the Central Europe region, despite the growing importance of these countries in the current and future increasing demand for energy consumption, due to the progressive socio–economic development of this region. Few studies tackle this issue [14][15] thus emphasizing the pressing need for focus on transition economies and accentuating the specificity of the energy transformations from traditional energy to Smart Energy supply.

Last, but not least shortfall is in the prevalence of studies based on single cities (or just a few cities) as the object of the research, (e.g., [16][17][18][19][20][21]), which was the natural starting point at the initial phase of the development in this research field. However, the progressive development and pressing need for improvements in this area are giving rise to a trend of using multi-city samples as the objects of the research, (e.g., [22]), to which this entry contributes.

2. The Stakeholders' Involvement

Representative involvement and diverse representation of Smart Energy key stakeholders in Smart City planning and implementation is a paramount characteristic of the Smart Energy agenda [23][24][25]. Its significance is based on the cooperative nature of stakeholders' collaborations, which provides the intersectoral perspective and accelerates the better understanding and consensus among the key actors [4][26], leading to the joint decisions that are better accepted among the interested groups and are more sufficiently implemented with the lesser risks of the projects' failures [23][26].

However, the competing interests, conflicting objectives, divergent tactics and other barriers [1][4][27] constitute a challenge, which requires flexibility [27], specific communication infrastructures, and collaborative tools [26] in the form of specific platforms and decision support tools, etc. [28][29].

The literature on a Smart Energy inclusion in Smart City planning abandons in numerous taxonomies of the stakeholders' involvement in the planning, decision-making, and implementation processes. Some of these taxonomies just mention the key stakeholders such as: "decision makers, service providers, target groups, and lateral effective stakeholders" [26] and "municipality, utilities, transport companies, citizen groups, market associations" [29]. Further taxonomies classify them by the specific clusters, e.g., Energy Providers and Utility Companies, Building Components Manufacturers, Construction Companies, and Investors and Financiers [28]. Other taxonomies have either categorized them as: institutional, field of expertise, and key sectors (key words) [2], or organized them according to a bottom-up approach within the triple helix system of internal, external, and lateral stakeholders [23].

Almost one-third of the reviewed UDPs comprise the key stakeholders' involvement either in a form of legal entities involved in the UDPs' compilation or as the key stakeholders involved in the Smart Energy Cities' projects. The taxonomy of the stakeholders involved in these projects includes all the main stakeholders playing leading roles in the implementation of the Smart Energy agenda, like Universities, local businesses, and public governance institutions with the projects focused on Smart Energy investment processes, the establishment of Technological Centers for Smart Energy technology transfer, and relevant educational activities aimed at raising the general public awareness of Smart Energy issues.

The future areas of potential improvements of Smart Energy agenda's inclusion in Smart City planning in terms of the stakeholders' involvement could potentially cover the involvement of the so-far under-represented stakeholders like NGOs, community groups, experts' organizations, and the more comprehensive spectrum of collaboration projects which go beyond just the organization of discussion groups and the financing of collaborative projects.

3. The Spatial Dimensions

The importance of the specification of the spatial dimensions (spatial scales) for a Smart Energy agenda and Smart City planning is widely recognized, as the different spatial structures (e.g., single building, quarters, municipalities, cities, provinces, and countries) require different strategies and techniques for the planning and implementation of the Smart Energy solutions [2][3][26]. Ideally, each Smart Energy solution proposed by the Smart City planners should be adjusted by its spatial scale applicability.

Recent academic literature provides the numerous classifications of spatial structures (spatial scales) relevant to a Smart Energy agenda 's components included in Smart City planning and implementation. They could roughly be categorized as either pure "dimension-oriented" or "business-driven" classifications of spatial structures. The "dimension-oriented" classifications most commonly comprise the individuals, buildings, quarters, districts, municipalities, cities, regions (provinces), and countries (nations) as the main structural elements [2][3][4][27], while the "business-driven" classifications include the residential, commercial, and industrial spatial structures [3].

The city-level is the most commonly referred spatial structure of the UDPs included in this entry. All seventeen reviewed UDPs have multiple references to the city-level as the main spatial structure of Smart Energy planning and implementation, which is *a priory* naturally, as the Smart City plans are innately city-specific. Other explanations of the dominance of the city-centric approach imply the prevalent role of the cities in the total greenhouse gas emissions [30], the sole responsibility of the cities' governors for setting the Smart Energy priorities in the absence of international agreement on Smart Cities' development paths [4], and therefore, the higher potential of the cities for the implementation of the Smart Energy solutions [26].

The next most commonly referenced spatial structures were the regional (sub-regional) and country levels: three of the reviewed UDPs referenced these spatial structures. Most often, they were mentioned in the context on how the particular city's Smart Energy development plan could align with or contribute to the regional (national) development or the national Smart Energy or Smart City development agendas.

The international (EU level) was another spatial structure mentioned almost as often as the region–country level: two UDPs made references to it, pointing out the importance of the cooperation efforts on an international level for Smart

Energy investments and the country's international specialization in the sustainable energy industry (among other specializations).

Although the movement from city-level towards region–country level, and then up to international level is a logical path, the gap between the number of references to the city-level and region–country–international levels is remarkably noticeable. This could be explained by the developmental stage of the incorporation of the Smart Energy agenda into Smart City planning for most of the UDPs reviewed, which provides the avenues for the future improvements of the Smart City spatial plans.

The individuals' level is another under-represented spatial dimension in the reviewed UDPs, with the only two references to the citizens' relevance to a Smart Energy agenda in the context of energy effectiveness and energy poverty issues. Such under-representation of the individual's involvement in a Smart City agenda, and the mainly passive attitude toward their potential involvement, is commonly acknowledged in academic literature and does not constitute a Polish-specific deficiency, but rather a world-wide tendency [23][31]. This is recognized as a substantial deficiency of the Smart Energy agenda inclusion in a Smart City context, as the individuals are the most under-represented group at the planning stage, even though the majority of Smart Energy projects are implemented at the individual level [23]. Therefore, the increased involvement of the citizens in a Smart Energy agenda would substantially improve the Smart Energy policies [31] and contribute to "people-smart sustainable cities" [32].

The commercial and industrial spatial scales were found to be the least represented spatial structures with only one reference to them concerning the potential relevance of small and medium enterprises to a renewable energy agenda and the overall importance of the energy efficiency and renewable energy for a business sector of the city. This, once again, calls for the more comprehensive and diverse representation of all relevant spatial structures in the planning and implementation processes of a Smart Energy agenda in the context of Smart City.

4. Smart Energy Conceptions

The review of the various Smart Energy conceptions and technologies referenced in the UDPs shows that renewable energy is the most commonly referenced conception. All the analyzed UDPs include the renewable energy notion, with the prevalent majority of them referencing it on a repetitive basis.

This aligns with the academic mainstream findings, where the Smart Energy systems are supposed to be *a priori* 100% renewable systems and are considered to be one of the main aspect of Smart City development [2].

Renewable energy in the literature was also found to be coupled with the energy-efficiency conception, which was found to be the second most commonly referred conception in the reviewed UDPs. Energy saving technologies were found to be the third most commonly referenced Smart Energy conception, followed by the energy security notion, which is either only briefly mentioned in the UDPs without a specific definition or very broadly defined ranging from the sufficient supply of energy to cover the city's needs to the physical security of energy lines. The remaining Smart Energy conceptions and technologies found in the reviewed UDPs were energy security, energy balance, Smart Energy storage, sustainable energy, smart grid, microgrid, energy from waste, energy poverty, and clean energy.

This initial quantitative analysis shows the profound gap between the most commonly referenced Smart Energy technologies and conceptions, (i.e., renewable energy, energy security, energy efficiency, and energy saving technologies) and the least-mentioned conceptions (i.e., smart grid, energy balance, Smart Energy storage, sustainable energy, microgrid, energy from waste, energy poverty, and clean energy), allowing the consideration of the former four conceptions and technologies as the "core" and the rest as the "periphery", thus implying that further research on the reasons for this divergence is needed and advocating for a wider inclusion of them in the UDPs' Smart City agenda.

Another very important characteristic of the prevalent majority of all the reviewed UDPs is that they are not single-focused on a specific Smart Energy conception or technology, but most commonly include at least three conceptions or technologies from the "core" and several others from the "periphery", leading to a more comprehensive inclusion of the Smart Energy agenda in Smart City planning.

As a concluding remark, it is noteworthy that despite being addressed to the general public, most of the reviewed UDPs have not provided the specific definitions or explanations of each Smart Energy conception or technology (except for those which have a glossary as a part of UDP), and are either relying on the self-explanatory nature of some conceptions or are preferring the broad statements over the specific ones [33], which could sometimes lead to the overlapping use of some conceptions.

5. Smart Energy Key Sectors

Buildings, transport, ICT, manufacturing industries, and energy sectors *per se*, are commonly acknowledged as the main "domains of intervention" and the key sectors for a Smart Energy agenda in Smart City plans [23][26]. This is mainly due to the significant share of the energy consumption by these sectors in the urban areas, e.g., Abu-Rayash & Dincer (2021) [1], and consequently the higher energy-saving capability of these sectors, was found to range from 25% up to 30% [34].

In the reviewed UDPs the buildings, transportation, lighting, and manufacturing sectors were the only sectors found to be referenced with regard to the Smart Energy agenda, with the remarkable dominance of references to the building sector over all the other sectors. The importance of the introduction of Smart Energy solutions for the building sector was highlighted in ten reviewed UDPs, for the transportation sector in four UDPs, for the lighting sector in four UDPs, and for manufacturing in one UDP, only.

This dominance is not surprising, as the overall and constantly growing importance of the building sector for the Smart Energy agenda in a context of a Smart City is highlighted in several EU directives and has led to the introduction of energy certifications and the definition of the Net Zero Energy Building (NZEB) conception, where the building's operational energy performance is one of the key elements [23]. This key significance of the building sector's energy performance is well-reflected in the reviewed UDPs, where the building-related references are primarily focused on the set of the "core" Smart Energy technologies: i.e., renewable energy, energy security, energy efficiency, and energy saving technologies.

Another distinguishing characteristic of the reviewed UDPs is that despite the significant gap among the building sector and the rest, the interconnection between these four key sectors is found to be very strong, i.e., all the UDPs included at least two key sectors, with a prevalent majority of them including the three key sectors. Such interconnection between the key sectors is found to be very important for the Smart Energy agenda's issues included in Smart City plans, as it allows for more achievable and affordable Smart Energy solutions and is widely recognized within the broad conceptions of "interoperability", "interconnectivity", "integrated focus, and "integrated holistic focus" defined by [4][23][26][35].

6. Concluding Remarks

The detailed content analysis of the 17 Polish UDPs allowed for the identification of the following four most commonly referenced components of the Smart Energy agenda: stakeholders' involvement, spatial dimensions, Smart Energy conceptions, and Smart Energy key sectors. All of these Smart Energy agenda components are found to be well-reflected in recent academic scholarship, thus granting the conclusion that this entry's findings are in line with the mainstream research in this area, although they also provide a more nuanced picture of the representational specificity of some of these components in the Polish context.

The thorough dissection of the aforementioned four Smart Energy agenda components shows that the development of the Smart Cities' spatial planning in the transitioning Polish economy follows the steps of the developed countries, leading to a more effective and efficient Smart Energy agenda inclusion. Some inconsistencies and divergences found by this entry could mainly be attributed to the initial stage of the Smart Energy agenda development in Poland, rather than the transitioning economy specificity, thus, allowing for the smooth inclusion of Polish Smart Energy and Smart City agendas into the wider international and developmental contexts.

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