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Tools, technologies and systems integration for the Smart and Sustainable Cities to come

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ABSTRACT

This paper introduces contemporary research on smart cities from the special issue of the International Journal of Sustainable Energy Planning and Management organised in conjunction with the EERA Joint Programme on Smart Cities. The topic - *Tools, technologies and systems integration for the Smart and Sustainable Cities to come* – highlights the variety of research within this field. From a starting point in a discussion on smart cities and smart energy systems, the paper goes on to describe new research findings within the wider area of smart cities and smart energy systems starting with cases of transition, moving on to data requirements and data generation for designing transitions and ending with theories and methodologies for designing transitions.

Keywords:

Smart cities;
Smart energy systems;
Environmental impact;

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1. Introduction

Cities are faced with tremendous challenges arising from rapid population growth, decline outside economic hubs, environmental degradation, and social inequality but also increasing expectations of city services from citizens and businesses alike. In recent years, cities have started to recognize that Internet Communication Technology (ICT) could be essential for a vibrant social, economic and cultural life and that could play a central role in moving the energy systems towards a more sustainable path while limiting the dramatic increase in urban energy consumption and associated CO_2 emissions.

Thus, the paradigm of Smart Cities has marked research, development and innovation projects in the last five year. Now, however, it is time for the new paradigm of Smart Sustainable Cities that enable the decoupling of high quality life and economic growth from resource consumption and environmental impact. Thanks to, but not only to, ICT.

The European Energy Research Alliance (better known by its acronym EERA) Joint Programme on Smart Cities, which officially started in September 2010 as a network of researchers, experts and stakeholders, has been able to explore the multidimensional aspects which characterized first the paradigm of Smart Cities, now Smart and Sustainable Cities. Also, there are starting some reflections on Positive Energy District emerging as a future element of the Smart Cities paradigm.

The idea to create a special issue series on behalf of EERA Joint Programme on Smart Cities (JPSC) came in 2017 with the approval of new EERA JPSC Work Programme which organized the JPSC activities in seven Work Packages: the aim of *Work Package 4 Academy* - coordinated by Paola Clerici Maestosi – was and still is to boost academic interest and participation, and to strengthen cooperation among Research and Technologies Organizations and University partners as well as external stakeholders.

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Accordingly, the idea developed to create the special issue series, and subsequently a Scientific Board was established as well as a well-defined scientific-editorial work plan which main characteristic was to establish collaborations with existing scientific journals through the development of a special issue. Furthermore, the plan is to collaborate with scientific journals edited in different EU countries to ensure a geographic expansion of the work, and to boost discussion on:

- an European approach to Smart Cities, which is why firstly a special issue entitled *European pathways for the Smart Cities to come* was published with the journal TECHNE in 2018 [1,2]*;*
- tools, technologies and system integration in Smart Cities which is why this second special issue entitled *Tools, technologies and systems integration for the Smart and Sustainable Cities to come* is published here in 2019
- Smart Cities as building block for tomorrow's low-carbon energy system for special issue 3 in 2020 with the potential title *Cities of tomorrow: Smart Sustainable Cities and Positive Energy District.*

So every year a new special issue is developed with a new host journal; 2018 was the time of TECHNE, an Italian scientific journal of technology on architecture and environment, while 2019 is the time of the Danish *International Journal of Sustainable Energy Planning and Management* which combines engineering with social science within energy system analyses, feasibility studies and public regulation.

Coming back to the this special issue 2|2019 the decision to join IJSEPM relay on the opportunity to join two scientific communities oriented to complementary research fields with the mission to promote scientific dialogue in the field of technologies.

From the IJSEPM's perspective, energy systems in particular have a large impact on development and basically the human habitat, and a change needs to be planned and implemented [3], however there are more ways to address the challenge. On the one hand, the emission of greenhouse gasses may be limited by simply changing to carbon-neutral fuels, however this is often not optimal or within the constraints given by resource availability [4]. Integrated – or smart energy systems [5,6] – on the other hand, enables a further integration of renewable energy sources where the potential exploitation is limitless. This applies to e.g. wind power and photo voltaics whose production shares are otherwise typically bounded by the temporal distribution of the electricity demand, the degree to which other production units in the system can regulate up and down and e.g. ancillary service supply. In smart energy system, such fluctuating energy sources are integrated using the entire energy system and drawing on low-cost energy storage particularly in the heating system [7].

While smart energy systems thus have a key-role to play in future energy systems, they also need to be coordinated with and coexist with smart cities, and indeed, the ICT solutions for Smart Cities will have as one its main requirements the ability to successfully coordinate the production, conversion, storage and consumption of all carriers of energy. This is a requirement for the successful transition to renewable energy sources, which are largely of a non-dispatchable nature.

In this special issue, a series of articles are presented, which advances the scientific knowledge within the nexus of Smart Cities, Smart Sustainable Cites and Smart Energy Systems with case of city or energy transition, data acquisition for planning purposes and tools and theories for transition studies.

The special starts with an article outlining European research projects and funding within smart cities [8] and ends with a virtual round table discussing the issues pertaining to smart cities [9].

2. Energy system transition

Outlining how cities have to take the lead due to inadequate national or international global warming mitigation policies, Ben Amer et al. investigate how an area may transitions its energy system in their work *Modelling the future low-carbon energy systems - a case study of Greater Copenhagen, Denmark* [10]. Using the energy systems scenario development model Balmorel, they show how expanding the present district heating system in Copenhagen to a new development area is preferable. This article adds to the present body of work using the Balmorel model in the IJSEPM [11,12]

Ancona et al. take a starting point in how district heating combined with renewable energy usage can lead to energy savings in *Low temperature district heating networks for complete energy needs fulfillment* [13]. Further advances may be made through the lowering of the district heating supply temperature, which benefits both grid losses, the exploitation of heat sources and efficiencies in the supply system. This work follows nicely in a tradition of low-temperature district heating studies published in the IJSEPM [14–16].

Using the energy plant design model energyPRO, Widzinski investigate the transition of a Polish coal-based power station to a natural-based cogeneration of hreat and power station in the article *Simulation of an alternative energy system for district heating company in the light of changes in regulations of the emission of harmful substances into the atmosphere* [17]. This article follows up on previous work using the energyPRO model for simulating CHP systems published in this journal [18,19].

In *A city optimisation model for investigating energy system flexibility* [17], Heinisch et al. address the electrification of energy systems and how sector-integration using electricity as an system-internal energy carrrier will play a more prominent role in future energy systems. The authors find amongst others that storage will increase the utility of power-to-heat technology. This is line with previous results on sector integration using the smart energy systems approach. [20–23]

Tötzer et al. investigate how urban manufacturing can be integrated into city energy systems in *How can Urban Manufacturing contribute to a more sustainable energy system in cities?* [24]. Manufacturing is changing, and while there on the one hand may be waste heat streams from industry to be tapped in, industry is also moving towards higher electricity demands. Thus in the future, urban manufacturing needs to be better integrated with other sectors and actors in the city.

Jaroszewska et al. address *A Sustainable energy management: are tourism SMEs in the South Baltic region ready?* [25] Their starting point is that the tourism industry needs to position itself, and that sustainability is one facet that European tourism industry can focus on. In their work, the authors focus on how energy management can assist the Polish tourism industry in developing. This article adds to the limited body of tourism-relate work published in the IJSEPM [26].

In *Sharing Cities: from vision to reality. A people, place and platform approach to implement Milan's Smart City strategy* [27], Cassinadri et al. describes the first results of the project *Sharing Cities* aiming at developing smart districts in London, Lisbon and Milan.

Finally, in Cellurale et al.'s article *Solutions and services for smart sustainable district: an innovative approach in Key Performance Indicators to support transition* [28], the authors look into Positive Energy Districts, and strategies for transitioning to smart energy districts.

3. Data for energy planning

In *Experimental demonstration of a smart homes network in Rome* [29], Romano describes a project in the Centocelle district in Rome where a so-called *Energy Box* collects data on energy consumption and indoor climate with a view to establishing the data foundation for a Urban Smart District. Data is gathered and may be used for monitoring the system, may be shared among citizens, and is intended to provide a sense of participation in the energy system. Ultimately, the Energy Box may also enable the citizens to participate in energy markets.

Dochev et al. take a starting point in the need for heat demand data in their article *Spatial aggregation and visualisation of urban heat demand using graph theory* [30]. While many municipalities in Germany are actively developing such heat maps, there are also potential privacy issues. In their work, the authors seeks to transcend this complication by aggregating data using an algorithm based on graph theory. This articles adds to the considerable body of literature on spatial data on heat demands [31], electricity demands [32], and energy sources [33–36] from the IJSEPM.

4. Tools and theories for transition

Miguel-Herrero et al. focus on the circumstance that data is a prerequisite for doing good local energy planning. In *Supporting tool for multi-scale energetic plan through procedures of data enrichment* [37], the authors focus on generating typologies of houses which can be used in the wider assessment of energy demands needs using geographical information tools. In this way, the authors expand on the knowledge already presented in the IJSEPM by authors like Grundahl and Nielsen [38] and Knies [39].

In *Decision Support System for smart urban management: resilience against natural phenomena and aerial environmental assessment* [40], Taraglio et al. present a new decision support system focusing on risk analysis including assessment of the consequences of events on citizens and more

Taking the case of Zero Energy Bergen as a starting point, Gohari & Larssæther investigate the governance structure surrounding the energy transition in the article *Sustainable energy planning as a co-creative governance challenge. Lessons from the zero village Bergen* [41]. The character of the transition trancends current governance structures, thus the authors seek to develop a new theoretical understanding of the political and institutiuonal challenges at hand.

Meloni et al. show how local governance must be strengthened in the article *Energy sustainability and social empowerment: the case of Centocelle smart community co-creation* [42]. However, innovation processes and participation are focused on in their analyses, showing how these may contribute to the transition. Based on the Centocelle district in Rome, their work shows how such elements can form part of a governance structure. This is in line with how previous work from the IJSEPM has indicated a need for appropriate governance structures [43].

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