Green Energy and Technology

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Smart and Sustainable Planning for Cities and Regions

Results of SSPCR 2019—Open Access Contributions

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ISSN 1865-3529 ISSN 1865-3537 (electronic)
Green Energy and Technology
ISBN 978-3-030-57763-6 ISBN 978-3-030-57764-3 (eBook)
https://doi.org/10.1007/978-3-030-57764-3

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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Preface

Third Time's a Charm: Highlights from SSPCR 2019

Several years have passed since we brainstormed the idea to organize an international conference on innovative, smart and sustainable urban and regional planning approaches at Eurac Research in Bolzano/Bozen.

When we decided to propose the SSPCR conference in autumn 2015, it was a leap in the dark. We did not know whether anyone would actually answer the call for papers (because the conference was competing with a high number of already well known international events) and travel to Bolzano/Bozen (which for sure is a lovely place, but not exactly easy to reach!) to take part in the first edition of *Smart and Sustainable Planning for Cities and Regions*. There was some skepticism, but there was also a lot of excitement. In the end, we decided to organize it around the concept of "debate" with two full days of engaging discussion, exchange of opinions, open arenas, and inspiring keynote speeches.

Although from the beginning international and sparkling, thanks to the involvement of ISOCARP—the International Society of City and Regional Planners—SSPCR 2015 was still a small scale conference, with just some dozens of participants, but the feedback from delegates and presenters encouraged us to proceed further in this direction. Moreover, teaming up with the international publisher Springer for the publication of the conference results in the valuable book series "Green Energy and Technology" ensured adequate standards and broad dissemination of scientific results.

So, it was quickly decided to invest in SSPCR, elarging and improving the format. In the spring of 2017, at the Eurac Research headquarter we held the second edition of the conference, SSPCR 2017, under the motto "inspiring the transition of urban areas towards smarter and more sustainable places to live". The conference experienced quite some growth, more than doubling the number of presentations and participants. We started to team with symposium "New Metropolitan Perspectives", of high reputation at the national level; at the same time, the presence of international speakers and representatives from global institutions such as the OECD—the Organization for Economic Co-operation and Development—ensured the necessary attractiveness and diversity of the related scientific ecosystem.

In parallel, with the evolution of the SSPCR, also the “smartness” concept evolved. Researchers, practitioners and decision-makers have experienced the diversity, contradictions and evolution of the “smart city”, “smart region” and “smart specialization” concepts, the criticism emerging about purely technological approaches and the need to recombine these with the previous concept of “sustainability”, leaving more space to the “co-creation” of innovative solutions. In particular, mobilizing urban-planning conceptual frames for open, integrated and common solutions, defining ICT smart city governance investments and driving sustainability transitions for carbon-neutral cities and contributing to the overall resilience of our settlements and achievement of the Sustainable Development Goals (SDGs). Thus, SSPCR 2019, the third edition of the conference, friendly named the “winter edition”, aimed to provide orientation to delegates within the giant galaxy of smart and sustainable planning, supporting the transposition of research into practice and visionary approaches into groundbreaking planning policies and tools. This objective has been transposed into various thematic tracks, each investigating specific topics and recurrent keywords. Around 150 research results, including poster exhibitions, originating in 38 countries were presented at the SSPCR 2019.

Delegates have been inspired by the keynote speech of Håvard Haarstad (University of Bergen) addressing the question of how to catalyse sustainable transformation in places and cities and Claudia Baranzelli (European Commission—Joint Research Center) about the challenges influencing the future of cities in Europe and beyond, with a focus on the interoperability of data.

For the first time ever, the SSPCR 2019 was also complemented by special sessions or side events organized and promoted by relevant national or European networks and partnerships, which decided to come to Bolzano/Bozen to have one of their recurrent meetings (e.g. EERA JPSC; SMARTENCITY project, HAPPEN Programme), providing training (HOTMAPS project), an update on funding opportunities and integrated approaches offered by the forthcoming Horizon Europe program (UERA, JPI, EIP—SCC), as well as national strategies (ENEA, EIP—SCC).

By summing this all up, the publication “*Smart and Sustainable Planning for Cities and Regions. Results of SSPCR 2019*” will provide the reader with a comprehensive overview of recent and original work in the field and expand shared knowledge among researchers, professionals, decision-makers and civil society.

A selection of the top contributions is offered within this volume under the Open Access licence, while others are in the twin volume having the same title but distributed under a conventional non-Open Access licence.

In Part One, the climate–energy transition at the urban and regional levels is addressed from various perspectives. Energy master planning is starting to be understood as a societal challenge and not only a system improvement and fuel-shift issue (Haase and Baer; Unluturk and Krook-Riekkola). New integrated solutions are emerging for the deep-energy retrofit, calling for a systemic approach (Capogrosso et al.), supported by advanced metering systems (Ntouros et al.).

Part Two investigates how the availability of urban (big) data poses great challenges and opportunities for information retrieval and knowledge discovery, especially thanks to the diffusion of smart city platforms and dashboards

(Mitolo et al). Even more, the data becomes a powerful tool for planners in pursuing the Sustainable Development Goals implementation (Garcia Lopez et al.) and monitoring the impact of public policies (Sisto et al.).

Part Three addresses how new value propositions are emerging at this time of urban innovation ecosystems and sharing economy. An outlook on past, present and future of PV funding in Europe (Pezzutto et al.) could be jointly discussed with the analysis of household electricity consumption (Antoniucci, Bisello and Marella) to draw some additional insights on next urban policies. The circular approach in economic development (Avdiushchenko) and action–planning drafting (Scuderi et al.) ensure the unlocking of additional resources, while natural-resource management considerations spillover to local regional economies (Capecchi et al.).

Part Four argues that new forms of urban and rural interrelationships may create new opportunities for a better quality of life in rural or mountain areas, helping fragile and marginalized territories to reduce social and spatial inequalities. To this regard, proper identification methods (Cattivelli), as well as mapping and diagnosis approaches (Pisman and Vanacker), become crucial.

In Part Five, the final part of this Open Access volume, the authors debate how advanced governance models are needed to identify the sources of the problems, to address them in an integrated strategic way (Wesołowska, Mirecka and Majda) and to increase the local authority capacity (Kalakou et al.). Citizen-engagement methodologies and social innovation become even more key aspects in the co-design and co-implementation of nature-based solutions (Mahmud and Morello) or energy transition policies (Tomasi and Gantioler). Similarly, intermediary organizations play a pivotal role in the urban transition by linking national and supranational policies to cities (Meyer and Kalcik).

Additional thematic contributions, as well as a section dedicated to energy poverty, may be found in the "non-Open Access" volume "*Smart and Sustainable Planning for Cities and Regions. Results of SSPCR 2019*".

Concluding, we would like to thank all the people actively involved in the organization of the SSPCR 2019 conference, in particular the Eurac's Meeting Management team for their priceless technical assistance, the Scientific Committee, the keynote speakers and sessions' moderators and to all actively contributing to the conference through their initiatives, posters and presentations. A special thanks to our supporting partners for providing financial support to the event and contributing to communication and dissemination activities. Our gratitude to Claudia Baranzelli (European Commission—Joint Research Center) and David Ludlow (Faculty of Environment and Technology—UWE) for joining the editorial board of this volume and to the anonymous reviewers who donated their precious time and competence in reading, assessing and commenting the submitted manuscripts, providing a valuable contribution in ensuring a high-level quality (despite the COVID-19 outbreak and personal, as well as work-related, difficulties). Looking forward to welcoming you at the next SSPCR "Summer Edition" (the only one missing so far!).

Bolzano/Bozen, Italy

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About This Book

Investigating the potential of urban planning to make cities and regions more sustainable in a smart way: This was the purpose of the 3rd international conference *Smart and Sustainable Planning for Cities and Regions*, held in December 2019 in Bolzano/Bozen, Italy.

This book offers a selection of research papers and case studies presented at the conference and exploring the concept of smart and sustainable planning, including top contributions from academics, policy-makers, consultants and other professionals.

Innovation processes such as co-design and co-creation help establish collaborations that engage with stakeholders in a trustworthy and transparent environment while answering the need for new value propositions.

The importance of an integrated, holistic approach is widely recognized to break down silos in local government, in particular, when aimed at achieving a better integration of climate-energy planning. Despite the ongoing urbanization and polarization processes, new synergies between urban and rural areas emerge, linking development opportunities to intrinsic cultural, natural and man-made landscape values. The increasing availability of big, real-time urban data and advanced ICT facilitates frequent assessment and continuous monitoring of performances, while allowing fine-tuning as needed. This is valid not only for individual projects but also on a wider scale. In addition, and circling back to the first point, (big) urban data and ICT can be of enormous help in facilitating engagement and co-creation by raising awareness and by providing insight into the local consequences of specific plans. However, this potential is not yet fully exploited in standard processes and procedures, which can therefore lack the agility and flexibility to keep up with the pulse of the city and dynamics of society.

The aim of this book is thus to provide a multi-disciplinary outlook based on experience to orient the reader in the giant galaxy of smart and sustainable planning, support the transposition of research into practice, scale up visionary approaches and design groundbreaking planning policies and tools.

Highlights

- Offers empirical and theoretical insights into planning for smart and sustainable cities and regions
- Combines multidisciplinary approaches, giving new suggestions to both researchers, policy, and decision makers
- Delivers a grounded perspective on contemporary challenges for smartness, a circular economy, climate-neutrality and overall sustainability through a wealth of local and regional case studies from Europe and beyond
- Constitutes an excellent overview of up-to-date tools, models and methods for implementing and scaling up smart city solutions

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Adriano Bisello is a senior researcher in the Urban and Regional Energy Systems research group at Eurac in Bolzano/Bozen, Italy. Coordinator of the SSPCR conference series, he manages international European co-funded projects in the field of smart cities and visionary urban solutions. His research focuses on the assessment of the multiple benefits of energy transition and urban transformation processes.

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Shaping the Climate and Energy Transition: Clean Energy and Robust Systems for All

Constraints, Stakeholders, and Framing Goals in Energy Master Planning Between Neighborhood and District

Matthias Haase and Daniela Baer

Abstract This paper analyzes and contrasts the constraints, stakeholders, and framing goals that must be considered when Energy Master Planning (EMP) is conducted for communities in seven countries. The analysis is based on findings from seven countries participating in the International Energy Agency's "Energy in Buildings and Communities Program Annex 73". The analysis covers design constraints such as emissions, sustainability criteria, and resilience goals, regulations and directives, regional and local limitations, such as available energy types, local conditions, and various levels of stakeholders, as well as community objectives. An analysis of the various constraints on different planning levels was done, and the key stakeholders were identified. They can be characterized by different governance structures and thereby stakeholder constellations. Mapping of the stakeholders involved provides insights in further constraints resulting into issues within the EMP that will need to be addressed for multi-owner, multi-stakeholder neighborhoods and districts. With a closer look at a case study in Elverum, Norway, the paper identifies constraints related to stakeholders involved and their impact on applying EMP.

Keywords Stakeholder analysis · Energy master planning · Neighborhood level

1 Introduction

Climate change challenges regulators to put in place more ambitious building and community energy-related requirements to fulfill the ambitions Sustainable Development Goals of the UN.

In the EU, reaching the climate gas-reduction goals of the Paris Agreement challenges stakeholders on all geographical and organizational levels from nations,

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_1

regions, cities, and communities. Following bottom-up approaches for energy planning on the neighborhood level is a promising attempt to reduce energy demand, increase efficiency, and lower the carbon footprint in a multi-stakeholder approach. This is important for the future task to decarbonize our cities, which will have to focus on neighborhood and district level (Jank 2017). The concept of Energy Master Planning (EMP) can help to initiate a better planning and implementation process to fulfill these goals through providing a roadmap for energy planning. The application of principles of a holistic approach to neighborhoods and districts often termed community energy planning in the literature (EED 2012; Jank 2017; Strømann-Andersen 2012; Fox 2016; Zhivov et al. 2014; Robinson et al. 2009) and the concept of Energy Master Planning (EMP) can help to initiate a better planning and implementation process to fulfill these goals by providing a roadmap for energy efficiency in the district as a basis for energy planning that points to the future. Haase and Lohse (2019) tried to define EMP and explained the various steps involved in the process: (1) energy efficiency and (2) comprehensive energy planning.

(1) When it comes to energy efficiency, in the context of the 2012 EU directive (EED 2012), several important measures have been adopted throughout the EU to improve energy efficiency. These include national long-term renovation strategies for the building stock in each EU country, mandatory energy-efficiency certificates accompanying the sale and rental of buildings, the preparation of national energy-efficiency action plans (NEEAPs) every three years, minimum energy-efficiency standards, and labeling for a variety of products, as well as obligation schemes for energy companies (to achieve yearly energy savings of 1.5% of annual sales to final consumers). However, Member States have yet to fully implement the directive and additional support in building capacity and know-how is needed (EPBD 2018).
(2) Significant additional energy savings, reduced emissions, and increased energy security can be realized by considering holistic solutions for the heating, cooling, and power needs of communities, on the neighborhood and district scales, comprising collections of buildings. As a result, a considerable amount of literature has become available including both guidance and assessment tools aimed at EMP at the neighborhood and district level, e.g., campuses (DOE 2013; Huang et al. 2015; EnergyPlan 2019; CASBEE 2019; BREEAM 2019; LEED 2019). But the existing guidance and tools do not seem to be fully solving the challenges. The energy planning consists of determining the optimal mix of energy sources to satisfy a given energy demand. The major difficulties of this issue lie in its multi-dimensional and scale aspects (temporal and geographical), but also in the necessity to consider the quantitative (economic, technical), but also qualitative (environmental impact, social criterion), criteria.

In addition, Schiefelbein et al. (2017) concluded in their investigation of case studies and energy guidelines for energy-efficient communities that "the primary challenges result from inefficient organizational processes and unsupportive framework for implementation".

To provide the necessary methods and instruments to the stakeholders involved, it is essential to identify and frame the constraints that bound the options towards an optimized energy master planning solution (Sharp et al. 2020). Existing literature on EMP guidance indicates that identifying and establishing project goals is a critical first step (Jank 2017).

Far less common in EMP guidance and related literature is information on the identification of constraints that limit energy technology options and how stakeholders influence the decision-making process. Literature in this area mentions options analysis or prioritization, or optimization analysis (EED 2012; Fox 2016; Robinson et al. 2009; Zhivov et al. 2017), but few mention constraint identifications related to energy technologies as Sharp et al. (2020) pointed out when comparing energy technology constraints in EMP in the seven countries. Although the work of Sharp et al. (2020) contributes by widening the definition of constraints into EMP, it is limited in its scope by focusing on single-ownership neighborhoods like campuses or military garrisons.

Not much work is done on constraints, stakeholders, and boundary conditions in EMP for multi-owner, multi-stakeholder neighborhoods. But many cities and regions are characterized by diverse ownerships and a multitude of stakeholder groups involved, which results in more complex framing goals that can lead to further constraints in EMP.

2 Objectives

As more and more countries push to improve the efficiency, environmental impact, and the resilience of buildings and neighborhoods, the need for front-end comprehensive EMP on a neighborhood level is critically important. A successful EMP is highly dependent on a thorough understanding of framing goals and constraints, both local and regional, and their associated limitations that will dictate the optimum master planning design. This paper addresses the gap by developing a broader framework of EMP by incorporating framing goals and constraints for energy technologies and stakeholders' engagement within a multi-stakeholder (eco)system on a neighborhood level.

3 Method

Our research approach is twofold: in the first step, we analyze framing goals and constraints for energy technologies on a global level by comparing seven countries, as part of a larger effort to analyze existing EMP practice in an international team with partners from Austria, Australia, Denmark, Finland, Germany, Norway, and the USA. A constraint analysis based on ongoing research in the participating countries for single owner neighborhoods (military bases and campuses) was used in this step (Sharp et al. 2020).

In the second step, we chose an in-depth analysis of stakeholders involved in EMP on a neighborhood level. We have chosen a case area in Norway because the case is the furthest developed when it comes to the availability and application of new energy technologies, as well as access to stakeholders (availability of interview partners and data was given).

3.1 Analysis of Design Constraints

The constraint analysis was divided into two steps. The first analysis of framing goals in seven countries (Austria, Australia, Denmark, Finland, Germany, Norway, and the USA) covers design constraints such as emissions, sustainability criteria and resilience goals, and regulations and directives and regional and local limitations, such as available energy types, local conditions and different levels of stakeholders, as well as community objectives. It then illustrates how a comprehensive consideration of these can be used to guide the planner toward design options that will lead to an optimum solution for a master plan. The second analysis was based on the local constraints and site-specific goals in the case study of Ydalir in Norway. With this analysis, the key stakeholders were identified, characterized by different governance structures and thereby stakeholder constellations.

3.2 Mapping of Key Stakeholders

The case of Ydalir in the city of Elverum was chosen as a case study as one of nine pilot projects within the Research Centre on Zero Emission Neighborhoods which has implemented various phases of EMP. Nine stakeholders involved from various sectors were interviewed and transcripts of the interviews were analyzed applying qualitative content analysis (Mayring 2000).

This mapping of the stakeholders involved gives insights into other constraints resulting in issues within the EMP that will need to be addressed for multi-owner, multi-stakeholder neighborhoods.

4 Results

Local stakeholders are interested in natural locational constraints, but also are planners who relate their design on locational constraints such as climate data on wind access, solar radiation, air-temperature distribution and time series, and water (and wind) temperatures.

The distribution system and storage constraints are mostly important to local maintenance staff and facility managers, but larger thermal storages equipment could be visible and important for inhabitants as well. Also, the level of noise of the distribution system could be of interest to inhabitants and users in the neighborhood.

When it comes to the building and facility, there are planners and architects involved. The end users or inhabitants play a limited role because they are often unknown and therefore categorized (according to building typology and use of the facility). Here, building codes have the role of defining the minimum requirements that would ensure comfortable use of the building. Involvement of planners and architects is normal, even more so in the next set of constraints that in particular is concerned with the indoor environment. Again, minimum requirements are established through building codes and standards. The building owner can decide on the level of indoor comfort, typically choosing between different levels/classifications (low, medium, high).

When it comes to the equipment in buildings and district systems, the technical functionality is defined in building codes and related standards. Planners and architects have the expertise to define them. However, some technologies can be chosen by the building owner or investor, e.g., if the building shall have a certain heating technology or specific façade technology.

There are different levels for applying EMP within an urban context: starting from the city level, followed by the neighborhood and then the group of buildings with their building regulations. The stakeholders involved can be framed into different categories as illustrated in Fig. 1.

Ideally, the potential reduction goals should be discussed on different levels with the relevant stakeholders in various constellations. A stakeholder forum would encourage a top-down approach, however, in some cases, a bottom-up approach

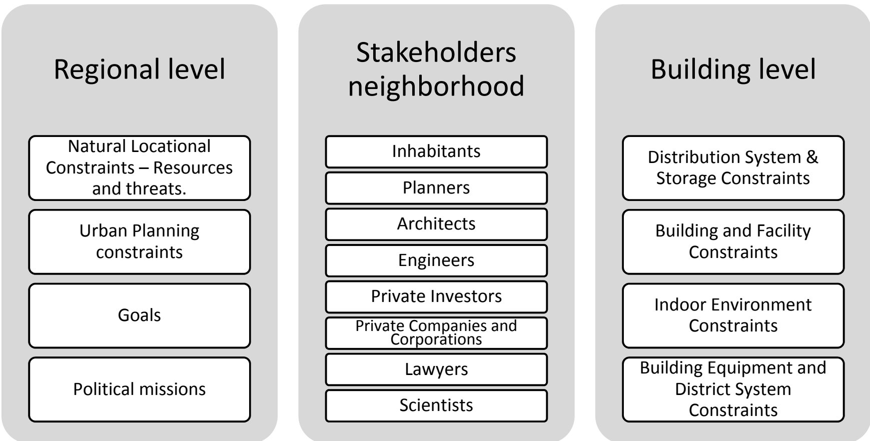

Fig. 1 Stakeholders involved in EMP at neighborhood levels and constraints and framing goals on the regional and building levels

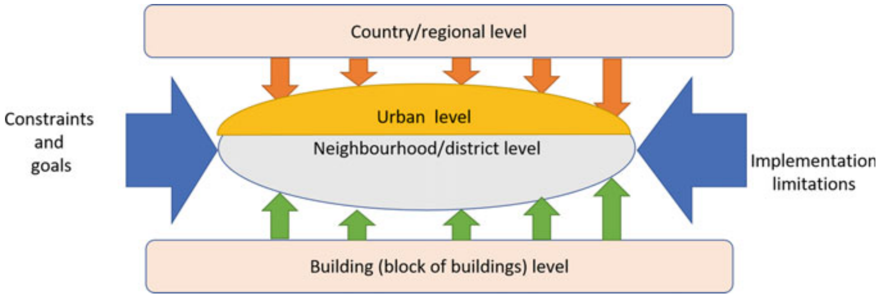

Fig. 2 Constraints in EMP on a neighborhood level

seems more promising. There is the intrinsic problem that different stakeholder perspectives may result in an unclear nature of the problem since stakeholders at different levels view the problem differently. Architects and planners must rethink buildings and spaces; public authorities need to adapt organization and procedures; lawyers need to adapt legal and policy adaptation, etc. This can cause a lack of a unique problem statement and the choice of inadequate solutions for emission reduction.

Figure 2 illustrates the model by visualizing the boundaries in EMP by diagramming the top-down and bottom-up approaches for EMP on a neighborhood level. There are constraints coming from the building level, as well as from the regional level that will limit the technical possible solutions for a site-specific EMP. Various valid objectives possibly conflicting on short-to-medium terms require prioritizing (carbon-free cities; cheap affordable energy for all; regional energy self-sufficiency; job promoting energy system; fully renewable energy sources; etc.). This problem is intensified by the dynamic nature of energy planning parameters (energy price fluctuation; evolving new technologies; population growth; high urbanization rates; changing political actors and agendas etc.).

The quality of physical data is often not available, hindered by privacy and/or measurability issues. This aspect is enhanced by a vast set of technology options, uncertainties on effectiveness, and constantly evolving new solutions at different technological readiness levels.

While locational threats usually do not influence technology selections, locational resource limits, as well as the limits of existing distribution and energy storage systems, can profoundly affect technology selection.

Ambiguity in purpose leads to a lack of clarity about successful outcomes. This may lead to conflicting objectives. On the other hand, ambiguity in values prevents the clear assessment of outcomes. Different stakeholders will value sustainability criteria differently depending on their objective (societal benefits of clean energy opposed to the need for low investment costs, the “landlord- tenant” dilemma; top-down planning or bottom-up collaborative planning; etc.). Therefore, it is important that key performance indicators are introduced and that their weighted values are agreed upon at the beginning of the process.

Identified framing constraints should be evaluated as either a hard or soft constraint. If not, constraints that can be overcome may be missed and promising technologies stripped out of a final EMP solution.

On the political level, we find often unclear policy responsibilities and ambiguous values to address climate change, as well as disagreement on societal effectiveness of climate change policy. This is enhanced on the administrative level with ill-defined responsibilities, budgets and implementation procedures, no established standardized way on the definition and the monitoring and reporting of key performance indicators. On top of this, governments need to reach sustainability targets and safeguard public interest, while energy providers need to make profits and individuals need to reduce expenses.

5 Discussion of a Case Study in Norway

So far, three phases of EMP have been implemented within the Ydalir case—a new neighborhood development within the city of Elverum: goalsetting, assessment and development options and implementation. While two buildings are already completed and in use, the development of a comprehensive plan is still under development (Baer and Haase 2020). We present the following case study under the following three categories: ambitions, commitment to the problem and timeline.

Ambitions

The ambition for Ydalir is to become zero emission neighborhood (ZEN), the amount of emissions through materials and energy used within the construction and operation phase of the neighborhood shall be offset by locally produced energy (Elverum Tomteselskap 2017).

With regard to energy, these general measures are identified within the master plan to achieve the ambition:

- Buildings built after passive house standard or even better, and a high use of wood or other materials with low greenhouse-gas emissions as a building material,
- District heating based on bioenergy for residential buildings,
- Local electricity generation based on solar cells and bioenergy-based power/heat production.

Within the Assessment and Development Options phase of EMP, three studies were undertaken in 2018 and 2019 to analyze future energy and emission performances. Lund et al. (2019) applied a Lifecycle Assessment analysis (LCA) model for neighborhood development based on a modular structure, integrating buildings, mobility, infrastructure, networks, and on-site energy. The study reveals that, regardless of which scenario is considered, the Ydalir project does not achieve the ambitious goal of becoming a zero-emission neighborhood, using the existing planning status as the basis for consideration.

There are several general factors particularly influencing the Ydalir development with regard to attaining high ambitions in cutting down energy and emissions. Through qualitative interviews with the stakeholders involved, we have identified two main factors: commitment to the project and the timeline, that do influence the stakeholders involved and the implementation of EMP (Baer and Haase 2020).

Commitment to the Project

The analysis has shown that commitment to the project depends on the individual stakeholder's vision and agenda. The collaborative development process of the master plan was pointed out by the interviewees as an important step for knowledge and trust development besides the establishment of a common understanding and vision, thereby strengthening the commitment to the ambitious project goal. The local land-development agency ETS received co-funding for the master plan development through Enova, the Norwegian environmental funding agency. Housing developers are indicated as crucial in this phase of development because they have to commit to the general vision of Ydalir by developing an energy system and buildings with climate ambitions that go beyond existing regulations. In its first version, the master plan of Ydalir contained no parking lots for buildings, but the establishment of a car park. These ambitions were already lowered and parking spaces allowed because housing developers feared a lack of interest from buyers. The fear of higher development costs due to higher building standards is also expressed by housing developers and could influence future commitments.

Timeline

The timeline is always a factor influencing project development, but it is especially important because planning of the energy system and the management of the system, including reducing load on the system, depends on the realization of a minimum quantity of buildings and infrastructure within a limited timeframe. In this phase of development, windows of opportunities are open regarding developing a holistic energy system based on minimized loads. It is much more difficult to realize economies of scale for energy solutions if they are added stepwise to the neighborhood system. The time of realization of community services such as the car park is crucial for housing developers with regard to developing their own plots. Future buyers may not be interested to buy houses without their own parking lots as long as the planned shared car park at a central position is not in place.

6 Conclusions

This paper addresses the gap by developing a broader framework of EMP by incorporating framing goals and constraints for energy technologies and stakeholder's engagement within a multi-stakeholder (eco)system on neighborhood level.

The energy master planning on a neighborhood level is confronted with constraints from higher and lower levels. A city consists of several districts or neighborhoods, which must have a consistent energy plan within the municipal EMP. This strategic level from urban planning, as well as natural constraints, are limiting options from the top, while a number of imposed constraints limit technology selection from the bottom. This understanding should be taken into consideration when an EMP is conducted. The stakeholders involved play a crucial role when it comes to EMP and its implementation. The main barriers identified have a strong impact on EMP and are all influential by the stakeholders involved. However, due to the complexity of urban planning and energy master planning, there remain some issues. These issues point to a wicked problem that needs to be solved. The main issue is linked to how to best involve different stakeholders in the EMP process. Which tools are needed to facilitate the stakeholder involvements? How does one communicate and visualize analysis results in the decision-making group?

In the study on the neighborhood of Ydalir, we identified the stakeholders involved, as well as stakeholder constraints with regard to EMP and its implementation. The type of stakeholders involved, how they communicate, and how they are involved in the process play a crucial role. The main barriers identified have a strong impact on EMP and are mainly influenced by the involved stakeholders themselves. The Ydalir case has shown that a collaborative master plan development can help to strengthen the commitment to the project and lower uncertainty in an early phase of development. The realization of this collaborative process was enabled through the initiative, and thereby commitment, of ETS. The external funding was crucial here, as financial resources for broad stakeholder engagement are often limited.

To maintain consistent quality in the EMP process, it is recommended that the identification of framing constraints and their limits, and perhaps their evaluation, be standardized (perhaps starting in checklist form). If identifying constraints and applying their limits were standardized, the results here could perhaps help to establish a baseline that can be used by others, built upon experiences, and improved to establish a standardized process. For the concept of EMP applied on the neighborhood level with multiple stakeholders involved, we learned through the Ydalir case that there is a need to incorporate aspects of stakeholder management and engagement, process management, and tools for the identification of the appropriate neighborhood design. As there are today, no tools or indicators available, as well as a lack of interest from the academic side, to identify appropriate neighborhood sizes, we recommend elaborating and identifying appropriate neighborhoods within a multi-stakeholder approach by screening the whole city and/or region. In this selection process, factors, e.g., constraints regarding available energy sources, possible stakeholders involved and their interests, and location within the greater urban and regional infrastructure system, have to be considered. We recommend conducting a SWOT-analysis to assess development opportunities with regard to strengths, weaknesses, opportunities, and threats for neighborhood development, in general, and specifically in realizing ambitious energy and emission goals.

Acknowledgements The authors gratefully acknowledge the support from the Research Council of Norway and its partners through the Research Centre on Zero Emission Neighborhoods in Smart

Cities (FME ZEN). Additionally, we acknowledge the support of Enova for discussions within the IEA EBC Annex 73 participation.

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Energy System Models for City Climate Mitigation Plans—Challenges and Recommendations

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Abstract Many cities around the world have adopted climate neutrality targets, and, to reduce their greenhouse gas emissions, they need climate action plans. Energy system optimization models (ESOMs) can be used as tools to support their energy transitions. ESOMs have been in use at the national level for several years and also have recently been used at the city level. Even though several researchers have focused on how city ESOMs can be developed, the literature lacks a discussion of the challenges that are faced in data collection during model development. In this paper, we share the challenges encountered in the model development, as well as in the scenario development and recommend practical solutions for overcoming these challenges. The following three challenges were identified and discussed in the model development process: (a) data availability and quality; (b) communication; and (c) knowledge and background of civil servants and researchers. The main challenges in the scenario development were: (a) parameter selection and (b) complexity. It was found that explanation of the terminology used in ESOMs, presentation of the model structure and preliminary base-year results were crucial actions for overcoming challenges during model development. During the scenario development, collaboration between modelers and civil servants when reviewing parameter combinations and working with preliminary scenario results were decisive strategies for improving the civil servants' understanding of ESOMs. Complementarily, it was found that continuous communication between the researcher and the civil servant and good comprehension of the model on the municipality's side helped improve the usefulness of ESOMs in cities' energy transitions.

Keywords Climate mitigation plans · Energy transition · Energy system optimization models · Municipalities · Stakeholder engagement

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_2

1 Introduction

The global temperature rise is aimed to be limited to well below 2 °C above pre-industrial levels with the Paris Agreement (Rogelj et al. 2016). Cities have a crucial role to play in achieving this aim since they are responsible for around 75% of the global greenhouse gas emissions (Edenhofer et al. 2014: 90). Many cities have committed to climate neutrality targets and have developed climate mitigation or adaptation plans, or both, to reduce emissions and prepare for climate change. At the time of writing, 9884 cities have signed the Covenant of Mayor agreement (Covenant of Mayors 2019). Under the agreement, cities develop climate mitigation and adaptation strategies, Sustainable Energy Climate Action Plans (SECAP) and commit to reducing CO_2 emissions by at least 40% by the year 2030 (Covenant of Mayors 2019). In Europe, these strategies, plans and commitments are most common among cities with more than 500,000 inhabitants or among those that are signatories to the Covenant of Mayors, or both (Reckien et al. 2018).

In a comprehensive energy system optimization model (ESOM), various ways of achieving a transition to a climate-neutral energy system can be explored and assessed, taking local resources and other constraints into account. Therefore, ESOMs can be of benefit to climate mitigation plans. ESOMs have been used at the national level for a long time, e.g., UK TIMES (Daly and Fais 2014), TIMES-PT (Simoes et al. 2008), TIMES-France (Maïzi and Assoumou 2014), TIMES-Sweden (Krook-Riekkola 2015), MESSAGE-Brazil (Nogueira de Oliveira 2016) and TEMBA (Taliotis et al. 2016). Recently, ESOMs are also increasingly being applied to cities, e.g., TIMES model for the city of Pesaro (Comodi, Cioccolanti and Gargiulo 2012), KomMod (Eggers and Stryi-Hipp 2013), TIMES-Oslo (Lind and Espegren 2017), INSMART (Simoes et al. 2019) and TIMES-city (Pardo-García et al. 2019). Model development and results from these models are available in the literature. Nevertheless, few literature contributions describe the process of developing or populating the model with city-specific data and information.

Models at national level are typically used to address national wide policies that can impact all kinds of energy use, while municipalities have a smaller room for maneuver. There is a need to develop a city-level model to support municipalities in decision making. Accordingly, city-level models, such as the generic TIMES-city model, should be structured to differentiate between aspects that municipalities can directly and indirectly impact (Krook-Riekkola et al. 2018). Furthermore, national-level models can be calibrated for base-year, based on national energy statistics that represent the energy supply and use of the country. On the other hand, the energy statistics on municipality level sometimes have another system boundary and do not have the desired granularity. The difference in system boundaries can be illustrated by the energy consumption for transportation, which is based on purchased fuels in the energy statistics. At the national level, this represents the fuel consumed by the citizens and companies, but it is not the case for the municipality level, i.e., since people can fuel their vehicle in another city. Lack of granularity of data in city-level energy statistics could be explained through an example: When there is only one company within a sub-sector, the energy use of this company is combined with a more aggregated sector, e.g., if there is one pulp and paper plant in the municipality, its energy use is only reported under industry sector, and not under pulp and paper sub-sector as in the national statistics. Therefore, it is not straightforward to populate a city-level model based on the official statistics. Another challenge is to identify the energy use by various users and activities and to split it between municipal and other use, thus breaking down the statistics into finer details. Consequently, a big challenge when developing city-level ESOMs is to make appropriate assumptions about the current energy system: The civil servants often have knowledge of the cities' energy systems but not the competence to identify the data needed to populate the model, while the energy system modelers have the energy system competence but not enough knowledge about the municipalities. Hence, the city-level modeling requires close communication between the cities and modelers.

In the SureCity project, a generic city-level ESOM (TIMES-city) was developed to support cities with reaching the climate targets of Covenant of Mayor (Pardo-García et al. 2019). The TIMES-city model was developed considering cities' needs and their energy systems and engaging in continuous communication and collaboration with the municipalities during model development. The modeling process started with workshops in which civil servants and researchers came together and discussed the cities' needs, how the model could support their needs and which result indicators could be useful. These workshops were followed by model development and continuous communication, where researchers were responsible for developing the model and cities were responsible for providing the required information needed to populate the model.

The aim of our paper is to share the challenges that were encountered during data collection for model and scenario development and to recommend practical solutions for overcoming these challenges.

2 Methodology

2.1 Energy System Optimization Models

In the study, energy system optimization modeling based on The Integrated MARKAL-EFOM System (TIMES) modeling framework was used to describe existing and future energy systems at the city level. TIMES models are technology-rich and can be used for medium- to long-term scenario analysis and policy support (Loulou et al. 2016). They generally include all the steps from resource extraction, transformation, transport, distribution and energy conversion to supply of the cities' energy services (Loulou et al. 2016). In the case of TIMES-city, the researchers have developed the model based on city-specific information from the civil servants of each municipality.

2.2 The Generic TIMES-City Model

In the generic TIMES-city model, nine sectors for service demands and their energy supply were included. These are energy supply, electricity generation, residential buildings, private commercial buildings, municipality managed buildings, waste, water and waste-water, public lighting, transport and industry (Krook-Riekkola et al. 2018). In the model, the urban energy system is defined as a Reference Energy System (RES). It is a schematic representation of technologies and energy commodities needed to meet the demand for energy-intensive goods and services (Krook-Riekkola et al. 2018). The calibration of the model was achieved with the city's existing technologies and infrastructure and energy use, whereas the database of the future technologies and fuel options are kept independent from the city. For the model, city administrative borders defined the boundaries for the determination of an activity's location, as inside or outside the city. Moreover, the energy, material and people flow going into and out of the city were included to represent the whole energy footprint of the city. Temporal resolution in the model makes it possible to see the variations between the years, and within a year and this leads to long-term and yearly assessments as mentioned in the Outline of the City-level Modeling framework report (Krook-Riekkola et al. 2018). Additionally, emission factors for greenhouse gases (GHGs) and air pollutants were included in the model which can be counted as another feature of the model to assess the environmental impact of the city.

2.3 Scenario Generator

The scenario generator is the part of the model where the municipality can define the scenarios they would like to assess. It is possible to change the following parameters to assess different pathways for the future: demand increase or decrease that is related to population and GDP, prices of fuels, electricity and district heating, CO_2 mitigation levels (i.e., the target that a city sets to decrease its emissions rates from the calibration year of the model), availability of transport options in the future that the municipality can effect (e.g., public transport, car-pooling), building insulation and efficiency. In addition, it is possible to define scenarios with targets for the share of renewable energy sources and/or to only allow certain low-carbon technologies.

2.4 Identification of Modeling Needs

Comprehensive energy system models require a substantial amount of data. This data is not always straightforward to find, especially not on the city level. For this reason, we identified three different ambition levels in relation to data collection and modeling—rough, adequate and "perfect." The perfect model obviously does not exist and is not described further within this paper but was defined as a benchmark for the other two. The rough and the adequate models are further defined in this section.

A rough city-level ESOM is a model that does not have detailed city-specific data. We identified that the following information are needed in order to develop a rough model:

- Energy balance calibration based on aggregated city statistics, disaggregated based on expert knowledge.
- Aggregated demand per energy-intensive services, e.g., space heating.
- Demand projections based on growth index.
- Techno–economic–environmental characteristics of key technology options.
- Country policies and energy prices.
- Scenarios with varying climate targets.

An adequate city-level ESOM is a model populated with detailed city-level statistics. We identified the following information that is needed to develop the model:

- Scenarios with varying climate targets.
- Energy balance based on measured energy flows at the city level.
- Splitting demands into categories, e.g., space heating split into different building types.
- Demand projections based on city-specific drivers, e.g., population growth projection.
- Technology constraints.
- City-specific policy options.
- Thoroughly defined scenarios, based on cities' conditions, by civil servants with good understanding of how the scenario assumptions affect the model.

3 Challenges of Using ESOMs at City Level

From our experience working with cities with energy systems models, we identified particular challenges both when developing the model, i.e., in meeting the modeling requirements, and when developing scenarios.

3.1 Identifying Challenges in Meeting Model Requirements

We have realized some patterns that were challenging when developing the model. Sometimes, it concerned the data collection, and sometimes it was about the communication with the stakeholders (municipality officials). We categorized the challenges in meeting the modeling requirements as the following: data availability and quality, communication, knowledge and background.

Data availability and quality: The existing data at the city level are mostly financial, while it is energy data that is needed for the model. For example, municipalities know how much they paid for fuel in a year for city-owned vehicles, but they do not necessarily know how much fuel they consumed. In another example, total electricity consumption in buildings was known, but the purchase distribution per building type was only documented in the economic system. Thus, the available unit of data is not in energy units. Data quality is crucial for base-year calibration, and good data quality is challenging to attain when demand and supply data do not match. This is especially the case when converting financial data to energy units. In the cases when collection is required by law and regulations, data is available. It has been straightforward to collect information on energy-related entities (e.g., district heating plants), even if the companies are privately owned, when their profession is energy. On the other hand, data on non-energy-related entities (e.g., schools), was more difficult to find. Final energy consumption can be directly measured in municipality-owned entities, but it is often not done. In these cases, when only aggregated energy statistics were available, these needed to be disaggregated in order to calibrate the model for the base-year.

Communication: It is crucial that cities understand their energy systems, the model and how they can benefit from it in order for these models to become useful. However, conveying this information is a complex task, since municipalities usually lack energy systems expertise and modelers generally do not have municipal insights. Thus, clear and continuous communication is required between the researcher and the city officials. Moreover, several models and data files are shared during model development. Therefore, finding ways to communicate the model and to share the files are important to have a smooth model development process.

Another challenge is the terminology used in the model and by the researcher, which can make it difficult for the civil servants to understand which data to collect unless there is a common language to communicate about the model. Misunderstanding the required data slows down the data collection and base-year calibration processes. For example, in energy system models, the difference between the final energy demand and the final energy consumption is important, but a civil servant who has not been working on ESOMs might not pay attention to this detail. Therefore, when the data required is not understood, the data collection process takes longer. Communication is crucial, and there is a need, in the beginning, to define how to communicate the project. Multiple ways of communication are needed for different purposes, e.g., file sharing, model explanation, clarification of required data, etc.

Knowledge and background: Civil servants have different backgrounds that may not be related to the field of energy. Even in the case when they have an energy-related background, our experience was that they rarely have energy system modeling expertise. Therefore, one of the main challenges to the collection of adequate information was that the civil servants providing the information had difficulties interpreting the energy system concepts because they lacked the relevant terminology. This sometimes meant that we retrieved the wrong kind of data and sometimes no data at all. This slowed down the process of data collection significantly.

3.2 *Identifying Challenges in Working with Scenario Development*

In ESOMs, scenarios let us explore future pathways for, e.g., meeting specific climate targets under different conditions. Scenarios typically include coherent assumptions about the main drivers of the energy system and available energy resources, policy options and technologies, which should be internally consistent (Loulou et al. 2016: 10). In the scenario generator, the cities can define scenarios by combining assumptions about the various parameters. However, the scenario generator cannot serve its purpose if the parameters are not clearly understood by the civil servants. We wanted the civil servants to define their scenarios, but many times we saw that they had difficulty understanding how to select parameter combinations. The reason was due to the complexity of the model (capturing the comprehensive energy system, including both energy supply and demand sectors) and that they often wanted to see the impact from using a certain technology and/or energy source (while technologies and energy commodities are chosen by the model in this kind of scenario analysis). Consequently, the challenges are both in the parameter selection and in the complexity topics, and we elaborate them subsequently.

Parameter selection: The scenario generator includes several assumptions like change in demand, CO_2-mitigation levels, policy options for the transportation sector, energy savings in the building sector, fuel prices, targets for renewable technology implementations and so on. These assumptions can be divided into two sub-groups: externalities that may impact city energy systems and assumptions that cities can directly impact. Examples of external parameters are: population evolution (impacting the living area, thus impacting the future demand for space heating and hot water), GDP (impacting purchase of goods, therefore impacting the demand on freight transportation) and fuel prices (a key assumption in the model). Examples of scenario parameters that the city can impact and may vary are: targets (e.g., renewable energy target for the purchased electricity; emission reduction target in transportation sector within city borders); and infrastructure (e.g., expansion of cycling infrastructure may impact the share of people who choose cycling instead of driving the car). Among all the various assumptions, selecting consistent parameters to define a scenario and collecting relevant data is challenging because it requires knowledge of national and local targets and conditions.

Complexity: How the parameters defined in the scenario generator may affect the overall energy system is not clear when the civil servants does not have experience of using ESOMs, which might lead to misunderstanding of the assumptions and the scenarios. Understanding the energy system and how various inputs affect the system is not easy, and it is not straightforward to explain. Interactions between the multiple parts of the system produce a complexity that is difficult to understand if you are not an expert.

4 Recommendations

In response to the challenges identified in this paper, we share some recommendations based on our experience of using ESOM to support cities on their transition to low-carbon energy systems. We categorize the recommendations in the same order as the challenges, data availability and quality, communication, knowledge and background for modeling requirements and the scenario assessment.

4.1 Recommendations for the Challenges in Meeting Model Requirements

Data availability and quality: Firstly, the data collection time should not be underestimated and should be considered in the project timeline because it might not be available in the desired unit or not available at all. In this case, a combined top-down and bottom-up approach is needed to retrieve the required data. For instance, total electricity consumption in buildings was known but purchase distribution per building type was only documented in the economic system. Thus, these two were used to obtain the required data. Similarly, in the transport sector, national average values were used in combination with information about fuel purchased for the population of the model.

Another approach could be to develop the model according to the available data that is not the most desired solution because the level of detail or desired scope might not be modeled. The most beneficial solution for the city and the modeler is having statistical documentation to ease the modeling load and to facilitate the civil servants to have correct information. To get better decision tools for working with city energy transitions, municipalities need to focus on statistical documentation of their final energy consumption per energy commodity and site, if possible, on hourly or monthly bases. This quite easy measure will significantly improve the quality of the analysis; hence, this is where the cities should prioritize putting their time.

Communication: To overcome the challenges, we identified various ways of communication in different parts of the process and for different needs. For file sharing, cloud services provide the most efficient solution according to our experience because the latest version of the file is available to every party at the same time. File sharing with e-mails is another option, which we recommend avoiding, as there is the possibility of using older file versions instead of current ones in model runs, thereby leading to attempts to re-correct problems that had already been encountered and overcome. For model explanation, we found online presentations by the researcher in combination with a report are useful for describing the model structure and explain the required data in detail. These were followed up with a question-and-answer session to support the understating from the city's side. For the model population, face-to-face meetings (physical or online) will speed up the process and are highly recommended based on both our own experience and feedback from the municipalities. A reason for holding face-to-face meeting, instead of using a chat forum or having a "voice-only-meeting" (a phone call or a Web-based meeting without camera), is to make it possible for the modeler to see the reaction of the civil servants to better apprehend if they have understood which data to collect and thereby avoid gathering the wrong information.

Knowledge and background: Civil servants can have different backgrounds and might not have an understanding of energy systems. We worked with several solutions to overcome this challenge. Initially, we tried collaborative–interactive meetings between researchers and civil servants for the base-year calibration. This can clarify many of the questions regarding the data population and can help eliminate the collection of wrong data. However, often the data to populate the model is not available during these initial meetings, so there is a need for several face-to-face meetings. Another approach that we used, and found more efficient, was showing preliminary results to the cities for the base-year of the model, and revealing the underlying preliminary data that had been gathered from available statistics and initial discussions with the municipality. This helped civil servants to get a better understanding of how the data, that is supposed to be gathered by them, is used in the model. This also contributed to municipalities' understanding of how the energy system is defined in the model. Furthermore, online or pre-recorded presentations of the file structure used for modeling are crucial for the cities to understand what kind of information is needed and where it is used. In addition, we put effort into explaining the required data as well as the energy concepts in the model templates to overcome the confusion that is caused by having a different understanding of the terminology than that used by the model developers.

4.2 Recommendations for Scenario-Assessment Challenges

The keys to achieving the aims of modeling are assuring to assist the civil servants to provide input for the scenarios and making sure that they understand the scenario analysis. Recommendations to the challenges mentioned in Sect. 3.2 are described here.

Parameter selection: For the cities to understand the outcomes from the scenario analysis, they need to be a part of the process of developing scenarios to reach their targets. To achieve successful assessments of the different pathways of how the energy system can evolve over time, cross-communication between modeling experts and civil servants is needed, both when defining and when analyzing the scenarios. In the cases, when civil servants are not experienced working with drivers (which we found is frequently the case), it is useful if the researchers first propose a way to define parameter combinations to form scenarios, which thereafter are discussed and revised in cooperation between researcher and civil servants. With regards to the parameters that the city can directly impact, it should be the other way around: First, the civil servant should propose the decisions that have been thought upon, e.g., to reduce their climate impact and, second, these should be discussed with the modelers with respect to how these can be captured in the model. Keep in mind that the model will identify cost-efficient technology and fuel options under each of the defined scenarios, thus this should typically not be varied in the scenario generator. Parameters used in the scenario generator of the TIMES-city model are listed to illustrate what kind of assumptions that the cities can work with while defining scenarios (see Table 1). In the scenario generator, there are three parameter variation options, namely, "high," "medium" and "low." These simple options made scenario definition easier for the cities. If an assumption is not going to be included in a scenario, the option to exclude it is defined as "none."

Complexity: To choose relevant scenario parameters, the city decision makers should ideally know how different parameters impact different parts of the energy system. One way to achieve this is to provide them with the Reference Energy System diagram of their city. However, this was not enough. Instead, it was found that the most efficient and practical solution was to define a simple scenario with a few targets for a preliminary model run and to provide example results to cities. To support this, well-thought-out visualization (good examples, reader-friendly graphs) will make it easier for the city to understand how the parameters that the city can influence may affect their future energy system. This also helps the cities see that they can make

Table 1 Scenario parameters defined in the scenario generator of the generic TIMES-city model

Scenario parameters	Parameter variation options (rate of change)
Socio-economic evolution (GDP/capita)	High/Medium/Low/None
Population evolution (number of inhabitants)	High/Medium/Low/None
Inhabited residential buildings variation (m^2)	High/Medium/Low/None
Variation of the electricity consumption per capita of electric appliances in residential sector (kWh/capita)	High/Medium/Low/None
Evolution rate of municipality growth (starting year 2015 = 100)	High/Medium/Low/None
Variation in useful energy demand for commercial sector/industry sector/public-lighting sector	High/Medium/Low/None
CO_2 mitigation level	High/Medium/Low mitigation/None
Transport policy options based on population evolution	High/Medium/Low/None
Energy efficiency in residential buildings	High/Medium/Low insulation/None
Local renewable power and heat production	High/Medium/Low/None
Fuel market	High/Medium/Low price/None
Target renewable energy sector and low-carbon technologies	High/Medium/Low/None
Variation of the investment cost of the technology for the user (this includes subsidies and taxes at technology level)	High/Medium/Low/None

a change, when they are doubtful of their ability to have an impact on the energy transition. The most crucial recommendation to the modeler is to assist cities during the scenario-definition stage because this will help to focus on varying the scenario parameters with main impact on the results.

5 Conclusion

Cities have been working on climate mitigation and ESOMs are becoming more and more common at the city-level for supporting cities in their energy transition. In this paper, challenges in energy system modeling of cities in the data collection processes for model and scenario developments are discussed. For model development, we found that it is important to: (a) explain the terminology used and data required in the model in face-to-face meetings; (b) explain the structure of the model files through presentations and reports; and (c) provide preliminary results from the base-year as they are critical for overcoming the challenges pertaining to data availability and quality, communication, as well as knowledge and background. Similarly, to overcome the challenge of parameter selection and complexity in the scenario development, we found that it was crucial to: (a) review scenario parameter combinations in collaboration with the cities; and (b) provide examples with preliminary model results to show how city targets affect their energy systems. All the solutions provided in this paper have a common theme, i.e., continuous communication between the civil servant and the researcher. This helps to overcome the misunderstandings of the terminology used in ESOMs and creates a platform to describe the model structure for the city, which helps to improve the energy systems understanding of the city representatives. A better systems understating can support comprehension of what is critical for achieving the transition to a climate-neutral energy system and thereby robust decision making.

The workflow of the modeling process and the recommendations given in the paper are summarized in Fig. 1 that covers the steps from model description to scenario runs. It should be kept in mind that this is a simplified sketch to describe the process conceptually and several steps might require reiteration.

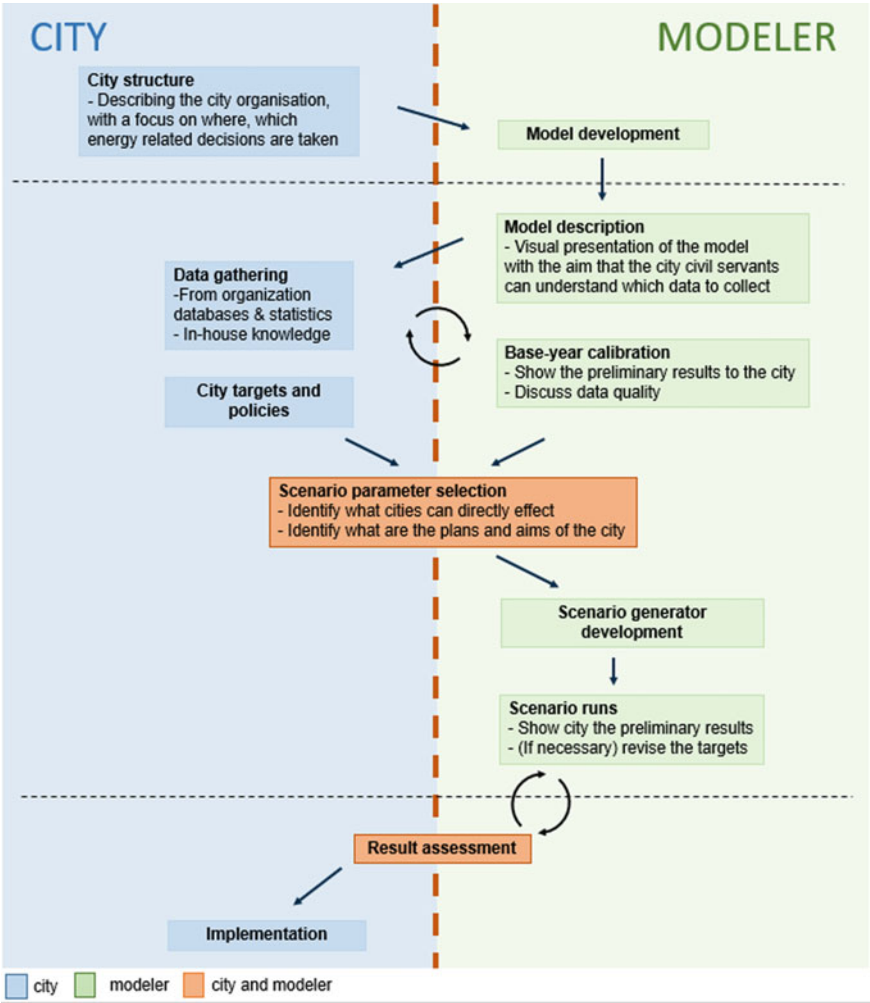

Fig. 1 Workflow on how civil servant and modelers can cooperate in modeling the city's energy system

Acknowledgements This study was carried out within the project "Swedish City's transition to a sustainable energy system—Can models support the decision-making process?", funded by the Swedish Energy Agency under the research program *Människa, Energisystem och samhälle* (Human, Energy and Society) (Energimyndigheten 2017). The authors acknowledge and thank the two anonymous reviewers for their constructive comments. Finally, we would like to thank our colleagues Jonas Forsberg and Carina Lundmark for the valuable discussions on the presented concept and Yawer Jafri for proofreading.

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Deep Energy Retrofit of Residential Buildings in the Mediterranean Area: The MedZEB Approach

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Abstract Mediterranean deep retrofit markets are characterized by common barriers and bottlenecks, which barely have been identified as shared challenges, and this has led to a lack of dedicated solutions and to a substantial delay in achieving the 2020 EU policy targets. This situation is addressed by the H2020 HAPPEN project by proposing a new MedZEB approach characterized by the following features:

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*,
Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_3

- *Holistic*, i.e., aimed at integrating the most relevant aspects of the retrofitting supply chain;
- *Transparent*, i.e., aimed at putting on the market novel tools for enhancing investors' trust;
- *Adaptive*, i.e., aimed at enhancing "added values" of the retrofitting such as flexibility, well-being, etc.

Having arrived at its midpoint, HAPPEN has produced an advanced version of its main outputs, among which are:

- the HAPPEN cost-optimal technical solutions, developed according to a step-by-step logic;
- the HAPPEN financial solution, fully integrated with the step-by-step logic, and aimed at funding the retrofitting process by relying on the energy savings achieved;
- the MedZEB protocol conceived as a guarantee scheme for the achievement of retrofit targets;
- the HAPPEN platform, an assisted digital marketplace aimed at matching demand and offer according to a one-stop-shop logic, at defragmenting the retrofit value chain, and at supporting actors with dedicated tools.

These outputs have been developed also thanks to an extensive living laboratory and pilot-building program, carried out within ten pilot sites across seven EU Med countries; this has made it possible for a large engagement of potential users, which resulted in the ideation of the HAPPEN program, an overall framework aimed at integrating project outputs into an exploitable renovation procedure powered by the HAPPEN platform. This paper describes the first simulation of such a procedure in its entirety based on a real case study. After characterizing the building according to the HAPPEN reference buildings and climates lists, a step-by-step cost-optimal package of solutions was calculated, followed by the application of the HAPPEN financial solution, and by the draft issue of the MedZEB protocol. Results provide the first evidence of the effectiveness of the MedZEB approach in potentially unlocking the deep retrofit market in the Med area, with special attention to the possibility of funding the interventions by relying on the economies generated by the energy savings achieved. Further, the project activities will be aimed at co-creating, together with relevant stakeholders, a go-to-market strategy for the HAPPEN program.

Keywords MedZEB approach · MedZEB protocol · Cost-optimal holistic solutions · HAPPEN program · HAPPEN platform

1 Introduction and General Methodology

This paper describes the first outcomes of an ongoing research and experimentation project, namely HAPPEN,[1] aimed at boosting the market uptake of deep energy retrofitting of residential buildings within Mediterranean EU countries (Padula et al. 2018). As a matter of fact, the development of the deep retrofitting market (DRM) is facing difficulties throughout Europe, but in the Mediterranean (Med) space, these assume specific characteristics due to environmental and climatic factors, to the ownership structure, to the characters of the built stock, to peculiar social and economic conditions and to the consequences of the economic crisis. It is thus necessary to set up a strategy that goes beyond the physical needs of the buildings and technological issues for also integrating social, entrepreneurial, financial, regulative and environmental aspects, as means to deal successfully with the complexity of the Med living spheres, and with the behaviors of their communities. For this purpose, HAPPEN is developing *a specific Med zero energy buildings approach*(MedZEB), aimed at reconnecting the fragmented value chain, at enhancing trust, and at increasing the overall DRM convenience and appeal**.** The MedZEB approach features the following characteristics:

Tailored	Transparent	Holistic	Adaptive
Med area (residential sector)	HAPPEN platform	Engagement and training	**To persons**: focus on well-being
			To relations: living laboratory methodology
		Financing and regulation	**To resources**: step-by-step approach
	MedZEB protocol		**To situations**: alternative investment options
		Optimal solutions	**To environment**: district scale design
			To context: smart integration

The "*transparency"* of the approach is pursued through the following main tools:

A. *The HAPPEN platform,* an assisted digital marketplace aimed at matching demand and offer, at defragmenting the value chain, and at supporting renovation actors with dedicated tools.
B. *The MedZEB protocol,* a guarantee scheme for the good execution of the retrofitting process.

[1]HAPPEN—Holistic APproach and Platform for the deep renovation of the Med residential built ENvironment; H2020 grant n. 785072; Call EE-11–2017; duration: 04/2018–03/2021; LP: ITC-CNR.

The "*holism*" of the approach is pursued through the following main project pillars:

1. *Engagement and training*: a wide range of target groups (encompassing owners and inhabitants, building professionals, entrepreneurs, policy makers, etc.) were engaged in order to stimulate knowledge transfer and behavioral upgrade.
2. *Optimal solutions:* an extensive work of optimization of the available technologies has been carried out, in order to compose cost-optimal packages of solutions (POS) to be applied to different residential typologies according to a one-stop-shop and a step-by-step logic.
3. *Financial and regulation:* Basing on a review of available innovative financial solutions (i.e., guarantee and solidarity funds, credit transfer mechanisms, etc.), the HAPPEN financial solution has been developed, aimed at flexibly assisting the funding of the retrofitting process according to a staged approach fully integrated with the POS.

Research activities have been carried out within ten pilot sites in seven EU Med countries, where living laboratories have been activated, and pilot buildings have been identified, to gather requirements, feedbacks, beta-testing and fine-tuning, in view of the project outputs development.

2 Insights from the Research

Having arrived at the midpoint of its implementation, HAPPEN has delivered its main outputs in an advanced version; testing and fine-tuning within pilots will be carried out until the end of the project.

2.1 Cost-Optimal Technical Solutions

The methodology adopted is described in the amending EPBD (Directive 844/EU 2018). Global costs have been based on life cycle costs (LCC), and the primary energy consumption (PEC) has been calculated dynamically on an hourly basis by using a software complying with the BESTEST of the IEA. The same methodology has been used also in other references, like BPIE (2010), Brandao et al. (2016), Becchio et al. (2015). An extensive abacus of renovation measures has been produced, by gathering technical solutions country per country. A common climatic zoning for the EU area has also been developed, as well as a common abacus of reference buildings for the Med countries. This led to the calculation of *546 cost-optimal packages of solutions* (42 reference buildings $\times$ 13 reference climates) in total (Fig. 1).

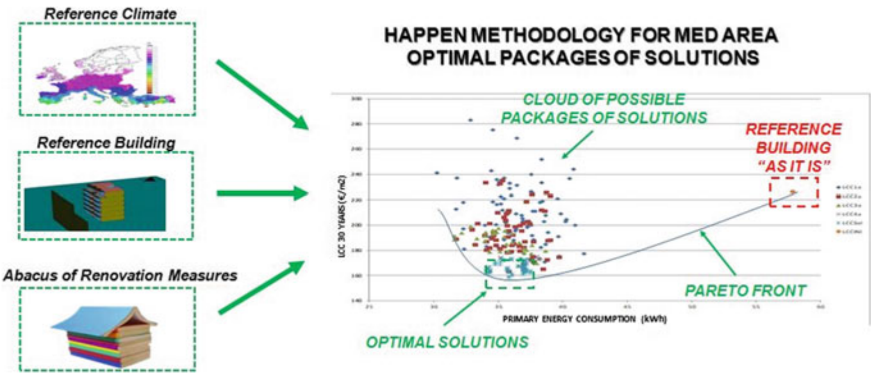

Fig. 1 Life cycle cost versus primary energy consumption for all the renovation measures analyzed per reference building and reference climate to identify the cost-optimal POS

2.2 The HAPPEN Financial Solution

The research was aimed at developing a new financial solution able to flexibly assist the deep retrofitting process according to a step-by-step approach, thus enabling taking into account unpredictable events occurring to the homeowners in the long run of a reimbursement plan (e.g., asset sale or inheritance, technological updates, fluctuation of energy costs, etc.). The research resulted in the development of the *versatile energy loan (VEL)* solution, which consists of a single mortgage arrangement (30-year basis) with multiple steps of disbursement, each one corresponding to the cost of the renovation steps. This feature makes possible a reduction of the initial mortgage (see Fig. 2), to the benefit of low-income or low-resources families, as well as for a full flexibility of the solutions, since the plan can be updated or interrupted after each step. Furthermore, the VEL solution is based on a fixed interest rate for the whole duration of the plan, which would enable taking advantage of the actual situation in the money market. Finally, the reimbursement plan would be shaped to be funded by the economies generated at each step by the energy savings achieved, thus allowing for the full financial sustainability of the interventions.

2.3 The MedZEB Protocol

The MedZEB protocol was designed and developed with the aim of incentivizing clients to invest in building retrofitting, by offering them a *guarantee that the retrofitting process will be carried out properly along the whole value chain.* Furthermore, the protocol contains the quality requirements necessary for accessing the HAPPEN financial solution (see Sect. 2.2), as well as specific KPIs addressing comfort, behavioral and well-being aspects (Fabbri 2016; Antonucci 2019).

The protocol includes also the following main documents:

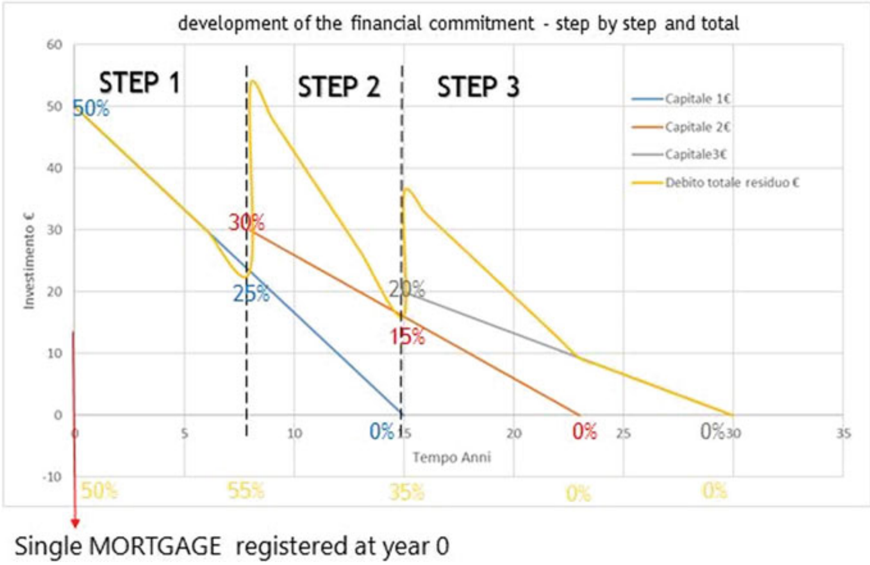

Fig. 2 General plan of the versatile energy loan on a three-step basis, with reimbursement in 30 years, 50% of the total investment concentrated in the first step and mortgage based on 50% of the total investment

- Energy Performance Certificate (EPC. BPIE 2014; Caceres and Diaz 2018);
- Preliminary Retrofitting Project, identifying the boundary conditions and the design objectives;
- Building Renovation Roadmap, describing the breakdown of the retrofitting project into steps;
- Business Plan, based on the HAPPEN financial solution;
- MedZEB Voluntary Certification Scheme (VCS).

The VCS will be issued at the end of each renovation step, after a positive assessment of the achievement of energy saving targets. For this reason, the MedZEB VCS entails a "relative," and not an "absolute," certification of the energy performance (see Fig. 3).

To this end, a monitoring process will be implemented after each renovation step, based on a dedicated monitoring protocol. In case, the assessment is not fully

Fig. 3 General layout of the MedZEB Voluntary Certification Scheme

positive, the guarantee framework of the protocol will be activated, leading to the definition of a contingency plan, the execution of which will be mandatory for the activation of the next step. The development of the MedZEB protocol was based on extensive literature research, including building environmental assessment methods (Triple E 2014; EnerPhit 2015; Kudryashova, Genkov and Mo 2015; Hamelman 2016; Asdrubali 2017; Mattoni 2018; Sesana and Salvalai 2018) and Building Passports running experiences (Sesana and Salvalai 2018; Fabbri 2016). The protocol was designed not only as a detailed, standardized and transparent tool, but also as a simple and cheap one to be used throughout the renovation process.

2.4 The HAPPEN Program

The outputs described above have been included into the *"HAPPEN program"*, which is a comprehensive framework of actions, tools and services aimed at boosting the uptake of the MedZEB approach. The program is composed of three main stages:

1. *Engaging phase:* Potential clients (e.g., households and property owners) are engaged by offering them effective information on the opportunities offered by HAPPEN, as well as an easy-to-use tool for getting oriented on the potentialities related to their own building retrofitting.
2. *Convincing phase:* The engaged client is proposed to contact a MedZEB expert who is a trained professional responsible for the overall application of the MedZEB approach. The expert develops a feasibility retrofit study based on the HAPPEN technical and financial solutions.
3. *Performing phase:* If the convincing phase is successful, the expert produces a full retrofit design, and the MedZEB protocol is subscribed by all the actors involved in the process. Monitoring of results and the issue of the MedZEB VCS are then carried out after each renovation step.

2.5 The HAPPEN Platform

The HAPPEN platform is conceived as the main vehicle for the market uptake of the HAPPEN program. To this extent, it has been structured in order to support the program main stages with dedicated digital services, by providing different final user types (owners, makers and influencers) with a differentiated access to the HAPPEN outputs, according to their specific needs:

- *Owners* will access educational and awareness raising materials (e.g., e-pills, basic training, success stories, etc.) and a quick configurator for a first assessment of their savings potential *(engaging phase).*
- *Makers* will access relevant documents of the *HAPPEN knowledge base* and will have the opportunity to attend the MedZEBinars, the training course for

becoming MedZEB experts. Furthermore, the experts will gain access to the *"expert dashboard,"* which provides interactive data tables and tools for exploring and customizing the POS, for shaping VEL-based financial plans *(convincing phase)* and for elaborating the MedZEB protocol and VCS *(performing phase).*

- *Influencers* will access relevant documents of the *HAPPEN knowledge base*, as well as a dedicated dashboard for keeping track of retrofit market trends.

All groups will access digital forums where they will be enabled to interact among each other and to provide feedbacks on the MedZEB approach. In this way, the platform will act as an *assisted marketplace*, as an *e-learning and services provider*, and as a *digital community* for defragmenting the retrofitting supply and value chain, and it will aim to become the reference portal at EU level for the DRM in the Med area. To this extent, the platform has been co-designed with potential end-users thanks to their deep engagement in the HAPPEN Living Laboratories.

3 Application to a Case Study

The outputs described above have been tested on a real case study to verify their interoperability and to facilitate the assessment and fine-tuning of the research results. The case study is a multi-family building of 12 dwellings on six stories, inserted within a larger district block in Milan (IT). Geometry and U-values of the envelope are showed in Fig. 4 (for more details see Appendix §5.1). The total energy consumption per year is 176.5 kWh/m^2 and the PEC per year is 187.7 kWh/m^2, with 35.16 kgCO_2/m^2 of emissions on a yearly basis.

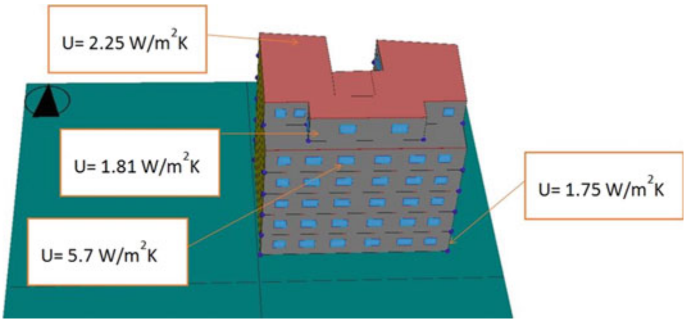

Fig. 4 Geometry and U-values of the case study building envelope

3.1 Application of Cost-Optimal Solutions

The climate of Milan corresponds to the W2S2 HAPPEN climate scale (for more details see Appendix §5.1). The building corresponds to the multi-family reference building typology "Italy 1980–2000." Costs for the renovation measures have been evaluated using the Milano Municipality price-list for public works. The POS identified for this case study, expressed in terms of minimizing the life cycle cost, is briefly described as follows (for more details see Appendix §5.2).

- *Building envelope.* Roof: eight cm of XPS insulation on the outdoor surface; windows: double glazing filled with argon; façades: ETICS with eight cm of EPS; air-tightness: in the contour joints of the new windows; thermal bridges: reduction of the external psi-value of slabs-–façades junctions and window contours; and shadings: reduction of the solar factor by 50%.
- *Building systems.* Controlled mechanical ventilation system (CMVS); heating: new condensing gas boiler; domestic hot-water system (DHWS) based on aerothermal technology (50% RES).
- *Building surroundings.* According to the Solene project outputs for this typology of intervention, glazing ratio and level of insulation, the optimum solution is to plant trees along the street (Morille et al. 2015).

Because the whole intervention cost would be very high to be sustained in one step, also provided the large number of owners, *a step-by-step approach has been defined*. The inner constraints assumed for the definition of the steps are the following: Façades and thermal bridges related to façades are improved simultaneously; air-tightness and façades are improved together; windows and outside glass-doors are changed together; window renewal is associated with the improvement of thermal bridges on the windows contour; limited investment per step: max. 144,000 € (120 €/m^2 of useful surface). Basing on this, the POS has been divided into three steps (Fig. 5), the characteristics of which are the following (for more details see Appendix §5.3):

- Step 1: outdoor façades, windows and thermal bridges;
- Step 2: roof, CMVS, shading elements;
- Step 3: condensing gas boiler, DHWS (50% RES).

Step	Total cost	Yearly savings	Upgraded PEC	By steps PEC reduction (%)
1	€ 132,996.37	€ 8923.60	146.2 kWh/m^2	22
2	€ 84,741.49	€ 140,226.42	82.36 kWh/m^2	44
3	€ 50,097.60	€ 3903.60	64.4 kWh/m^2	22

As final result, the PEC has been reduced from the initial value of 187.7 kWh/m^2 to 64.4 kWh/m^2, which implies **a cumulative reduction of 66%**, thus fulfilling the "deep retrofitting" standard (>60%). The LCC reduction is from 806.9 €/m^2 to 304.1 €/m^2 of useful surface. Figure 5 graphs this evolution.

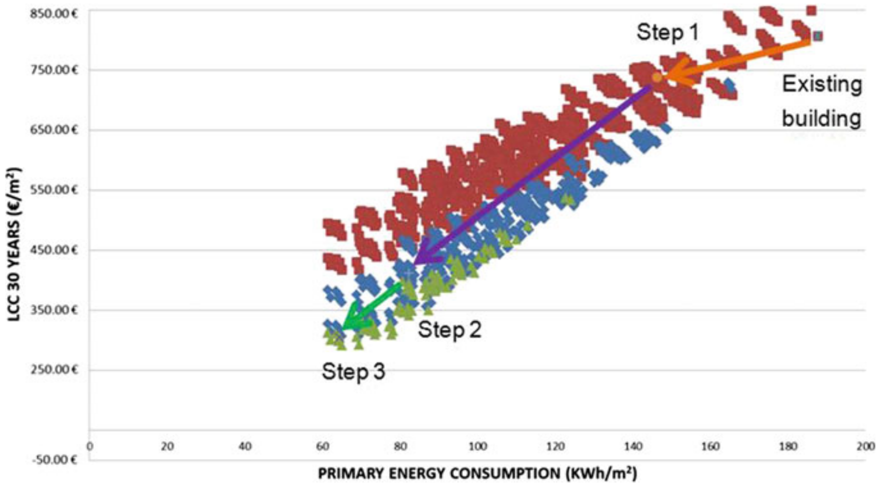

Fig. 5 PEC versus LCC diagram showing the clouds of solutions of the step-by-step renovation. Dots in red, blue and green are those considered for determining, resp., the first, the second and the third step

3.2 Application of the Financial Solution

The simulations have been carried out by assuming an interest rate at 3%, and by introducing an excess approximation of the costs, as well as an efficiency decrease of the installation/envelope system, to test the robustness of the solution under stress conditions. The fiscal incentives available in Italy according to actual laws have also been considered (tax credit mechanism with 70% of reimbursement in ten years), but only for the first step, to cope with uncertainties on their future confirmation. Starting data and results of the simulation are the following (for more details see Appendix §5.4);

- First step: reimbursement in eleven years.
- Second step: reimbursement in seven years from the date of the eight year of the first step.
- Third step: reimbursement in seven years from the date of the total reimbursement of the first step.

The plan is **largely sustainable in 18 years,** with wide margins of guarantee. According to this simulation, the objective of supporting the 100% costs of energy renovation with the savings obtained seems to be fully achieved. A feasibility assessment in the absence of the tax credit has also been performed to test the financial solution in other EU countries without incentives schemes. The plan proves to be **largely sustainable in 27 years,** with the following reimbursement plan: the first step as long as 22 years, the second step lasting ten years from the tenth year of the first step and the third step lasting seven years from the end of the second step. An analogous test (no incentives) was then carried out in the case of a single-stage intervention, resulting in a plan **largely sustainable in 15 years** (see Appendix §5.4), decreasing to eleven years if incentivized according to the actual Italian system.

3.3 Application of the MedZEB Protocol

- *Retrofitting Design:* To set the baseline for defining the savings targets, the energy performances of the building have been taken into account as the starting point before undertaking building retrofitting. The heating and cooling needs have been evaluated, as well as the energy needed for domestic hot-water. The carbon footprint of the building has also been assessed. Figure 6 shows the main results in terms of energy parameters and of CO_2 emissions.
- *Building Renovation Roadmap*: It was planned over a period of 18 years, by scheduling three renovation steps. Several KPIs have been taken into account to assess not only energy performance, but also comfort and well-being. The HAPPEN cost-optimal POS was applied and evaluated; with reference to the energy aspects, the performances of the heating and cooling systems have been analyzed, as well as the energy produced by RES.
- *Business Plan:* It was designed in three steps over a period of 18 years, by basing on the VEL solution (for the application of the HAPPEN technical and financial solutions see §3.1 and §3.2).
- *Voluntary Certification Scheme:* it is issued at the end of each of the three steps. A specific rating system has been drafted to take into account the energy savings achieved for each renovation level, as well as for including comfort and well-being standards (see Fig. 7).

4 Conclusions and Further Perspectives

The paper illustrated a first positive assessment on the application of the MedZEB cost-optimal approach to a real case study; in particular, the potentialities of the approach were highlighted to pragmatically achieve deep renovation standards

	HEAT (kWh/m^2)	COOL (kWh/m^2)	DHW (kWh/m^2)	PEC (kWh/m^2)	FEC (kWh/m^2)	Life Cycle Cost (€/m^2)	CO_2 Emissions (kg/m^2)
BASE	139.31	3.46	16.23	187.68	176.49	806.09 €	35.16

Fig. 6 Energy performance of the building before retrofitting

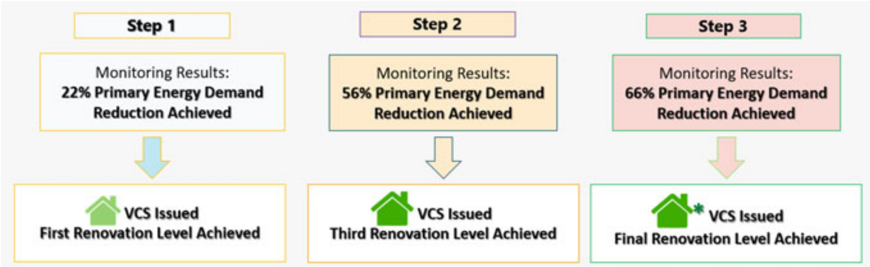

Fig. 7 Overview of the PEC reductions achieved after each step and of the VCS issued; the asterisk reported in the third step symbolizes the full achievement of energy and comfort objectives set in the MedZEB protocol

(above the threshold of 60% of energy savings, according to Fabbri et al. 2016) through a self-repayment mechanism for which intervention costs are largely sustainable through the economies generated by energy savings. The system looks robust, also considering the stress conditions introduced in the simulations, which enable one to consider the results obtained as conservative. In case of incentives (fiscal or cash incentives), payback times are further reduced in favor of all actors involved.

Further testing will be needed and extended over various climatic ranges, built typologies and regulatory situations of the Med area, also considering different technical and financial constraints, to allow generalizing these first results and outlining a complete exploitability field for the MedZEB approach. This will be done in the second part of the HAPPEN project, thanks to an extensive testing of the overall approach within the ten pilot sites identified across seven EU Med countries.

A crucial development will consist of designing a scoring system for evaluating non-energetic aspects, such as comfort and well-being, to foster positive decision making by offering substantial spillovers beyond the energy savings. To this extent, the final protocol should also include specific KPIs, such as bio-meteorologic indexes (e.g., Golasi 2016) tailored for the Med countries and will take into account the global use of natural resources in the retrofitting process.

Moreover, the HAPPEN platform has been co-designed through an active engagement of final users and partners in living laboratories environment, with the aim of becoming a common benchmark for the deep retrofitting markets in the EU Med countries. Future research activities in this field will be focused on transferring the project outputs into dedicated digital tools for owners, makers and influencers, with the aim of assisting them in the tailored and integrated application of the HAPPEN solutions, thus fostering the de-fragmentation and upgrade of the whole retrofitting supply and value chain.

This will also be done by activating in each partner country a "HAPPEN incubator," in which relationships among stakeholders will be promoted for all targeted groups, with the aim of developing a go-to-market strategy for the MedZEB approach, and of drafting a general business model for the widest and sustainable market uptake of the HAPPEN program. The ultimate objective of these incubators is turning the variegated retrofit markets of the EU Med area into a homogeneous market space, thanks to the adoption of a common approach specifically designed to overcome their current barriers, and to cope with local contexts in an adaptive and flexible way.

5 Appendix: Technical Details of the Application to the Case Study

5.1 Technical Details of the Case Study Building

The winter severity climatic index is 1.24; the summer severity climatic index is 0.62 according to the methodology proposed by Salmeron et al. (2013). Total useful surface is 1198.7 sq.m. Compactness, defined as volume to area ratio, is 2.96 m because the two lateral walls—east and south oriented—are party-wall in contact with other blocks. The north façade is glazed 6% while the south façade is 12% glazed. The global thermal transmittance (U-value) of the façades is 1.81 W/m^{2}K, the U-value of the roof is 2.25 W/m^{2}K, the U-value of the slab-on-grade is 1.75 W/m^{2}K and the U-value of the windows is 5.7 W/m^{2}K, giving an average U-value for the whole building envelope weighted by the surface of each element of 2.54 W/m^{2}K. The heating needs of the building are 139.31 kWh per sq.m. of useful surface (u.s.) and the cooling needs are 3.46 kWh/m^2 of u.s. The heating and domestic hot-water system is a mixed gas boiler with a seasonal performance of 0.89. The cooling system consists of a centralized heat pump per dwelling, with a seasonal energy efficiency ratio (SEER) of 2.0.

5.2 Technical Details of the Overall Cost-Optimal Solutions

Building envelope:

- Roof: Increase in thermal resistance of 2.35 m^{2}K/W, installing eight cm of XPS insulation on the outdoor surface of the roof. Investment of 3593.3€ (21.42 €/m^2 of roof).
- Windows: Double glazing filled with argon. U-value of the whole window including frame of 2.7 W/m^{2}K, investment of 56,700.0€ (420 €/m^2 window).
- Façades: Increase in thermal resistance of 2.22 m^{2}K/W, using a ETICS with eight cm of EPS. Investment of 34,542.6€ (46.02 €/m^2 façade).
- Air-tightness: Reduction to an n50 value of 3 h^{-1} installing the new windows using an air-tightness system in the contour joints. Investment of 19,184.2€.
- Thermal bridges: Reduce the external psi-value of slabs-façades junctions from 1.25 W/mK to 0.624 W/mK, and the external psi-value of windows contour from 0.589 to 0.05 W/mK. Total investment of 22,569.6€.

- Installation of shadings that reduce the solar factor by a 50%. Investment of 5616 € (60€ per sq. m. of window)

Building systems:

- Controlled mechanical ventilation system, supplying 0.24 equivalent ACH, investment of 75,532.2€ (6294.4 € per dwelling).
- Heating production based in a new condensing gas boiler. Investment of 19,800€.
- Domestic hot-water production based on aerothermal technology with a 50% of renewable energy contribution. Investment of 30,297.6 €.

Building surroundings: Basing on the Solene project outputs, for this typology of intervention, glazing ratio and level of insulation, the optimum solution is to plant trees in the street (Morille et al. 2015).

5.3 Technical Details of the Step-By-Step Cost-Optimal Solutions

- First step: Improvement of the outdoor façades, windows and thermal bridges of windows contours. Initial investment of 132,996.4€ (110.8 €/m^2 of useful surface). Primary energy consumption after the intervention of 146.2 kWh/m^2, which is a reduction of 22% compared to the existing building, and implies an economic saving of 8923.6 €/yr.
- Second step: Installation of the insulation on the roof, the controlled mechanical ventilation system and the shading elements. Initial investment of 84,741.5€ (70.6 €/m^2 of useful surface). Foreseen primary energy consumption after the intervention of 82.36 kWh/m^2, which is a reduction of 44% compared to the building after the first step renovation, and implies an economic saving of 14,226.4 €/yr.
- Third step: New condensing gas boiler and aerothermal domestic hot-water system with a 50% of RES contribution. Initial investment of 50,097.6€ (41.8 €/m^2 of useful surface). Foreseen primary energy consumption after the intervention of 64.4 kWh/m^2, which is a reduction of 22% compared to the building after the second step renovation, and implies an economic saving of 3903.5 €/yr.

5.4 Technical Details of the Financial Solution

Step-by-step approach, with Italian incentives applied only on the first step:

- First step. Savings: €8.900 per year; reimbursement: eleven years; cost of the reimbursement: from €7000.00 in the first year to €5900.00 in the firth year, €5000.00 of the eight year, etc.
- Second step. Savings: €14,200.00 per year (to which the savings of the first step are added, reduced from €3900 to €2500.00); total available financial resources € 16,700; cost of the annual reimbursement €13,500.00; reimbursement: seven years from the date of the eight year of the first step.
- Third step. Savings: €3900 per year (plus the saving deriving from the end of the debit for the first step, estimated in €4100); available resources € 8000.00; cost of the annual reimbursement €7900; reimbursement: seven years from the date of the total reimbursement of the first step; therefore, it is not necessary to recover also the savings of the second step that we consider as marked up to a guarantee.

Step-by-step approach, without incentives:

- First step. Savings: €8900/year; reimbursement: 22 years; cost of the reimbursement: €8262/year,
- Second step. Savings: €14,200.00 per year; cost of the annual reimbursement €9840.00; reimbursement: ten years from the date of the fifth year of the first step.
- Third step. Savings: €3,900 per year (plus the saving deriving from the end of the debit for the second step, estimated at €4100); available resources €8000.00; cost of the annual reimbursement €7900; reimbursement: seven years from the date of the total reimbursement of the second step; therefore, it is not necessary to recover also the savings of the second step that we consider as marked up to a guarantee.

Single-step approach, with Italian incentives:

Starting parameters: loan of €270,000.00 for eleven years, with a fixed rate 3%; maximum financial commitment: €14,322.00/year (about 57% of the prudentially estimated savings of €25,000.00/year).

Single-step approach, without incentives:

Starting parameters: loan of €27,000.00 for 15 years, with a fixed rate 3%; 180 monthly payments of €1865.00, equal to €22,380.00/year (about 89% of the prudentially estimated savings of €25,000.00/year).

Acknowledgments This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 785072.

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Smart Meter Awareness in Italy, Ancona

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Abstract Smart meters, one of the crucial enablers of the smart-grid concept and cornerstones in smart planning for cities, offer the opportunity for consumers to address their energy consumption effectively through timely and accurate data on their energy usage. However, previous studies have shown that smart meters may not lead to the desired energy savings unless actively used by households. To this end, the research presented in this paper investigates the penetration of smart meters at community level and explores how such a metering system can help people to understand and manage their energy use better. It examines the awareness about smart meters, looks into their presence in current accommodation and focuses on the views people have about smart meters. For this purpose, a questionnaire was prepared and distributed to a group of individuals residing in the wide area of Ancona province in Italy. Although the deployment of modern second-generation smart meters started in 2017 replacing the outdated smart meters massively installed in the 2000s, the results show low-to-moderate levels of awareness of modern smart meters among the respondents and a low presence of second-generation metering devices in their current accommodation. However, the general view expressed by the participants about smart meters is positive. The findings demonstrate that respondents are in need not only of a gauge that measures energy consumption but also of a tool that assists them to manage effectively their energy use.

Keywords Smart meters · Residential sector · Energy consumption · Energy usage

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_4

1 Introduction

The European residential sector is responsible for approximately one quarter of electricity use and more than one-third of gas consumption in the European Union (Eurostat 2020a). Because of these high shares of electricity and gas consumption in households, there is a significant socioeconomic and environmental interest in understanding and optimizing energy usage in the residential sector (Himpe 2017). By monitoring energy consumption at a fine granularity on the order of minutes, high-resolution data from smart meters can give valuable insights into domestic energy usage patterns (Wang et al. 2018). Understanding these insights and addressing any deficiencies is important for energy planning and management strategies, as well as for evaluating cost-effective optimizations and potential for energy efficiency amelioration. For this reason, alongside the development of smart grids, a 34% penetration of electricity smart meters across the EU was reached by 2018 while the EU Member States are expected to replace 92% of the traditional electricity meters by 2030 (TRACTEBEL–Engie 2019). With regard to the gas smart meters, there are no indications of the number to be replaced or a specific timeline. Smart metering and smart grids rollout can lead to reduced annual energy consumption by up to 9% within the European Union (EU) while some pilot projects suggest that actual energy savings for consumers can be even higher (European Commission 2011). By providing real-time feedback about energy usage, smart meters are supposed to help consumers reduce their electricity or gas bills. As indicated in a study conducted in 900 households in Linz, Austria, feedback on energy usage patterns was likely to have triggered investments in household appliances of higher energy efficiency, as well as to stable behavior changes with regard to energy saving (Schleich et al. 2017).

Initially, a goal of at least 80% of consumers to be equipped with intelligent metering systems by 2020 was set out in the Electricity Directive 2009/72/EC, while in 2012, the European Commission (EC) recommended a set of minimum functional requirements for the smart metering systems (European Commission 2012). As stipulated in the Third Energy Package, the deployment of smart metering systems is required in those EU Member States (MS) where smart meters' rollout is assessed positively through a cost-benefit analysis conducted in each MS. However, a massive smart meter rollout for electricity is underway only in Denmark, Estonia, Finland, Italy, Malta, Spain and Sweden. In most EU MS, at least 80% of the consumers will be equipped with a smart meter between 2020 and 2025, while, in about one-third of the countries, wide-scale installation will take place by 2030 or later (TRACTEBEL–Engie 2019). According to a 2014 report on progress in smart meter deployment, issued by the EC, it is expected that almost 72% of European consumers will have a smart meter for electricity by 2020 (European Commission 2014a). However, delays in starting the deployment, a lack of a legal framework, late approval of rollout plans and political and/or financial instability across Europe call into question the 72% expectation (Bularca et al. 2018).

According to Eurostat's 2018 data, across the EU-28 households, the total final-energy consumption was 283,301.425 thousand tonnes of oil equivalent (Eurostat 2020b). Of this amount, the share of electricity was 24.6% and gas 36.2%. Nevertheless, even if the rollout of smart meters had been completed, those intelligent metering systems alone would not have led to the desired energy savings, and the aforementioned levels of consumption will not be reduced significantly unless consumers are willing to actively use them and optimize their daily energy consumption patterns (Wallenborn et al. 2011).

In addition, previous studies have shown that direct feedback on energy consumption is of great importance because it enhances the saving efforts of households. However, the savings reported in individual studies differ due to various contexts, methods and the design features of feedback of the respective projects (Fischer 2008). Darby (2006) has shown that direct feedback on energy consumption may result to a reduction in the region of 5–15%. Grønhøj and Thøgersen (2011) reported a 8.1% reduction in electricity consumption in households that received feedback through displays, whereas Carroll et al. (2013) reported a 2.1% savings. Interestingly, in a report made on the impact of feedback on energy consumption, a mean saving for electricity of 5% and for gas 3% (Ea Energy Analyses 2015) was calculated. Various challenges are identified in the literature that pose a burden for consumers to fully familiarize themselves with intelligent metering systems and increase their energy savings (Mela et al. 2018). Consumers consider the information from smart meters as complicated and difficult to understand, while other reported barriers include lack of feedback on energy-saving assistance, residents' decreased level of interest toward smart meters after an initial period of use, technical problems and concerns about loss of privacy. Thus, providing households with meaningful feedback on their energy consumption accompanied with tailored tips on energy saving, while ensuring residents for their data safety, are critical factors for the next phase of the household energy sector.

Smart meters as one of the cornerstones of intelligent metering are among the crucial enablers of the smart-grid vision that increases the network's reliability. They are the next generation of electricity and gas meters capable of two-way communication since they enable the remote exchange of information about the amount of energy being used and/or produced between any node in the grid and energy suppliers or other denominated parties (Page et al. 2010). In addition, they provide information to consumers on their actual consumption, and the bills issued by the energy suppliers are based on actual consumption and not on estimations. Thus, smart metering offers the opportunity for consumers to address their energy consumption effectively through timely and accurate data on their energy usage. However, there are concerns that smart meters potentially come with some privacy and security risks (Depuru et al. 2011). Overall, for the successful development of smart grids in cities or nationwide, it is critical for consumers to raise their awareness of smart metering and become familiar with these intelligent systems (Park et al. 2017).

In Italy, the experience gained from Enel's "Telegestore" voluntary project when the Italian distribution company replaced 30 million of its conventional meters with digital meters during the period 2001–2006 paved the way for the realization of smart metering in the country. The Italian government, recognizing the benefits of implementing smart meters, defined the legal framework for mandatory rollout to all metering points in the country in 2006, prior to 2009s EC communications, and by 2011, 95% of metering points were equipped with a smart metering device, achieving EU's 80% goal well ahead of 2020 (European Commission 2014b). This first generation of deployed smart meters is compliant with the requirements set by the EC in 2012, except for not providing updated readings at least every 15 min.

In 2016, the Italian Regulatory Authority issued a decision for the deployment of the next generation of smart meters and set the minimal functional requirements to further enhance the accuracy of the metering data and improve customers' experience with the services. Soon after, in 2017, Enel, now called e-distribuzione, being among the biggest Distribution System Operators (DSO) in Europe and in Italy in terms of connected customers (Prettico et al. 2019), operating with the oldest generation of smart meters by that time, started the rollout of the second generation of smart meters. The newly introduced metering system, contrary to its predecessor, is capable of delivering raw metering data directly to the costumer and to forward even more precise measurements to the DSO (Piti et al. 2017).

The aim of this survey is to investigate the views of people who have already utilized the first generation of digital electricity meters, as is the case in Italy, have on smart meters and explore how the metering system can help people to understand and manage their energy use better. It examines the awareness of smart meters and looks into the rate of penetration of the new smart meters within the community. Another aspect of this study is its focus on individuals holding tertiary qualifications. The literature suggests that education is expected to raise wages (Frini and Muller 2012) and consequently motivates consumption because income directly affects household energy consumption (Cayla et al. 2011). Therefore, investigating the opinions of a group likely to have a high-savings potential could add to the further improvement of smart metering systems.

The rest of this article is structured in three sections. The second section describes the specific elements of the methodological design employed in this study. The third explains the quantitative insights that emerge from the results and the fourth summarizes and concludes.

2 Methodology

For the scope of this study, a purposeful sampling technique was used for the identification and selection of information-rich cases for the most effective use of limited resources. This involved identifying and selecting individuals who have tertiary qualifications and are knowledgeable about automation and data-acquisition systems and who, at the same time, were available and willing to participate in this research. To find an appropriate sample of participants, a company from the technology sector was approached through a contact person because the profile of its employees suited the purposes of this study. Finally, 70 individuals were approached, and a questionnaire was prepared and distributed through email to them.

From those 70 persons, only 47 fully completed the questionnaire and their answers were considered valid. All of them resided in the wide area of Ancona province, Italy. The survey was conducted in June 2018, one year after the deployment of the second generation of smart meters began in Italy. Due to the small sample size, the results should not be considered as representative of the entire energy consumers' universe but as indicative, and so they should be used with prudence.

An online version of the questionnaire survey was created on LimeSurvey in English. The questionnaire was disseminated to participants through their company's mailing list. The questionnaire includes multiple choice and dichotomous questions. In the first type of close-ended questions, participants were offered a set of answers they have to choose from, while in the second type, respondents can choose the "yes" or "no" option. Finally, the answers were collected online, and afterward they were coded, quantified and analyzed using the statistical computer-based programs Microsoft Excel and IBM SPSS. For the derivation of the results, a quantitative analysis that involves bar charts and percentages was used. The questionnaire is available in appendix.

Before participating in the actual survey, the participants were told the purpose of the survey and asked for their informed consent. After providing their consent to participate in the survey, the following short explanation of what smart meters are was also given:

> Smart meters are the next generation of electricity and gas meters capable of two-way communication. They remotely send and receive information about the amount of energy being used directly to energy suppliers and other nominated parties. They provide information to consumers on their actual consumption and bills issued by the energy suppliers are based on actual consumption and not on estimations.

3 Results

A large number of male, as compared to female, respondents participated in the survey as a result of the research conducted within a technology company: 85% of the respondents male versus 15% female. Only a small minority of the participants in the survey are between 18 and 25 years of age. The vast majority of the respondents (55.3%) were 26 to 34 years of age. Moreover, almost 32% percent (31.9%) of those surveyed were 35–45 years of age, while very few participants (6.4%) were between 46 to 57 years old. None of the participants were younger than 18 years old or older than 58.

Most of the participants (51.5%) pay their energy bills exclusively by themselves. This is an indication that, overall, they have an overview of their energy consumption. Approximately, 28% (27.7%) of the respondents do not contribute to paying the energy bills in their household. Almost one out of five respondents (21.3%) share the cost of their energy bills with others living in the same accommodation.

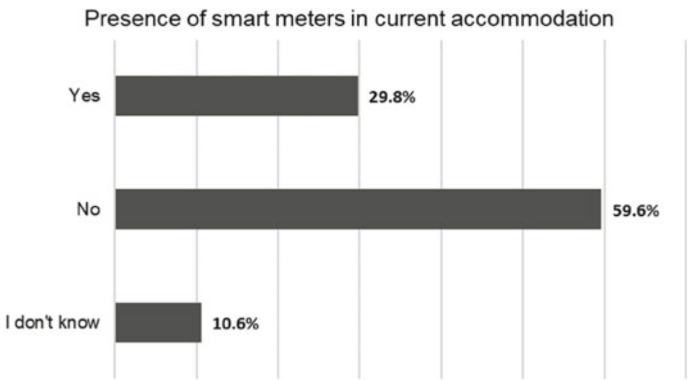

Fig. 1 Presence of smart meters in respondents' current accommodation (sample size $N = 47$)

3.1 Presence of Smart Meters in the Current Accommodation

Respondents were asked if there is a smart meter in their current accommodation. As depicted on Fig. 1, over half of those questioned (59.6%) reported that there is not a smart meter in their current accommodation, whereas less than thirty percent of the respondents answered positively (29.8%). Interestingly, 10.6% do not know if there is a smart meter installed in their homes.

3.2 Awareness of Smart Meters and Their Function

Respondents were asked if they were aware of a smart meter and its function. As depicted in Fig. 2, the most frequently occurring response was "I have a general idea" (38.3%). On the other hand, only a small percent (4.3%) of those interviewed reported that they have an excellent idea what a smart meter is. Interestingly, 12.8% of the respondents stated that they have no idea what a smart meter is. The findings have also revealed that 25.5% have a vague idea, whereas 19.1% have a good idea about smart meters and their function.

3.3 Sources of Information About Smart Meters

Respondents were asked to select from a list the sources from which they received information about smart meters. This question allowed for multiple answering choices, and thus respondents could select as many options as relevant. Therefore, the sum of the percentages reported per option is greater than 100%. The results are shown in Fig. 3.

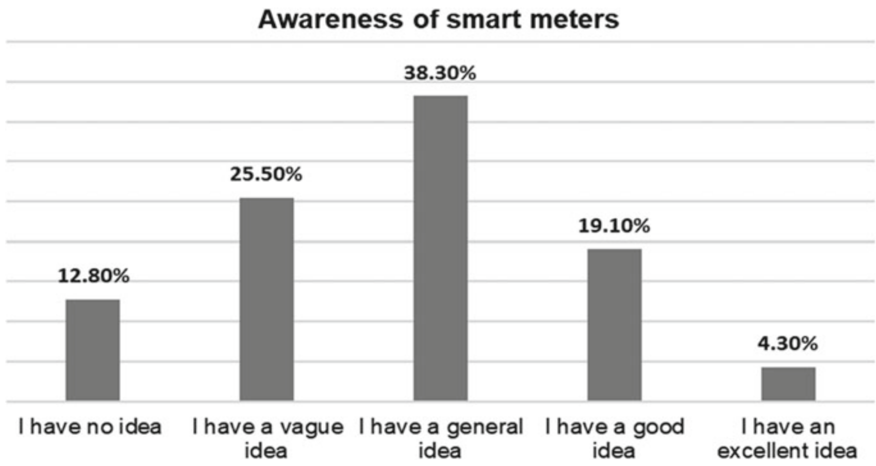

Fig. 2 Awareness of smart meters and their function (sample size $N = 47$)

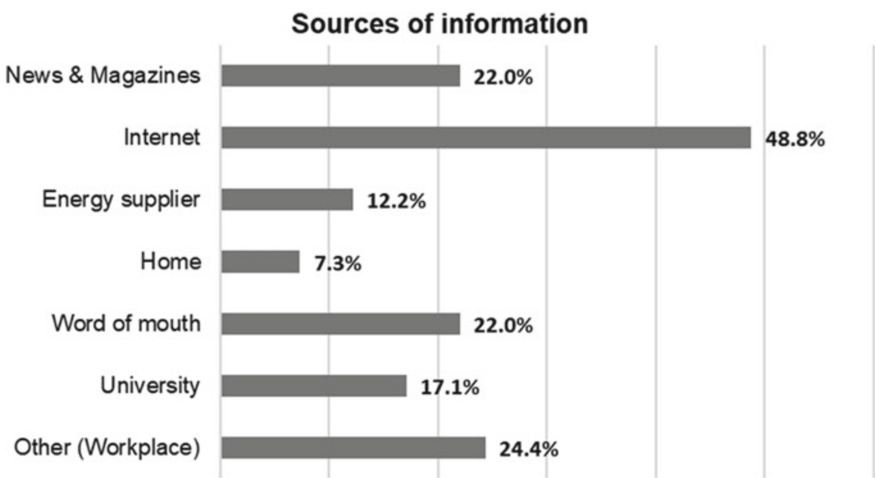

Fig. 3 Sources of information about smart meters (sample size $N = 41$)

The near majority of the respondents (48.8%) reported that they were informed about smart meters from the Internet. On the other hand, a 7.3% minority stated that they were informed from "home". Approximately, one out of four respondents (24.4%) added that they were informed about smart meters from their jobs, i.e., workplace. Twenty-two percent (22%) of the respondents selected "news and magazines" or the "word of mouth" option. About seventeen percent (17.1%) stated that they had heard about smart meters at their university, whereas 12.2% surveyed reported that their energy supplier provided them information about smart meters.

3.4 *Shared Opinions About Smart Meters—Benefits and Drawbacks*

Respondents were asked about the level of agreement, if at all, with given statements with respect to possible benefits of smart meters or the drawbacks they might pose. Results are on a 1 to 3 scale (1 = Disagree, 2 = Neither agree nor disagree, 3 = Agree). Mean values (M) over 2.5 indicate agreement with the statement. The results with regard to possible benefits are presented in Figs. 4 and 5, whereas the findings about the drawbacks are shown in Figs. 6 and 7.

The total sample of respondents agreed the most that smart meters "keep track of the energy consumption" ($M = 2.95$, St.Dev = 0.3), whereas they agreed the least with the statement that smart meters are likely to "increase energy efficiency" ($M = 2.5$, St.Dev = 0.73). The total sample of respondents agreed with all of the proposed possible benefits of smart metering.

In Fig. 5, a segmentation of the given answers per statement is shown. Most of the respondents (97.7%) agree that keeping track of energy consumption is an advantage of smart metering. Moreover, a 91.1% majority of those surveyed regard as a benefit that smart meters provide accurate bills instead of estimates. Although there is a high share of respondents (63.6%) who agree that smart meters help consumers to reduce their energy bills, 29.5% of those questioned neither agree nor disagree with that. However, a larger share of respondents, 73.3%, agrees that smart meters help consumers to reduce their energy consumption. Interestingly, an 86.6% majority

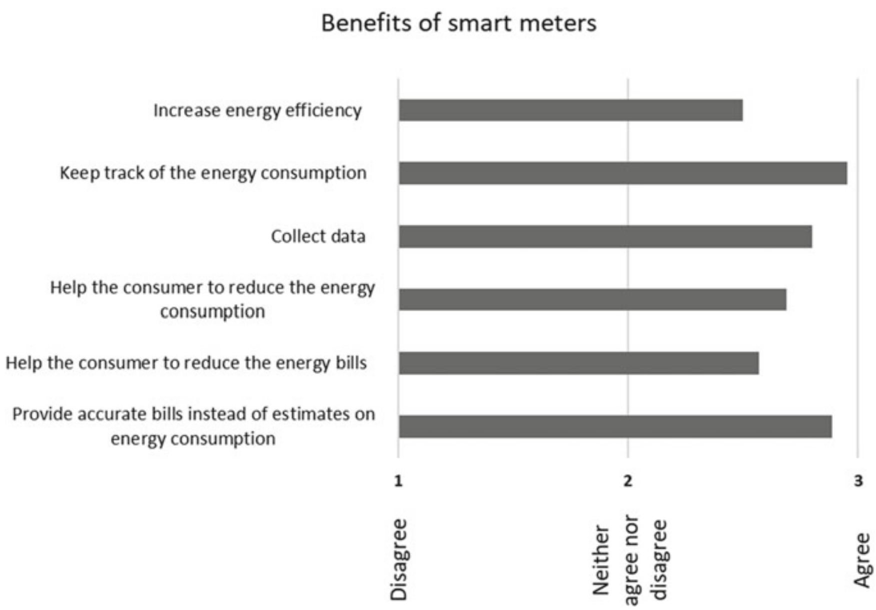

Fig. 4 Respondents' level of agreement on possible benefits of smart meters—total sample

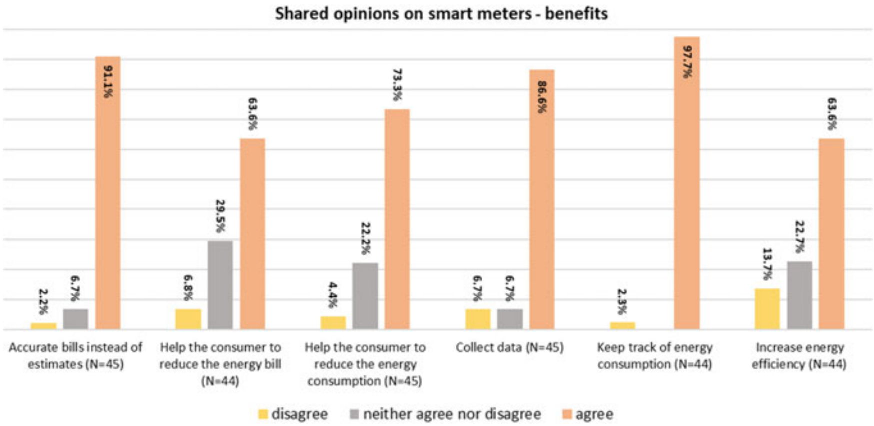

Fig. 5 Shared opinions about possible benefits of smart meters (sample size N indicated in parenthesis)

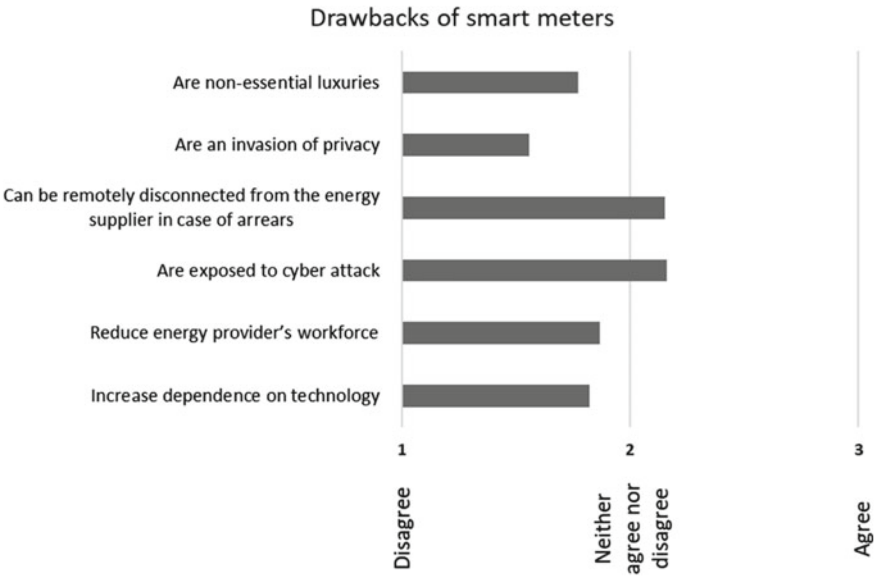

Fig. 6 Respondents' level of agreement on possible disadvantages of smart meters—total sample

regards collection of data as a benefit of smart metering. Finally, for 13.7% of respondents, it is questionable if smart meters are able to increase energy efficiency, and they stated that they disagree with this statement, whereas 63.6% of the respondents agree.

Interestingly, when it comes to possible disadvantages of smart meters, the total sample of those questioned is rather indifferent with any statement in particular (see

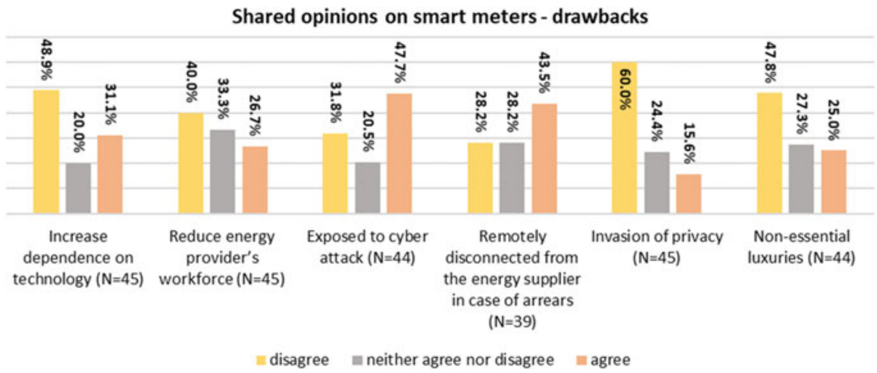

Fig. 7 Shared opinions about possible drawbacks of smart meters (sample size N indicated in parenthesis)

Fig. 6). They neither agreed nor disagreed that smart meters' possible disadvantages are that they "are exposed to cyberattack" ($M = 2.16$, St.Dev = 0.89) and "can be remotely disconnected from the energy supplier in case of arrears" ($M = 2.15$, St.Dev = 0.84). On the other hand, the total sample of participants disagreed the most with the statement that smart meters "are an invasion of privacy" ($M = 1.56$, St.Dev = 0.76).

When the responses are broken down (see Fig. 7), then the findings reveal that the vast majority of the respondents (60%) disagree that smart meters are an invasion of privacy. On the other hand, 47.7% of those surveyed agree that smart meters are vulnerable to cyberattacks.

Almost 47% (48.9%) of the participants disagree that smart meters increase customer's dependence on technology. Moreover, 40% of those questioned are in disagreement that smart meters reduce the number of the energy provider's personnel, whereas 33.3% stated that they neither agree nor disagree. A share of 43.5% interprets as a drawback the fact that smart meters can be remotely disconnected from the energy supplier in case of arrears. Finally, 47.8% of the respondents disagree that smart meters are non-essential luxuries.

3.5 Energy Control Readings

Respondents were asked what they would like to see on their smart meter's screen that would help them understand and better manage their energy use. A targeted list based on various information types provided to households equipped with a smart meter by different energy distributors across Europe was given, and the results are depicted on Fig. 8. The vast majority of the respondents (80.9%) would like to see any unusual energy consumption when they are away from home. On the other hand, only 25.5% would like to know the daily carbon footprint of their energy use.

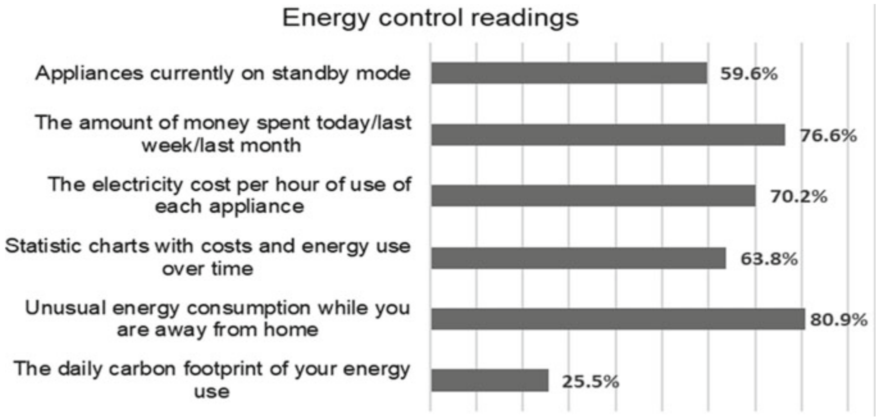

Fig. 8 Readings from smart meters that could help consumers to better understand and manage their energy use (sample size $N = 47$)

The findings have also revealed that more than three out of four respondents (76.6%) stated that seeing the amount of money spent for energy within the last period of time (today/last week/last month) would help them better understand and manage their energy use. On the other hand, less than three out of four respondents (70.2%) would like to see the electricity cost per hour-of-use of each appliance. Statistic charts displaying costs and energy use over time are preferred by 63.8% of the respondents, while almost 60% (59.6%) of those surveyed would like to see any appliances that are on standby mode.

3.6 *Future Services*

Respondents were asked which services, from a targeted list, they would like a smart meter to offer in the future. As depicted in Fig. 9, 78.7% of the respondents would like to have their smart meter connected with their smartphone or their personal computer. Following that, 63.8% of those surveyed would like their smart meter to show them notifications—credit alerts—in advance to help them keep track of their energy consumption. The findings have also indicated that 57.4% of the respondents would like to receive tailor-made suggestions from their energy provider on how to improve their energy behavior. Less than half of the respondents (48.9%) would like to receive information through their smart meters on market energy prices. Finally, 46.8% of those interviewed would like to be able to compare their energy consumption with that of a similar household in the neighborhood.

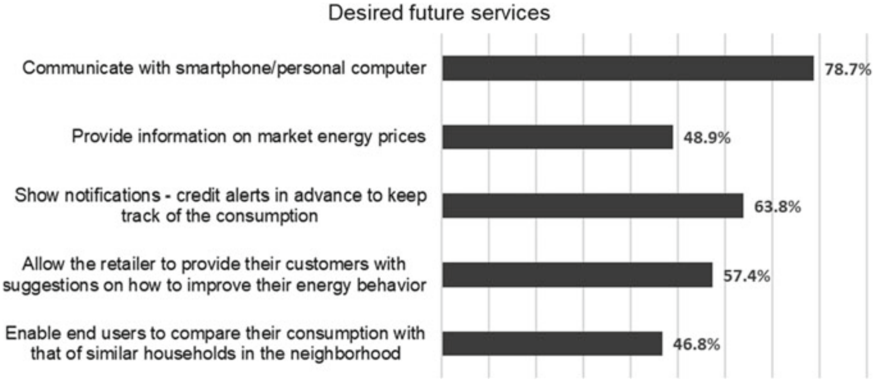

Fig. 9 Desired future services of smart meters (sample size $N = 47$)

3.7 Smart Metering Mobile Applications

Respondents were asked if they would like to have a mobile application connected with their smart meter with the aim of increasing energy awareness and savings in the house. The results are shown in Fig. 10.

The overall response to this question was quite positive, with 87.2% of the respondents to answer "Yes". Very few participants (8.5%) stated that they would not like to have a mobile application that is connected to their smart meter and aims to increase their energy awareness and help them to better control their energy use.

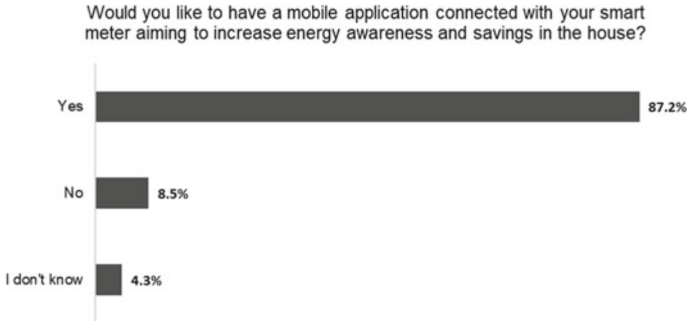

Fig. 10 Receptiveness to mobile applications connected to smart meters aiming to increase energy awareness and energy savings (sample size $N = 47$)

4 Conclusions

This survey investigated the penetration of modern smart meters in a small community of 47 well-educated employees from the automation and data-acquisition sector. All of them reside in the wider area of Ancona, Italy. It examined respondents' awareness of smart meters focused on the views they have on smart meters and explored how the metering system can help them to understand and manage their energy use better. Given the small sample size, it is unwise to rush to any hasty conclusions without further research in the form of a large-scale survey, however, some suggestive remarks could be made.

As depicted from the survey, the vast majority of the respondents have a low-to-moderate level of awareness of modern smart meters and their functions, while the presence of second-generation smart meters in their current accommodation is scarce. These could be partly attributed to the fact that the deployment of new smart meters in Italy, by the time this survey was conducted, was at an early stage. However, at the same time, it highlights the existing potential to improve the communication of smart metering and its functionalities. Wider installations of smart meters, as well as raising awareness of the benefits of smart metering, could help consumers make more informed decisions about energy efficiency and policy makers should be aware of this when creating their energy policy.

On the other hand, despite the low penetration of second-generation smart meters observed in this small community, the opinions respondents expressed about smart metering are positive. Respondents' being enthusiastic about technological advances possibly drives them toward a positive view on smart metering, but, at the same time, their knowledge of data-acquisition systems showcases the strong and weak points of this technology. According to those surveyed, the ability to track energy consumption and the resultant accurate bills instead of estimates are the most important features connected to smart meters. Moreover, neither the collection of data is seen as a drawback nor are smart meters perceived as an invasion of privacy by the vast majority of the respondents. However, almost 45% of the respondents agreed that smart meters' exposure to cyberattacks is a drawback. This latter aspect should be thoroughly investigated by the research community, authorities and relevant stakeholders to counteract threats by cyber adversaries and increase consumers' confidence in smart metering.

Smart meters can be a helpful tool for consumers to better understand their energy use. Any information about unusual energy consumption while they are away from home or energy costs displayed on a smart meter's screen are practical for consumers to regulate their energy use. Readings such as the electricity cost per hour-of-use of appliances or the total amount of money spent for certain periods of time are considered valuable. In addition, the respondents stated that in the future they would like to receive tailored tips on energy efficiency or credit alerts sent by their energy suppliers. Such information would assist them to save energy and keep their consumption between affordable limits. As the results revealed, feedback plays a key role by making energy usage visible and should not be seen only as stand-alone technological solution to provide energy use patterns. An all-inclusive approach to complementary services is considered important in assisting energy consumer's decision making about energy efficiency.

Another important insight derived from this research is the fact that a large percentage of participants expressed their willingness to have their mobile phone or PC connected to their smart meters. This would give them the ability to check their energy consumption instantly even if they are away from their homes. In addition, respondents showed high receptiveness to mobile applications that use data collected from smart meters and aim to increase energy savings and energy awareness. This might be attributed to the age of respondents and again their enthusiasm toward technologically advanced solutions, however, society's fast pace toward digitalization supports the interconnection of appliances and paves the way for energy-efficient behaviors assisted by digital tools. Such applications could showcase the potential of smart meters to serve as an educational medium for young people, and increase their awareness of energy efficiency and reasonable energy use. Concluding, it must be noted that the successful introduction of smart meters in our communities will enhance the successful evolution of smart grids. This survey confirms that respondents are in need not only of a gauge that measures energy consumption but also of a tool that assists them to manage effectively their energy use. Designing an intelligent metering system that is attractive to consumers is key to new technological developments that change radically the way energy is managed. Ensuring the smooth transition to smart metering, governments, agencies, energy suppliers, stakeholders and other associated parties should work together to increase confidence in the benefits of smart meters and provide reassurance about areas of consumer concern. Looking to the future, technological advances and modern technologies combined with smart meters can reshape the way in which consumers will involve themselves in energy control. To this direction, smart metering should be seen as part of a greater integrated electric/communication infrastructure that is able to dynamically optimize grid operations, mobilize resources and incorporate demand response. Thus, for the vision of smart grids to be successfully realized in our communities and be fully beneficial for the consumer, smart meters should be massively deployed and, at the same time, provide feedback that facilitates consumers process of learning about energy efficiency.

Funding Acknowledgements This work has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 645677.

Appendix

Survey on Smart Meters

This survey investigates the penetration of smart meters at the community level. It examines the awareness on smart meters at the community level, focuses on the views people have on smart meters and explores how the metering system can help people to understand and manage their energy use better.

This project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 645677.

For more information please follow the link:
https://www.smartgems.tuc.gr

Informed Consent

Voluntary participation

- Your participation is completely **voluntary and anonymous**.

Confidentiality

- The survey is being conducted with multiple people.

Sharing of results

- The completely anonymized results can be used in scientific research.

Privacy and security of the data

- All data are stored on an **encrypted database** on a **secured server environment**.

I have read the informed consent and want to participate ☐
I do not want to participate ☐

Smart Meters

Smart meters are the next generation of electricity and gas meters capable of two-way communication. They remotely send and receive information about the amount of energy being used directly to energy suppliers and other nominated parties. They provide information to consumers on their actual consumption and bills issued by the energy suppliers are based on actual consumption and not on estimations.

Q1. What is your age?

Q1_1 under 18	☐
Q1_2 18–25	☐
Q1_3 26–34	☐
Q1_4 35–45	☐
Q1_5 46–57	☐
Q1_6 58–69	☐
Q1_7 69 and over	☐

Q2. What is your gender?

Q2_1 Female	☐
Q2_2 Male	☐
Q2_3 Prefer not to say	☐

Q3. In your current accommodation, energy bills are paid by

Q3_1 Myself exclusively	☐
Q3_2 Others exclusively	☐
Q3_3 Myself and others—shared	☐
Q3_4 Other (please specify):	

Q4. Are you aware of smart meters and their function?

Q4_1 I have no idea what they are	☐
Q4_2 I have a vague idea of what they are	☐
Q4_3 I have a general idea of what they are	☐
Q4_4 I have a good idea of what they are	☐
Q4_5 I have an excellent idea of what they are	☐

If Q4_1 applies, then move to Q6.

Q5. How do you know about smart meters? please select all that apply.

Q5_1 News and magazines	☐
Q5_2 Internet	☐
Q5_3 Energy supplier	☐
Q5_4 Home	☐
Q5_5 Word of mouth	☐
Q5_6 University	☐
Q5_6 Other (specify)	

Q6. Is there a smart meter installed in your current accommodation?

Q6_1 Yes	☐
Q6_2 No	☐
Q6_3 I don't know	☐

Q7. From your point of view, a drawback smart meters have is that they

	disagree	neither agree nor disagree	agree	[don't know]
Q7_1 Increase dependence on technology	☐	☐	☐	[☐]
Q7_2 Reduce energy provider's workforce	☐	☐	☐	[☐]
Q7_3 Are exposed to cyberattack	☐	☐	☐	[☐]
Q7_4 Can be remotely disconnected from the energy supplier in case of arrears	☐	☐	☐	[☐]
Q7_5 Are an invasion of privacy	☐	☐	☐	[☐]
Q7_6 Are non-essential luxuries	☐	☐	☐	[☐]

Q8. From your point of view, a benefit smart meters have is that they

	disagree	neither agree nor disagree	agree	[don't know]
Q8_1 Provide accurate bills instead of estimates on energy consumption	☐	☐	☐	[☐]
Q8_2 Help the consumer to reduce the energy bill	☐	☐	☐	[☐]
Q8_3 Help the consumer to reduce the energy consumption	☐	☐	☐	[☐]
Q8_4 Collect data	☐	☐	☐	[☐]
Q8_5 Keep track of the energy consumption	☐	☐	☐	[☐]
Q8_6 Increase energy efficiency	☐	☐	☐	[☐]

Q9. What would you like to see on your smart meter's screen that would help you understand and better manage your energy use? Please select all that apply.

Q9_1 Appliances currently on standby mode	☐
Q9_2 The amount of money spent today/last week/last month	☐
Q9_3 The electricity cost per hour-of-use of each appliance	☐
Q9_4 Statistic charts with costs and energy use over time	☐
Q9_5 Unusual energy consumption while you are away from home	☐
Q9_6 The daily carbon footprint of your energy use	☐
Q9_7 Other (please specify):	

Q10. What would you like a smart meter do in the future? Please select all that apply.

Q10_1 Enable end users to compare their consumption with that of similar households in the neighborhood	☐
Q10_2 Allow the retailer to provide their customers with suggestions on how to improve their energy behavior	☐
Q10_3 Show notifications–credit alerts in advance to keep track of the consumption	☐
Q10_4 Provide information on market energy prices	☐
Q10_5 Communicate with smartphone/personal computer	☐
Q10_6 Other (please specify):	

Q11. Would you like to have a mobile application connected with your smart meter aiming to increase energy awareness and savings in the house?

Q12_1 Yes	☐
Q12_2 No	☐
Q12_3 I don't know	☐

Thank you for your participation. Your input is invaluable for us.

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Urban (Big) Data: Challenges for Information Retrieval and Knowledge Discovery

A Systematic Study of Sustainable Development Goal (SDG) Interactions in the Main Spanish Cities

Javier García López, Raffaele Sisto, Julio Lumbreras Martín, and Carlos Mataix Aldeanueva

Abstract In October 2018, the Spanish SDSN Network, REDS, launched the SDG Spanish Cities Index report summarizing the progress of 100 Spanish cities toward the Sustainable Development Goals (SDG). This study, developed in collaboration with the Technical University of Madrid, follows the methodology used by the Global SDG Index and Dashboards and the US Cities Index, which SDSN co-produces annually to assess SDG performance at both the national and international levels. This study, previously developed by the same researchers, identifies the most suitable indicators, metrics and urban data to measure the commitment and degree of compliance with SDG 17 for a selection of Spanish cities. It provides, through a set of 85 indicators, a unique vision of their sustainable development and allows monitoring the implementation of the SDGs at the local level in the Spanish context. In this paper, the analysis of their interactions using this dataset has been systematized. This is an innovative first step in defining the path toward urban sustainable development to make policies happen: dependencies among the goals in terms of potential interactions need to be evaluated in the Spanish context. Those results, improvements and applicability are presented and discussed in the following to identify action priorities and raise awareness of local governments and policymakers. It concludes that major efforts are required to increase sustainability and suggests an open framework that can be gradually improved as more data become available.

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_5

Keywords Sustainable Development Goals · Indicators · Interactions · Sustainability · Factorial analysis

1 Introduction

Sustainability has become a global concern (Keivani 2010) for urban development. Indeed, more people live in urban areas than in rural areas; with 55% of the world population residing in urban areas in 2018, by 2050, 68% of the world population is projected to be urban (UN-DESA 2018). While historically this was the desired goal of development (Brown et al. 1987), it evolved to maintain economic advancement and progress while protecting the long-term value of the environment (Emas 2015). Nowadays, it is understood as one of the major implementation science challenges (Moore et al. 2017).

Cities are at the forefront of sustainable development. The increase of urbanized areas poses some of the world's greatest development challenges, but it also creates huge opportunities to promote sustainable development. For example, cities nowadays generate 80% of global GDP (Moir et al. 2014), while consuming 70% of global energy and producing 70% of CO_2 emissions (IEA 2019). They are primarily responsible for the environmental degradation and highly contribute to climate change beyond city boundaries. But they are also centers of innovation and opportunity and support high-density habitation and efficient land-use.

Whereas SDGs have a global dimension, their action implementation depends on the level of priority assigned to them by the various countries and on how sustainability issues compete with the main problems faced by a country. It aims to force us to look not only at the overall progress of the country but also at the progress of its main cities.

SDSN has developed a series of global sustainability studies, the Global SDG Index, based on indicators from 2015 to 2019, which underlines the specific role of cities (Sachs 2016, 2017; SDSN 2018). In addition, to better inform regional and national analysis for the implementation of the SDGs, it has supported SDG Dashboards in African countries (SDGCA and SDSN 2018), metropolitan areas in the US (Espey 2018), major European cities (Lafortune et al. 2019) and Italian cities (Cavalli 2018). This research aligns with these studies to promote evidence-based policy making, mobilize regional and local communities and identify persisting data gaps for monitoring the SDGs.

As the Spanish Urban Agenda has recognized (Hurtado and González 2018), Spanish cities also face important urban challenges: pressure on natural resources, the threat of climate change, growing social inequality and, in particular, the depopulation of rural areas (MPTFP 2017), which constitute 80% of the territory, with half of the country's municipalities at risk of extinction (Collantes et al. 2014). Eight percent of the Spanish population lives in big cities and their metropolitan areas, whereas 4955 of the 8125 villages have less than 1000 inhabitants, according to the latest data published in the INE (INE 2018).

In a previous research, the most suitable indicators, metrics and urban data able to measure the commitment and degree of compliance with the 17 Sustainable Development Goals for the main Spanish cities and their metropolitan areas (Sánchez et al. 2018) have been identified by the authors. This urban diagnosis based on the SDGs is especially useful because it provides an objective and holistic analysis of the monitoring of the reality, and the main issues, challenges and opportunities for the sustainability of a city (Childers et al. 2014); it is a multidisciplinary assessment based on engineering, economic, social and environmental sciences (Ferrer, Thomé and Scavarda 2018), ranging from demographic changes and depopulation of rural areas to mobility, through urban metabolism and governance issues, among others.

The holistic nature of the SDG framework implies that a large number of potential interactions across the 169 targets have to be considered. A systematic data-driven analysis of all SDG interactions in the Spanish context is currently needed.

The main idea is to analyze the starting point and relevant variables of the Spanish cities for the advancement of SDGs through a set of indicators. To bridge the existing gap, a methodological framework that analyses the main interactions among this set of indicators is proposed. Thus, it is intended to recognize the main components among all the indicators of the cities to identify priorities for action in their policies for the achievement of the 2030 Agenda.

2 Method

This study has been carried out in collaboration with the Technical University of Madrid and with multiple group-support systems (Kolfschoten and de Vreede 2009), using the alliance approach proposed by the 2030 Agenda. This assessment has been inspired by the methodology used by the Global SDG Index and Dashboards and the US Cities Index, which SDSN co-produces annually to assess SDG performance at both national and international levels.

It has been articulated under various forms of collaboration that perform multiple tasks: facilitators from the local and national administration, civil society organizations, foundations, universities, researchers and other entities. The analysis has been carried out in three parts: (i) factor analysis, to determine a small number of factors that could represent the original variables, and (ii) principal component analysis and (iii) a correlation matrix, to identify correlation between two variables. All of them have participated in the discussions on the initial approach and in the interpretation of the results. In addition, each step and finding has been subjected to continuous validation by the focus group (Harrington 2016) formed by expert members of REDS working in sustainable development. The calculation of interactions and testing of the results have been developed on the basis of this dataset and the basic model established by REDS.

2.1 Factorial Analysis

First of all, to avoid redundancies in the study, the chosen variables needed to be independent of each other. By avoiding dependencies within the set of variables, we prevent them from affecting the validity of the final results. For this purpose, the factorial analysis technique is used as a statistical method that solves this problem while providing the basis for calculating the index that ranks Spanish municipalities according to the multiple values of the index. Thus, the main objective of the factor analysis is to determine a small number of factors that could represent the original variables.

The analysis is based on 17 variables available for the Spanish municipalities. Based on these values, the technique of factor analysis is applied and confirms these variables as relevant.

The rotating component factor matrix identifies the following relationships between the original variables and the extracted factors (Table 1).

The first factor mainly collects information from SDG 12 concerning responsible production and consumption. Also, this factor achieves high scores for SDG 8, Decent Work and Economic Growth, and SDG 4 and SDG 17, Quality Education and Partnerships for the Advancement of the Goals.

The second factor is mainly and negatively related to SDG 3, linked to Health and Welfare. In addition, it is negatively related to SDG 13, Climate Action.

The third factor firmly connects with SDG 9, Industry, Innovation and Infrastructure. It also correlates negatively with SDG 15, Life of Terrestrial Ecosystems.

The fourth factor is essentially linked with SDG 6, which is related to Clean Water and Sanitation.

The fifth factor basically collects information from SDG 1, End of Poverty. It also correlates positively with SDG 10, Reduction of Inequalities.

The sixth factor is negatively linked to SDG 2, Zero Hunger. It also scores significantly for SDG 5, related to Gender Equality, and SDG 14, Underwater Life.

Table 1 Rotated component matrix of factorial analysis

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
SDG 1 - No Poverty					0,8244	
SDG 2 - Zero Hunger						-0,7573
SDG 3 - Good Health and Well-Being		-0,8821				
SDG 4 - Quality Education	0,6157		0,3195		-0,362	
SDG 5 - Gender Equality		0,3608				0,659
SDG 6 - Clean Water and Sanitation				0,7092		
SDG 7 - Affordable and Clean Energy	0,3985			-0,5852		
SDG 8 - Decent Work and Economic Growth	0,7462			-0,3285		
SDG 9 - Industry, Innovation and Infrastructure			0,8327			
SDG 10 - Reduced Inequalities	-0,3867	0,3202			0,7101	
SDG 11 - Sustainable Cities and Communities		0,5466	-0,5712			
SDG 12 - Responsible Consumption and Production	0,8168					
SDG 13 - Climate Action		-0,7499				
SDG 14 - Life Below Water						0,6039
SDG 15 - Life on Land			-0,7048	0,3894		
SDG 16 - Peace, Justice and Strong Institutions	0,3571	0,5154		-0,5446		
SDG 17 - Partnerships for the Goals	0,6714	0,3411				

It should be emphasized that the six factors highlight remarkable information related to the 17 SDGs, with three of the SDGs not named in the above list: with regard to SDG 7, Affordable Energy and Non-Polluting Energy, information is collected from two different factors; with regard to SDG 11, Sustainable Cities and Communities, information is similarly collected from two factors; and three different factors include information with regard to SDG 16, Peace, Justice and Strong Institutions.

2.2 *Principal Component Analysis and Correlation Matrix*

A Pearson correlation analysis and a PCA analysis have been developed to capture the nonlinear correlation between the variables and its main factors and to identify the general relation beyond the linear correlation between two variables (Tables 2 and 3).

Table 2 shows the relationships among the 17 SDGs, which are very different. Since these variables are uncorrelated with each other, it is convenient to reduce those variables to a few components.

Table 2 Correlation matrix of main SDG

Correlaciones

		ods1	ods2	ods3	ods4	ods5	ods6	ods7	ods8	ods9	ods10	ods11	ods12	ods13	ods14	ods15	ods16	ods17
ods1	Correlación de Pearson	1	-,063	,116	,019	-,130	,028	,256	,303	,205	,353	-,304	,172	,028	,026	-,146	,054	-,029
	Sig. (bilateral)		,536	,252	,854	,198	,786	,011	,002	,042	,000	,002	,088	,780	,796	,150	,593	,777
	N	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
ods2	Correlación de Pearson	-,063	1	-,053	-,002	-,321	,011	,009	-,200	-,004	-,010	,213	-,011	-,057	-,190	,029	,032	,053
	Sig. (bilateral)	,536		,603	,986	,001	,917	,932	,046	,965	,922	,033	,911	,576	,058	,771	,749	,602
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods3	Correlación de Pearson	,116	-,053	1	-,097	-,318	-,125	-,064	,060	,012	-,269	-,440	-,017	,516	-,051	,064	-,390	-,217
	Sig. (bilateral)	,252	,603		,339	,001	,215	,529	,552	,909	,007	,000	,866	,000	,614	,530	,000	,030
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods4	Correlación de Pearson	,019	-,002	-,097	1	,333	-,023	,348	,336	,258	-,394	,092	,389	-,219	-,086	-,095	,354	,407
	Sig. (bilateral)	,854	,986	,339		,001	,819	,000	,001	,010	,000	,364	,000	,028	,397	,349	,000	,000
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods5	Correlación de Pearson	-,130	-,321	-,318	,333	1	,088	,222	,252	-,060	-,164	,229	,305	-,131	,115	-,112	,330	,164
	Sig. (bilateral)	,198	,001	,001	,001		,386	,026	,012	,552	,102	,022	,002	,194	,253	,266	,001	,102
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods6	Correlación de Pearson	,028	,011	-,125	-,023	,088	1	-,184	-,020	,059	,197	,096	,139	-,201	,110	,124	-,110	,172
	Sig. (bilateral)	,786	,917	,215	,819	,386		,067	,842	,562	,050	,343	,167	,045	,274	,220	,277	,088
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods7	Correlación de Pearson	,256	,009	-,064	,348	,222	-,184	1	,341	,063	-,297	-,008	,178	-,002	-,064	-,226	,358	,251
	Sig. (bilateral)	,011	,932	,529	,000	,026	,067		,001	,534	,003	,938	,077	,984	,524	,024	,000	,012
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods8	Correlación de Pearson	,303	-,200	,060	,336	,252	-,020	,341	1	,092	-,265	,021	,572	,029	-,153	-,110	,430	,305
	Sig. (bilateral)	,002	,046	,552	,001	,012	,842	,001		,363	,008	,836	,000	,771	,129	,278	,000	,002
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods9	Correlación de Pearson	,205	-,004	,012	,258	-,060	,059	,063	,092	1	,030	-,316	-,011	,030	-,004	-,358	-,070	,122
	Sig. (bilateral)	,042	,965	,909	,010	,552	,562	,534	,363		,769	,001	,912	,768	,968	,000	,488	,227
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods10	Correlación de Pearson	,353	-,010	-,269	-,394	-,164	,197	-,297	-,265	,030	1	-,039	-,207	-,168	,161	-,091	-,101	-,189
	Sig. (bilateral)	,000	,922	,007	,000	,102	,050	,003	,008	,769		,700	,038	,095	,110	,368	,317	,060
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods11	Correlación de Pearson	-,304	,213	-,440	,092	,229	,096	-,008	,021	-,316	-,039	1	,097	-,269	-,072	,354	,296	,266
	Sig. (bilateral)	,002	,033	,000	,364	,022	,343	,938	,836	,001	,700		,339	,007	,477	,000	,003	,007
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods12	Correlación de Pearson	,172	-,011	-,017	,389	,305	,139	,178	,572	-,011	-,207	,097	1	-,088	,000	,052	,262	,474
	Sig. (bilateral)	,088	,911	,866	,000	,002	,167	,077	,000	,912	,038	,339		,381	,998	,609	,008	,000
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods13	Correlación de Pearson	,028	-,057	,516	-,219	-,131	-,201	-,002	,029	,030	-,168	-,269	-,088	1	,171	,006	-,304	-,367
	Sig. (bilateral)	,780	,576	,000	,028	,194	,045	,984	,771	,768	,095	,007	,381		,089	,949	,002	,000
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods14	Correlación de Pearson	,026	-,190	-,051	-,086	,115	,110	-,064	-,153	-,004	,161	-,072	,000	,171	1	,083	-,141	-,113
	Sig. (bilateral)	,796	,058	,614	,397	,253	,274	,524	,129	,968	,110	,477	,998	,089		,412	,160	,262
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods15	Correlación de Pearson	-,146	,029	,064	-,095	-,112	,124	-,226	-,110	-,358	-,091	,354	,052	,006	,083	1	-,145	,105
	Sig. (bilateral)	,150	,771	,530	,349	,266	,220	,024	,278	,000	,368	,000	,609	,949	,412		,149	,296
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods16	Correlación de Pearson	,054	,032	-,390	,354	,330	-,110	,358	,430	-,070	-,101	,296	,262	-,304	-,141	-,145	1	,308
	Sig. (bilateral)	,593	,749	,000	,000	,001	,277	,000	,000	,488	,317	,003	,008	,002	,160	,149		,002
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ods17	Correlación de Pearson	-,029	,053	-,217	,407	,164	,172	,251	,305	,122	-,189	,266	,474	-,367	-,113	,105	,308	1
	Sig. (bilateral)	,777	,602	,030	,000	,102	,088	,012	,002	,227	,060	,007	,000	,000	,262	,296	,002	
	N	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

*. La correlación es significativa en el nivel 0,05 (bilateral).

**. La correlación es significativa en el nivel 0,01 (bilateral).

Table 3 PCA matrix of the main SDGs

Matriz de componente [a]

	Componente					
	1	2	3	4	5	6
ods1	,056	,473	,523	,052	,294	,485
ods2	-,042	-,237	-,097	-,634	,357	,036
ods3	-,384	,594	-,442	,076	,293	,010
ods4	,693	,193	-,081	-,080	,029	-,360
ods5	,556	-,086	,017	,429	-,462	-,141
ods6	,049	-,295	,312	,372	,476	-,267
ods7	,526	,373	-,023	-,196	-,210	,194
ods8	,638	,428	-,054	,176	,149	,295
ods9	,070	,434	,426	-,189	,136	-,560
ods10	-,349	-,255	,744	,081	,070	,294
ods11	,359	-,705	-,224	-,030	-,013	,159
ods12	,639	,161	-,085	,313	,396	,097
ods13	-,407	,505	-,391	,201	-,073	,093
ods14	-,175	-,026	,159	,615	-,166	-,104
ods15	-,092	-,439	-,462	,306	,387	,180
ods16	,701	-,092	,099	-,181	-,255	,305
ods17	,671	-,138	-,006	-,021	,391	-,186

Método de extracción: análisis de componentes principales.

a. 6 componentes extraídos.

3 Analysis and Discussion of the Results

An analysis of all the municipalities included in the sample has been carried out to address the characteristics or explanatory factors for the dynamics shown in the field of Sustainable Development.

By analyzing the geographical location of the municipalities with the best and worst rating, it is possible to point out characteristics and elements of territorial concentration that serve for further cluster analysis. On the one hand, the areas which perform best in Sustainable Development are clearly located in the northwestern quadrant of the Spanish Peninsula. On the other hand, the southeastern coastal axis of the Mediterranean and the coastal area of the south of the Iberian Peninsula show a concentration of areas with the worst values of Sustainable Development.

The first observations obtained from the analysis are:

- The communities in the area with the best results contain 15.06% of the total population as opposed to the worst-rated communities, which accumulate 31.73% of the Spanish population.
- The concentration of cities with the worst results coincides with the areas with the highest tourist concentration on the Iberian Peninsula.
- The territories with the best Sustainable Development results are among the most affected regions by the abandonment of the population of their municipalities.

Finally, to determine which factors contribute to the Sustainable Development situation of the Spanish municipalities included in the sample, a series of correlations that justify the data obtained in the study has been calculated. Specifically, these are the variables that correlate significantly:

- Average population density measured in inhabitant per km^2.
- Median age of the population measured in years.
- Population measured in number of inhabitants.
- Total number of households measured in absolute values.
- Rate of employment in industry measured as a percentage of total employees.
- Rate of employment in services measured as a percentage of total employees.
- Rate of foreign-born individuals as a percentage of the total population.
- Employment rate of people between the ages of 20 and 64 measured as a percentage of the working population.
- Rate of population over 65 years measured as a percentage of the total population.
- Rate of population between the ages of 0 and 14 measured as a percentage of the total population.
- Average annual net income per capita measured in euros per capita.
- Surface measured in km^2.
- Average household size of the municipality measured in number of inhabitants per household.
- Gross mortality rate.
- Unemployment rate.

Regarding the PCA analysis, the following interpretation of the results is inferred:

The variance shown by the components is low: 20%, 13% and 10% in all three components. This means that there is a large dispersion of the data and that the indicators for each SDG measure different aspects. This also means that it is more difficult to identify common trends. In principle, this could be seen as positive because each SDG measures different aspects (Table 4).

This is reflected through the correlation matrix since correlations are generally low (Table 2). The highest correlations are observed between SDG 12 and SDG 8 (0.57) and between SDG 13 and SDG 3 (0.52). These results differ from the most significant relationships in terms of synergies found in the UN meta-study (Singha

Table 4 Total variance explained

Component	Squared charge extraction sums		
	Total	% Variance	% Accumulated
1	3439	20,232	20,232
2	2339	13,759	33,991
3	1778	10,461	44,452
4	1495	8797	53,248
5	1388	8165	61,414
6	1196	7034	68,448

Extraction method: Principal component analysis et al. 2018). The interpretation of the second correlation is interesting and can be useful because better results in climate change management are associated with better health indicators. This conclusion is consistent with numerous international reports (Patz et al. 2005; UNFCCC 2017). Another powerful correlation associates the indicator of responsible consumption, SDG 12, with wealth sharing, SDG 10, and less unemployment, SDG 8. Other interesting correlations occur between SDG 17 and SDG 4 (0.41) and SDG 17 and SDG 12 (0.47). This new relationship complements those found in the UN meta-study (UN 2019).

The SDGs with the lower correlations, and therefore more independent of the rest, are SDG 6 and SDG 14; even among them, the correlation is very low. Their relationship with the rest of the SDGs is almost non-existent. This conclusion has similarities with the relationship's framework based on compatibility context dependent (Shinga et al. 2018).

The SDGs with more correlations with other SDGs are SDG 4 and SDG 16. They are the most transversal (Blind 2016; Boeren 2019). Education correlates positively with SDG 5, SDG 7, SDG 8, SDG 12, SDG 16 and SDG 17 and negatively with SDG 10. SDG 16 is positively correlated with SDG 4, SDG 5, SDG 7, SDG 8 and SDG 16 and negatively with SDG 3 and SDG 13. In other words, better data from justice and peace indicators show worse indicators of health and climate change.

4 Conclusion

This case study for Spanish cities takes the municipality as its reference unit, being the municipality the administrative and political entity mainly responsible for a large number of public policies that affect the territory under its jurisdiction. There is no single variable, composite indicator or set of indicators that measures sustainability universally (Wilson and Wu 2017). Therefore, the results presented should be interpreted as methodological assumptions and adopted conventions suitable in the Spanish context.

Data are indicators that point to a situation and do not reflect the urban complexity by themselves. They are limited and can mask part of the everyday reality of cities. Indicators are a tool that provides information showing reality through evidence. Thus, an interpretation exercise is needed. There are as many systems of indicators as realities to be built.

In view of all these factors, interesting results have been found in the comparison between territories. A large concentration of the tourism sector and a poorer development of education have been identified in the worst-rated areas of the index. In contrast, the municipalities with the highest values of Sustainable Development suffer from population exodus. It is important to note that correlation does not imply causation, and future lines of research should focus on locating the cause-and-effect relationship of the phenomena found.

On the other hand, the analysis shows that several factors have been identified that relate to the Sustainable Development situation of the various Spanish municipalities included in the sample. In particular, the results show how the municipalities with the best situation show significant positive correlations with the median age of the population, the average annual income per capita and the employment rate of working population between the ages of 20 and 64. By contrast, municipalities with the lowest unemployment rate are the ones with the best results.
This should ultimately lead us to consider the necessary complicity between active employment policies and sustainability and compliance with the 2030 Agenda, which is a major challenge for public administrations. SDG 8, Decent Work and Economic Growth, shows very low values in several of the Spanish municipalities; however, those with a higher economic activity are the ones that have shown the greatest progress in sustainable development. It is important that Spain is implementing policies aimed at ending job precariousness and promoting the growth and economic development of the regions. Understanding this necessary diligence means promoting educational development, which generates direct social benefits in the productivity of regions and creates decent jobs.

The following are some recommended actions which could contribute to the advancement of the 2030 Agenda at the municipal level:

- Using an open data-based approach for planning and implementation will enable a systematic assessment of the annual progress in sustainable development, improving the quality of comparable data on an urban scale and collecting it.
- Focusing on inequalities within certain groups to facilitate their approach. This study has shown acute inequalities in virtually every major city that makes up the sample analyzed. Implementing long-term policies and programs aimed at addressing inequalities between social groups in cities are critical for leveling the playing field and ensuring that all citizens, regardless of where they live, have equal opportunities in life.
- Promoting the exchange of knowledge and mutual learning between cities will be a crucial catalyst for change. Cities can use existing forums to share their experiences and forge new alliances based on shared challenges.
- Collaborations should be encouraged since the scale of the sustainable development challenges is enormous and the resources at the local level are limited. Local governments could rely on non-governmental actors such as universities, civil society and organizations to obtain technical support, collect data, design programs and strategies and support their implementation. As new strategies are defined, other actors, such as the private sector, can also be incorporated to help in supporting the implementation.
- Supporting the central government in its commitment to implement the 2030 Agenda, the Paris Declaration and Accra Agenda for Action and the Spanish Urban Agenda. This can be done by demonstrating local support for sustainable development through campaigns and public funding of the SDGs and, also, by

Table 5 Acronyms

Acronym	Full name
SDG	Sustainable Development Goals
UN	United Nations
UNDP	United Nations Development Programs
EU	European Union
EC	European Commission
SDSN	Sustainable Development Solutions Network
REDS	Spanish Network for Sustainable Development—SDSN Spain
UPM	Technical University of Madrid
ITD	Innovation and Technology for Development Center
OECD	Organization for Economic Co-operation and Development
INE	Spanish National Institute of Statistics
FEMP	Spanish Federation of Municipalities and Provinces
PCA	Principal Component Analysis

laying the foundations for practical and replicable strategies aimed at achieving the SDG in the cities and the rest of the country.

Appendix

See Table 5.

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City Assessment Tool to Measure the Impact of Public Policies on Smart and Sustainable Cities. The Case Study of the Municipality of Alcobendas (Spain) Compared with Similar European Cities

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Abstract Data analytics is a key resource to analyze cities and to find their strengths and weaknesses to define long-term sustainable strategies. On the one hand, urban planning is geared to adapting cities' strategies towards a qualitative, intelligent, and sustainable growth. On the other hand, institutions are geared towards open governance and collaborative administration models. In this context, sustainability has become a global concern for urban development, and the sustainable development goals (SDGs), defined by United Nations, are the framework to be followed to define the new city goals and to measure the advances of the policies implemented over recent years. The main objective of this research is to explain the methods and results of the application of a city assessment tool for measuring the impact of public policies on the socioeconomic and environmental structure of a city. It addresses the case study of the evaluation of the strategic plan "Diseña 2020" of the municipality of Alcobendas (Madrid, Spain, with 116.037 inhabitants), the document used to communicate the actions needed to achieve the city goals during the planning exercise. A selection of urban indicators has been aligned with the SDGs defined in the Agenda 2030 to develop a tool for the measurement of the impacts of policies in economic, social, and ecological terms. Through this set of indicators, the tool is able to quantify the impact of the policies on the city and the SDGs and to support the decision-making processes of the administration. The set of urban indicators is divided into five areas: economic development and employment, sustainable

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_6

development, open government, social responsibility, and quality of life. The data evolution, across the recent years 2012–2018, is used to monitor and benchmark the effects of the applied policies. In addition, Alcobendas can be compared with other Spanish and European cities with similar characteristics; it makes possible assessing the achievement of the city's strategic areas, incorporating the current trends and fostering the SDGs. Thanks to the quantitative comparable results and the objective approach, this research shows a methodology based on indicators that could be applied and scaled to other cities to generate a common framework for measuring the impact of public policies on cities.

Keywords Sustainable development goals · Indicators · Data analytics · City metrics · Socioeconomic impact

1 Introduction

Sustainability has become a global concern (Keivani 2010) for urban development, and the sustainable development goals (SDGs) defined by United Nations represent the framework to be followed as a combination of three global problems: ecological, economic, and social issues. The SDGs define new guidelines to be included in a holistic framework and offer quantitative goals to reach a global model of sustainable development (Sachs 2012). In this regard, cities have a fundamental role in the advancement of SDGs (OECD 2016), and European local administrations are beginning to establish local goals to design new strategies and policies that follow SDGs. Monitoring the SDGs is an important challenge and a strategic opportunity for stakeholders and beneficiaries involved in the Agenda 2030 at all levels (Sachs 2012), and this requires a method to measure SDGs for defining and eventually achieving them (Lu et al. 2015; Schmidt et al. 2015). In this context, data analytics for evaluation and policy-making is the key priorities for the future of smart and sustainable cities (Kamp et al. 2003), and public administration, at the national, regional, and local level, has acquired a new commitment towards horizontal strategies and performances called Open Government (Lu et al. 2015). Public administration generates and collects a vast quantity of data in many domains (Janssen et al. 2012), and data supports policy-makers in addressing complex problems (Arzberger et al. 2004); therefore, indicators are being increasingly recognized as a useful tool in policy analysis and public communication (Melchiorri and Siragusa 2018).

Over recent years various organizations have put in great efforts to establish a standard or a methodology of indicators to measure SDGs at the national and local level. Sustainable development solutions Network (SDSN) has developed the SDG Index (Biggeri et al. 2019; Sachs et al. 2017) to monitor progress across a diverse set of goals with multiple targets and indicators and to track overall progress. Several similar studies have been undertaken at the national level by various chapters of SDSN, and the first report that measured SDGs in cities in an European context was the *SDG Spanish Index Report* (Sánchez de Madariaga et al. 2018). The application of the tool is based on the SDGs framework following, as a starting point, the indicators defined in the *SDG Spanish Index Report* (Sánchez de Madariaga et al. 2018). The report assesses 100 Spanish cities with more than 80,000 inhabitants and all the provincial capitals, according to 85 indicators regarding the 17 Sustainable Development Goals (SDGs) defined by United Nations in 2015, and it is the primary official reference to measure SDGs at the local level in Spain.

The main objective of this research is to describe in detail the methods and results of the application of the city assessment tool, called the Smart&City SDG evaluation tool, for measuring the impact of public policies in the socioeconomic and environmental structure of a city in the framework of the SDGs. This research shows the methodology used to build the tool based on urban indicators to define valid metrics to evaluate the strategic plan of an urban area.

The city selected to apply the tool was Alcobendas, Spain (with 120.000 inhabitants), in the framework of the evaluation of its strategic plan "Diseña 2020." It is intended to obtain a final report, as objective as possible, that reflects the results achieved of the strategies of the public policies carried out. In addition, Alcobendas is compared with European cities with similar characteristics that enable positioning the city in the achievement of each of its strategic goals, incorporating the current trends, and the SDGs.

The goal is to give the administration a quantitative result of its strategy and to obtain results to scale and apply the tool to the Spanish and European city context to have a standard tool to evaluate the real impact on of the cities' strategies in the SDGs.

2 Method

The main procedure used for the construction of the tool is based upon the methods applied by SDSN (Sachs et al. 2017), by the Organization for Economic Cooperation and Development (OECD 2008) and by Sánchez de Madariaga et al. (2018) in the *SDG Spanish Index Report.* The first step in designing the tool is the selection of indicators followed by the SDGs alignment, standardization, normalization, and aggregation. The authors have carried out a quantitative analysis using time series from 2012 to 2018. With the selected set of indicators, and adapting it to the case of study, the tool is able to quantify the impact of the policies in the city and is also able to support the decision-making processes of the administration. A time-series data evolution is used to monitor and benchmark the effects of the applied policies at the local level and on the SDGs. The tool was developed using a set of Spanish and European cities with similar characteristics to those of Alcobendas, the city that was the object of the study (Fig. 1).

A strategic plan is a set of policies and/or projects that determine the general development of an urban area (Gubaidullina et al. 2018) and that, due to its transversal and general nature, must be analyzed by pragmatically considering the 17 SDGs. At present, the planning is mainly oriented towards adapting the strategy of the cities

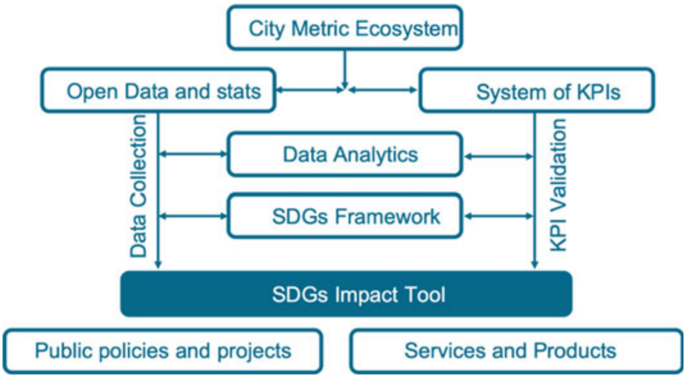

Fig. 1 Construction Scheme of the Smart&City SDGs evaluation tool case of application: the strategic plan of Alcobendas

to the changing times, reorienting its activity towards a qualitative, intelligent and sustainable growth, and reorienting institutions towards a model of open government and collaborative administration. In this context of change, the Alcobendas City Council defined a new vision for the city with which municipal actions would be aligned. The choice of this city is due to three main reasons: It is the city with the greatest availability of data in Spain; it is the first city in Spain that developed a long-term strategic plan untied to the duration of the legislature; and the city had the need to objectively evaluate the results of the strategies applied during the last eight years. The assessment of the strategic plan was carried out through the analysis and comparison of values of various urban indicators and their contrast with:

- the degree of achievement of the actions and objectives of the plan
- the degree of compliance regarding the SDGs
- a comparison with similar cities ("twin" cities).

Quantitative analyses were carried out among the various levels of disaggregation of approaches (Sisto et al. 2018). The objective was to identify which sets of urban areas or domains are relevant and what level of association should be reached with the indicators. Based on this analysis, paths and orientations were designed to be followed through five major strategic goals for the development of the city:

- Goal 1. Promotion of the city, economic development, innovation, education, and employment
- Goal 2. Sustainable development: smart growth
- Goal 3. Good governance, open, and responsible management
- Goal 4. Social responsibility
- Goal 5. Quality of life: culture, leisure, and sport.

The plan collects in detail the five strategic goals, 16 general objectives, 38 projects, and 206 actions. To measure the degree of fulfillment of the objectives and, therefore, of the strategic goals, a series of monitoring indicators was defined by means of which the advances in the implementation of the agreed strategies and its effects on the city have been measured.

2.1 Data Availability and Selection of Indicators

The first step of the procedure is an exploratory analysis of the available data at the local level and the selection of the known and official databases (local, regional, national, European). The starting point of the dataset is the one defined in the *SDG Index Spanish report* (Sánchez de Madariaga et al. 2018), and due to its special relevance, the following reference documents and databases were reviewed to complete the indicators:

- Global indicator framework for the SDG and targets of the 2030 Agenda.
- ISO 37120. Sustainable development communities. Indicators for city services and quality of life.
- CASBEE for CITIES 2015. Environmental Performance Assessment Tool for Municipalities.
- ITU-T Y.4903/L.1603. KPI for smart sustainable cities to assess the achievement of SDG.
- ICR iCityRate. *Classifica delle città intelligenti italiane. Citta e Comunita Sostenibili.*

The databases used to obtain data at the local level for the municipality of Alcobendas and the others cities selected (see Sect. 2.5) were: Statistics Portal of Alcobendas (*Observatorio* de Alcobendas), Statistics Portal of Community of Madrid (ALMUDENA), National Statistics Institute of Spain (INE) and Eurostat.

2.2 Characteristics of the Indicators

Once the urban domains have been identified and based on the experience and knowledge of the official databases available, indicators are screened by criteria such as quality, availability, and reliability. For the sake of future replicability of the evaluation, the compliance criteria of five key characteristics of the SMART scheme have been used: specific, measurable, attainable, realistic, and timely (Sisto et al. 2018). According to the reliability criteria, only official and/or prestigious sources were considered, with open data, grouped and consolidated. As far as possible, databases of international data according to replicability criteria have been prioritized. Likewise, the selection criteria of indicators were adapted to the official indicators proposed by the Inter-agency and Expert Group on SDG Indicators.

In turn, within the available indicators, three types are distinguished according to the approximation they intend to measure:

- Control indicator: It measures the execution of projects and politics; it is a subjective measure defined by the local administration.
- Effort indicator: It measures resources aimed to reach a particular goal (such as budget, number of policies); it is used to measure whether the resources allocated to the project have actually been implemented.
- Outcome indicator: It measures a magnitude directly related to the quality of life of citizens, (gdp, pm10, employment, etc.).

The tool mainly encompasses outcome indicators aligned with the SDGs. To the extent possible, outcome indicators should always be chosen for the evaluation of the elements of the plan because the effort is assessed according to the achievement percentages of the various projects. The outcome indicators reflect the true impact of the policies on the well-being of citizens, although there is a risk of confusing the real effect with the situation or the actions of other agents. Therefore, it is key to introduce comparisons between the subject of study and similar entities.

On the other hand, the value of the indicators is highly dependent on the contextual aspects. The composition of indicators and the creation of indexes is the technique that makes possible the mitigation of this effect and the monitoring of the evolution of an indicator among the various comparison elements. For the composition of indicators, a "matrix" with long-term context variables and more short-term evolution variables is established. The purpose of this diagnosis is to have continuity in the evaluation phase.

2.3 Alignment with SDGs

The next most relevant indicators for urban ecosystems have been identified from a sustainable development point of view. Indicators have been grouped according to the concepts or keywords described in each SDG; the most frequent and redundant have been preselected. From this first preliminary selection of indicators, consultations with experts from each sector have been made to validate and/or discard some of them; the associated databases have been identified and each indicator was related to one or more specific target of the SDGs. Some goals have not been considered due to one or more of the following reasons:

- the goal has already been reached;
- the goal is focused on the regional or national level;
- the goal is not susceptible to urban scale measurement.

As a result of the previous process, a definitive list of quantitative indicators (see the Appendix), considered valid only data at the municipal level was associated with the appropriate goals.

2.4 Comparability

The comparability is key to the objectiveness of the project because it will enables evaluating the real situation regarding its objectives and expectations. This means that, as far as possible, the proposal of indicators is put into context, on one hand, with the values of the entire environment and the city, and, on the other hand, with the values of similar cities to Alcobendas. The comparability is established in two dimensions; on the one hand, official public indicators must be calculable beyond the city of application itself. Therefore, the desirability of opting for open, public, and official databases is reiterated; on the other hand, benchmarking cities that, due to their similar characteristics, make possible a constructive comparison between them should be selected. Comparison cities were chosen at three geographical levels: regional, national, and European. The selection criteria, defined in consultation with sectorial experts, of these cities were:

- Population similar to Alcobendas—between 110,000 and 130,000 inhabitants
- Urban typology—cities in a metropolitan area
- Unemployment rate close to the country structural unemployment
- Gross domestic product per capita.

The cities selected were the following: Bruges (Belgium), Saint-Denis and Argenteuil (both, France), Bremerhaven, Offenbach, Recklinghausen (all, Germany), Zoemeter (the Netherlands), Bergamo and Monza (both, Italy), Pozuelo de Alarcón, Majadahonda, Las Rozas de Madrid, San Sebastián de Los Reyes, Rivas-Vaciamadrid, Sant Cugat del Vallès, Santa Coloma de Gramanet, Reus, Barakaldo and Getxo (all, Spain), Winterhur (Switzerland), and Bolton and Blackburn (the UK).

2.5 Normalization Procedure

After the identification of appropriate indicators, the next step was the normalization of data. The collected values for the indicator are composed of different units of measurement, which makes it difficult to proceed to the aggregation of data and the obtention of a total score. To compare indicators with different metrics within the objectives and projects groupings defined in the plan, a normalization of the values obtained was carried out, based on the definition of maximums and minimums for each metric according to the relative objectives to the current state. The standardization method applied is an escalation to a value in scale 0–1 using the Min-Max method (Sachs et al. 2017). This technique normalizes the indicators to attain an identical range (0–1) by subtracting the indicator value from the minimum value and dividing the difference by the range of the indicator values (Sachs et al. 2017; OECD 2008). The formula for the Min-Max normalization method is:

$$X' = \frac{X - X_{\min}}{X_{\max} - X_{\min}}$$

where X' = normalized value of the indicator (0–1), X = value of the indicator, $X_{\min}$ = the minimum value of the indicator, and $X_{\max}$ = the maximum value of the indicator.

Each indicator has been normalized using a scale 0–1, 1 being the best possible score and 0 the worst; but this equation is only applicable to values with a positive direction (the higher, the better). As the purpose of the normalization is to create a uniform set of values for the indicators in which all have a positive direction, and, to apply the equation also to the values with a negative direction (the lower, the better), a further normalization method was employed $(1 - X)$. At least, to differentiate the results between negative and positive, the minimum value (0) was transformed in −100 and the positive value (1) was transformed in +100.

2.6 Definition of Maximum and Minimum and Aggregation

The standardization of the obtained values was carried out, based on the definition of maximums and minimums for each metric. To define the optimal value, the following criteria were sequentially used: global goals as defined from recognized reports; national or regional goals, calculated from the values of the comparison cities (SDSN methodology) (Sachs et al. 2017); and local goals. For most indicators, the worst value has been defined as the 2.5 percentile of the distribution of the cities selected following the methods established in the SDSN methodology (Sachs et al. 2017). This standardization enables building an index per project by adding all its associated indicators and assessing its growth with an annual average of the normalized values of each indicator and the difference between the 2014 value and the 2018 value (Fig. 2).

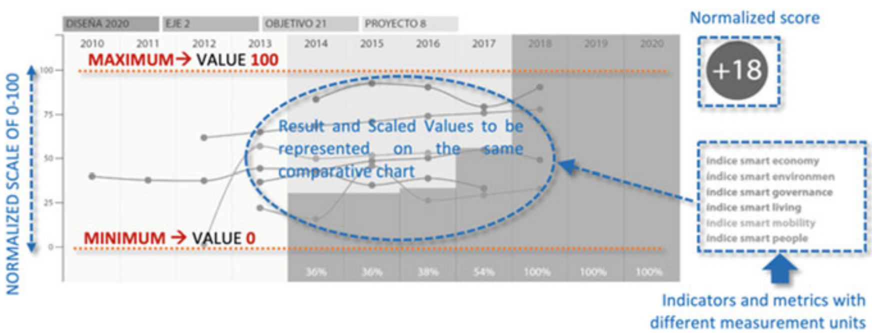

Fig. 2 Interpretation of the visual tool

Equal weights were given to each indicator with regard to its values in each aggregated index. Equal weighting is a viable alternative due to the fact that all the indicators involved are priority policy concerns. Thus, in light of the measurement of the projects, all indicators are equally considered and none is more important than the others. In terms of the aggregation method, the linear additive technique was adapted. This involves adding all the normalized values arithmetically:

$$\text{Score} = \sqrt{\frac{1}{n}\sum_{i-1}^{n} X_i}$$

where score = aggregated result of the subindices analyzed (total score, strategic goals, objectives, projects), X = value of the subindices and n = number of subindices.

The aggregation of several motor projects for the evaluation of a general goal is done in the same way (Fig. 3), calculating the mean of the resulting values per year of each project. More detailed information about the upper and lower limits of each indicator are shown in the appendix.

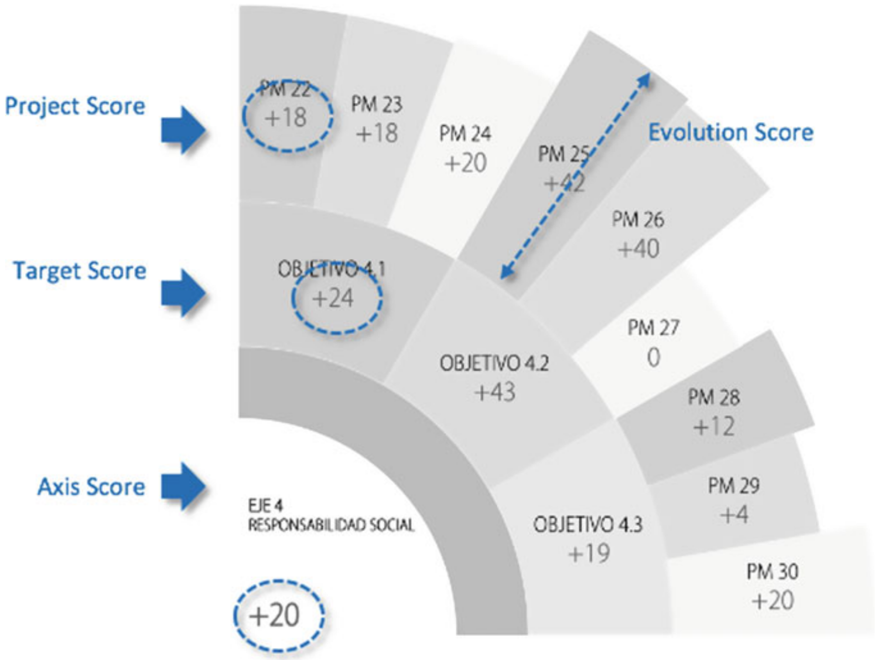

Fig. 3 Aggregation of values at various levels

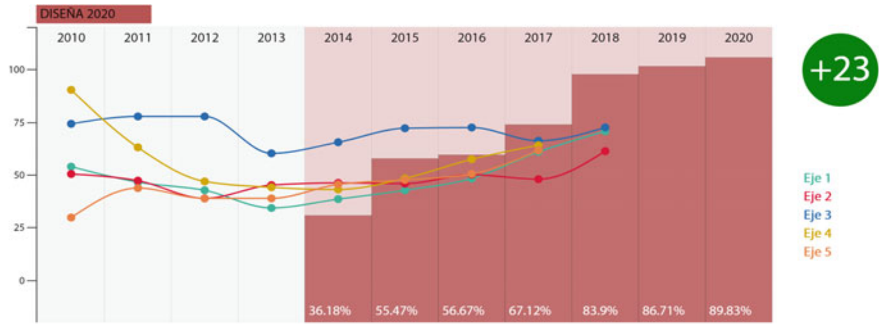

Fig. 4 Historical evolution of the results of the strategic goals of the plan (*Eje*)

3 Results

The results obtained from the analysis are summarized in the following time graph.

The actions that make up the Design Alcobendas 2020 Plan have so far been 83% executed, a very high percentage for such a plan. The 64 selected urban indicators reflect a positive evolution in all the strategic goals. Since the implementation of the strategic plan in 2014, the city has improved by +23 points (in a scale from −100 to +100) regarding the selected urban indicators. This positive evolution occurs in all strategic goals and is consistent with the compliance percentages achieved, according to the internal evaluations of its follow-up. In particular, strategic goal 1 (*Eje* 1 in Fig. 4) has improved by +36 points, strategic goal 2 has improved by +16 points, strategic goal 3 has improved by +12 points, strategic goal 4 has improved by +20 points and, finally, strategic goal 5 has improved by +23 points. In comparison with the rest of the cities, Alcobendas has also experienced a positive evolution above average. The most outstanding evaluation results are presented next.

4 Discussion

Strategic goal 1 highlights Project 1, "Employment Promotion," with a positive evolution of 48 points (Fig. 5). This is because the unemployment rate (7.1% in 2018) follows a trend of improvement well above the average of the Community of Madrid (11%) and that of Spain (14%).

In strategic goal 2, Project 14 citizen security stands out with a positive evolution of 53 points. The crime rate has continued its downward trend of improvement throughout the duration of the plan. However, a similar trend is observed in all the cities analyzed in the Madrid region (Fig. 6). This may point to the fact that some supramunicipal policy has caused the increase of citizen security.

Strategic goal 3 highlights Project 15 transparency, open government, and administration, whose level of excellence and demand has been preserved throughout the

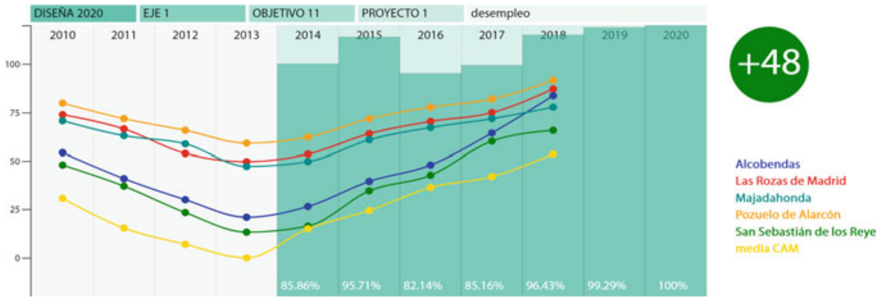

Fig. 5 Time series results of the evolution of the unemployment rate in Alcobendas

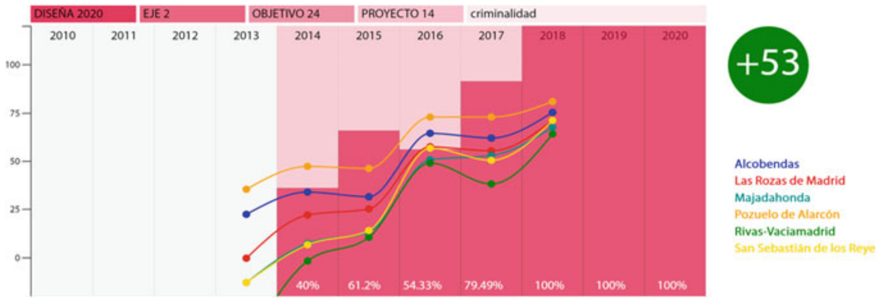

Fig. 6 Time series results of the evolution of the crime rate in Alcobendas

development of the plan. In this case, it should be noted that although Alcobendas is the best city in this respect (basically it cannot improve), it does not score positively, and the value is 0 (Fig. 7). This serves to highlight that it is necessary to maintain the level of excellence in this respect, but maybe the city council should also devote attention to other issues or problems in future strategic plans.

It can be reasonably deduced that the designed strategy has been largely implemented and that it has had, so far, a positive impact on the public policies that

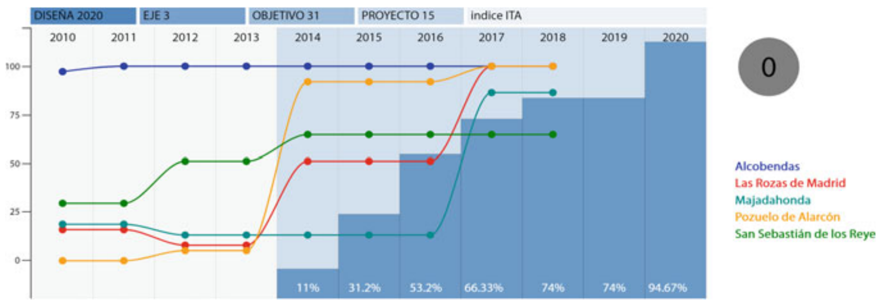

Fig. 7 Time series results of the evolution of the transparency index

were pursued. In view of future strategic plans and upcoming evaluation cycles, it is recommended:

- To realize a previous alignment of projects to the SDGs in their various applications in different contexts. This will allow comparability and result orientation with an international projection.
- To specify the actions in quantifiable objectives to be achieved based on a previous diagnosis. Thus, a more precise compliance can be monitored and the relevant corrective measures can be evaluated.
- To carry out a study of the analysis of results periodically during the implementation of the plan.

5 Discussion

The advantages of the tool are linked to the possibility of obtaining an objective picture of the strategic areas that work better or need more attention in the development of new policies. The tool shows and quantifies immediately which areas have performed better and which strategies need adjustments. The structure of the tool enables an in-depth analysis by using the scores attributed to each sub-index, which serves to better identify each element. The selected indicators were adequate as they accurately reflect the factors that most influenced the quality of life and the SDG achievement in urban areas. In addition, since the results are expressed in numeric values, the tool significantly reduces the subjectivity in the evaluation of the plan and enables comparability of the various topics.

Another strength is the time series used. It is essential to monitor the scores over time to show the tendencies, weaknesses, and opportunities that the public administration should consider when designing its policies and planning its actions.

This research also aims to explore and study the limits founded. The authors decided to apply the same weight to all indicators, but some topics should play more important roles in the urban context. The tool partially solves this problem, favoring the use of internationally recognized indicators in the measurement of each topic without using other specific variables that could distort the results. However, the introduction of a different weight for each topic, based on recognized criteria, is needed. Another important challenge is the limited availability of data: In some case, the indicators with available and comparable data were not the best for the measurement of policies or a topic. In this regard, much progress is needed in the availability of data and the homogenization of databases.

6 Conclusion

The value proposition of this tool consists of:

- Measuring the impact of the strategy deployed in the territory where it is applied.
- Being able to translate the global impact into a single aggregate indicator for stakeholders.
- Measuring the situation of the city compared with other similar cities in achieving its goals in strategic areas.
- Comparing the situation of the city against the SDGs of the 2030 Agenda.
- Identifying best practices within a strategy and serving as an input for the next planning cycles.

It should be noticed that, thanks to the quantitative comparable results and the objective approach, the Smart&City SDGs evaluation tool does not reflect SDGs and the achievement of local goals per se, but rather achievements in the identified indicators in comparison with other similar cities. Although the values do not necessarily imply that a city is smart or sustainable or not, they can help assess the performance of a city and how it fared in comparison with the achievement of other cities. This helps quantify the impact of the adopted policies, identify best practices within its strategy, and improve future policies for the next strategic plan. Furthermore, the subindices help identify the weaknesses and strengths of the city, which provides insights on how to improve their performance. The visualization of the urban economic, environmental, and social impacts goes beyond the support of the decision-making processes and can also be used as a political argument to promote and foster long-term planning (Waas et al. 2014) and urban sustainable development in European cities. Finally, the selection of urban indicators is proposed as a part of a standardization and scalable process which can be replicated in other cities.

Appendix

Table 1.

Table 1 List of indicators

Project	Indicator	Unit	Source	SDG
1. Employment promotion	Unemployment rate	%	Eurostat	8
	Women unemployment rate	%	Eurostat	5, 8
	Men unemployment rate	%	Eurostat	8
2. Promote creation of companies, entrepreneurial culture, and its associated talent	Number of companies by main activity	X1000 inh.	INE	9
3. Implementation of innovative economic activities	Number of patents/number of companies	Ratio	INE	9
4. Improvement of competitiveness of business and industry	Employment vulnerability index (index built by the number of companies by main activities)	Index	Eurostat	9
	GDP growth rate/employee growth rate	Ratio	ALMUDENA	8
5. Promotion of commercial activities	Number of commercial activities	X1000 inh	ALMUDENA	8, 12
	Number of commercial activities/total of productivity units	Index	ALMUDENA	8, 12
6. Coordination and improvements in training and employment policies	Municipal budget settled for education spending policy	€ cápita	INE	4
	Survival rate of pupils in non-compulsory education	%	ALMUDENA	4
7. Language knowledge	Number of language teaching places offered/number of students	Ratio	ALMUDENA	4
8. Smart City	Smart economy index (based on number of companies by activity; municipal debt)	Index	INE	9, 16

(continued)

Table 1 (continued)

Project	Indicator	Unit	Source	SDG
	Smart governance index (based on electoral participation; transparency index)	Index	INE, DYNTRA	16
	Smart environment index (based on indicators of "Project 10—environment and energy sustainability")	Index	Eurostat	7, 11
	Smart people index (based on resources for cultural and educational infrastructure per 1,000 hab.; budget in education/total number of non-university students; education level of population ISCED 5–8)	Index	Observatorio ALMUDENA Eurostat	4, 10 11
	Smart mobility index (based on indicators of "Project 9—New urban developments and public spaces" and "Project 13—sustainable mobility and transport")	Index	INE ALMUDENA	11
	Smart living index (based on indicators of "Project 12—Facilitate access to housing and promoting rental housing")	Index	INE ALMUDENA	10, 11
9. New urban developments and public spaces	Area of urban plots/total urban land	m2t/m2s	ALMUDENA	11
	Rate of the budget settled for public lighting spending policy	%	INE	11
	Broadband penetration	Index	ALMUDENA	11
	Urban land dedicated to green areas and utilities	M2/inh.	ALMUDENA	11
10. Environment and energy sustainability	Electricity billed	€ capita	ALMUDENA	7, 14
	Water billed	€ capita	ALMUDENA	6, 14
	PM10 (number of the days that exceeds 50 $\mu g/m^3$)	Days	INE	3, 11
	PM10 (annual average)	$\mu g/m^3$	INE	3, 11
	PM10 (number of the days that exceeds 50 $\mu g/m^3$)	Days	INE	3, 11

(continued)

Table 1 (continued)

Project	Indicator	Unit	Source	SDG
	Packaging waste collected (Plastic, metal, bricks)	kg/inh.	Ecoembes	11, 12
	Paper waste collected	kg/inh.	Ecoembes	11, 12
	Glass waste collected	kg/inh.	Ecovidrio	11, 12
	Packaging waste deposited incorrectly	%	Ecoembes	11, 12
11. Construction, refurbishment, maintenance, and access to municipal facilities and infrastructure	Rate of accessible municipal buildings	%	ALMUDENA	11
	Income from capital operations/expenses from capital operations	%	INE	11
12. Facilitate access to housing and promoting rental housing	Ratio of protected housing real estate transactions respect total transactions	%	INE	10, 11
	Rated value of free housing/Gross annual household income	Ratio	INE/AEAT	10, 11
	Average Housing price for rent/gross annual household income	Ratio	Idealista	10, 11
13. Sustainable mobility and transport	Number of cars	$n \times 1000$ inh.	ALMUDENA	11, 13
	Average age of the vehicle park	Years	DGT	11, 13
	Public services buses/total bus lines	Ratio	ALMUDENA	11, 13
	Number of car fatalities/number of traffic sanctions	Ratio	DGT	3, 11
14. Citizen security	Crime rate	%	INE	16
	Number of police	n	Observatorio	16
15. Transparency, open government, and administration 16. City observatory: knowledge management	International Transparency Index (ITA)	Index	ITA	16
	Use of transparency, open data and participation webpages based on the data of the number of users, number of visits, number of downloads	Index	Observatorio	16

(continued)

Table 1 (continued)

Project	Indicator	Unit	Source	SDG
17. Participation and open communication	Electoral participation at municipal and national level	%	INE	16
	Membership in national and international city networks	%	Own elaboration	16, 17
18. Excellence and innovation: online City Council	Online consultation over total consultations	%	Observatorio	16
	User perception of the attention received	Index	Observatorio	16
19. Governance and management responsible	EFQM score	Index	EFQM	16
	Average payment period to suppliers	Days	INE	16
	Payment compliance index	Index	SIELOCAL	16
20. Efficiency and quality of spending	Debt cost index	Index	SIELOCAL	16
	Live debt per capita	€/inh.	SIELOCAL	16
21. Planification 2.0	Municipal budget dedicated to quality management respect to the total budget	%	INE	16
22. Attention to dependence 23. Childcare and vulnerable youth 24. Support for families	Degree of alignment of other municipal plans with the objectives of the strategic plan of the city	%	Observatorio	16
	Municipal budget settled for social service and social promotion spending policy	€ capita	INE	1, 10
	Dependency assistance coverage rate	%	Observatorio	1, 10
	Amount of the financial aid granted to children, youth, and family	€ capita	Observatorio	1, 10
	Gross disposable household income/total population <25 years old	€ pop	INE	1, 10
	Accessibility to services in children's education based on available vacancies in nurseries	%	Eurostat	1, 4

(continued)

Table 1 (continued)

Project	Indicator	Unit	Source	SDG
	Total social staff/users of a telecare service	%	Observatorio	1, 10
25. Prevention of educational exclusion and educational support	Municipal budget settled for education spending per capita	€ capita	INE	4
	Survival rate in education	%	Observatorio	4
	Number of scholarships awarded respect total number of students	*n* capita	Observatorio	4
26. Health and active aging	Suicide death rate	*n*/100.000	INE	3
	Students in adult education	*N*	ALMUDENA	3, 4
	Number of vacancies for elderly people	*N* capita	ALMUDENA	3
27. Safe and responsible consumption	Number of sanctioning files over total population	*N* capita	INE	12, 16
28. Equality and prevention of gender violence	Gender pay gap	%	AEAT	5
	Accusations of gender violence	*n* capita	INE	5
	Gender equality in elected officials and executives	Ratio	Observatorio	5, 16
29. Solidarity initiatives, volunteering, and cooperation	Budget for cooperation project and development aid per capita	€ capita	FEMP	17
30. Development of coexistence, support networks and social relationships	Hate-crime rate	%	INE	16
	Number of integrated and/or refugees and immigrants	*N* capita	Observatorio	10, 16
31. Creative talent and artistic training 32. Visibility of production from local artists	Students enrolled in municipal music and dance schools per 1000 inhabitants	*n*/1000	ALMUDENA	–
	Municipal budget to subsidize local artistic dissemination	€ capita	Observatorio	–

(continued)

Table 1 (continued)

Project	Indicator	Unit	Source	SDG
33. Leisure and culture 34. Territorial distribution of facilities and activities 35. Activities in collaboration with educational centers	Surface area of theaters, museum, art galleries and cultural centers per capita	m^2/capita	Observatorio	4
	Surface area of sport buildings, cinemas, and playgrounds per capita	m^2/capita	Observatorio	11
36. Inclusive activities for different collectives 37. Attractiveness of the city as a model of culture and sport 38. Leisure, culture, and sport	Evolution of number of users of cultural and sports facilities	*n*	Observatorio	–
	Evolution of visitors of museums and cultural centers who are not residents	*n*	Observatorio	–
	Number of subscriptions to a sport activity compared to the total offer	%	Observatorio	–
	Citizen satisfaction survey	Index	Observatorio	–

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Snap4City Platform to Speed Up Policies

Nicola Mitolo, Paolo Nesi, Gianni Pantaleo, and Michela Paolucci

Abstract In the development of smart cities, there is a great emphasis on setting up so-called Smart City Control Rooms, SCCR. This paper presents Snap4City as a big data smart city platform to support the city decision makers by means of SCCR dashboards and tools reporting in real time the status of several of a city's aspects. The solution has been adopted in European cities such as Antwerp, Florence, Lonato del Garda, Pisa, Santiago, etc., and it is capable of covering extended geographical areas around the cities themselves: Belgium, Finland, Tuscany, Sardinia, etc. In this paper, a major use case is analyzed describing the workflow followed, the methodologies adopted and the SCCR as the starting point to reproduce the same results in other smart cities, industries, research centers, etc. A Living Lab working modality is promoted and organized to enhance the collaboration among municipalities and public administration, stakeholders, research centers and the citizens themselves. The Snap4City platform has been realized respecting the European Data Protection Regulation (GDPR), and it is capable of processing every day a multitude of periodic and real-time data coming from different providers and data sources. It is therefore able to semantically aggregate the data, in compliance with the Km4City multi-ontology and manage data: (i) having different access policies; and (ii) coming from traditional sources such as Open Data Portals, Web services, APIs and IoT/IoE networks. The aggregated data are the starting point for the services offered not only to the citizens but also to the public administrations and public-security service managers, enabling them to view a set of city dashboards ad hoc composed on their needs, for example, enabling them to modify and monitor public transportation strategies, offering the public services actually needed by citizens and tourists, monitor the air quality and

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*,
Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_7

traffic status to establish, if impose or not, traffic restrictions, etc. All the data and the new knowledge produced by the data analytics of the Snap4City platform can also be accessed, observing the permissions on each kind of data, thanks to the presence of an APIs complex system.

Keywords Big data architecture · Smart City Control Room · Decision-support system · Advanced APIs · IoT

1 Introduction

In most of the modern smart cities, there is a great emphasis on setting up the so-called Smart City Control Room (SCCR) that is an area in which all the data are collected and aggregated and where high-level data/results are summarized and made accessible for decision makers and city operators. In large metropolitan cities, the SCCR includes large panels/monitors on which the status of the city is displayed in real-time presenting predictions and alerts regarding: mobility, energy, social activities, the environment, weather, public transportation, people flow, health, water, security, ICT, governmental, first aid, civil protection, police, fire brigade, hospital triage, and thus almost all the city resources expressed via key performance indicators (KPI). Some of the city's monitored resources are representative of critical infrastructures such as: mobility and transport, energy, security, health, water, civil protection, governance, ICT, etc. In medium-sized cities, the daily management of city resources is performed by a set of city operators, which could be legally independent with respect to the central municipality and should autonomously manage their SSCR (Azzari et al. 2018). To realize a SCCR, it is necessary to understand: (i) the SCCR requirements; (ii) data sources needed to monitor the scenarios; and (iii) services the decision makers want to provide to various categories of users. One of the key aspects consists of establishing relationships that define guidelines and common operating modes with all the stakeholders and operators who have to work together to create/manage the dashboard (DeMarco et al. 2015; McArdle et al. (2016); Suakanto et al. 2013). In this regard, it is of fundamental help to use collaborative tools such as the Living Lab support on Web portals. In the context of the EC REPLICATE project, the City of Florence has set up a SCCR solution based on Snap4City technology (https://www.snap4city.org) by collecting and aggregating a relevant amount of data, performing data analytics to provide predictions, early warning, routing, heat maps, and a large set of dashboards for the SCCR. This paper is organized as follows: Sect. 2 reports the process of the adoption of the SCCR, including Living Lab support; in Sect. 3, the Snap4City architecture is described; Sect. 4 provides a scenario of data collected and aggregated for the SCCR and related services; Sect. 5 reports some statistics regarding the usage of SCCR in the case of Florentine area. Conclusions are drawn in Sect. 6.

2 Adoption Process

Smart cities are complex ecosystems in which many distinct aspects coexist, and many kinds of actors interact. Living Labs (LL) are instruments for the development and implementation of technology to accelerate innovation in cities (Villanueva-Rosales et al. 2016; Coenen et al. 2014). A LL is a starting point to collaborate on and generate models to create smart cities (Cosgrave et al. 2013; Majeed et al. 2017; Concilio 2016), i.e., it is a way to develop collaborative systems to engage the community/stakeholders (e.g., students, lecturers, computer scientists, electronics engineers, politician and tourists). Snap4City provides a set of tools and solutions to quickly setup and then maintain a LL. The approach has been realized involving different kinds of organizations (universities, SME and large industries and public administrations) and users (city and resource operators), in-house companies (company participated by the city body), tech providers, associations, corporations, research groups, start-ups, early adopters, large industries, advertisers, city users, community builders, etc.), thus reflecting the features described in quadruple helix (QH) (Arnkil et al. 2010; Alba M et al. (2016); Karvonen et al. 2018), to support the LL concept in smart cities (see Fig. 1), also considering a multi-organizational/multicity approach that enables the sharing of experiences among cities.

At the same time as the setup is done, the collaboration among stakeholders can start by creating: agreements, collaborations, networking, tutorials, workshops, hackathons, etc. (see Fig. 1), so as to arrive at involving all the stakeholders in concrete smart cases, signing agreements, partnerships, licensing, etc. This process should be driven by the municipality, which may need support for technical aspects that are provided by Snap4City at different levels. Typically, the single companies, even if supported by the city/operators, do not have the perspective and the mission to put in common so large a multi-domain multiservice framework and environment.

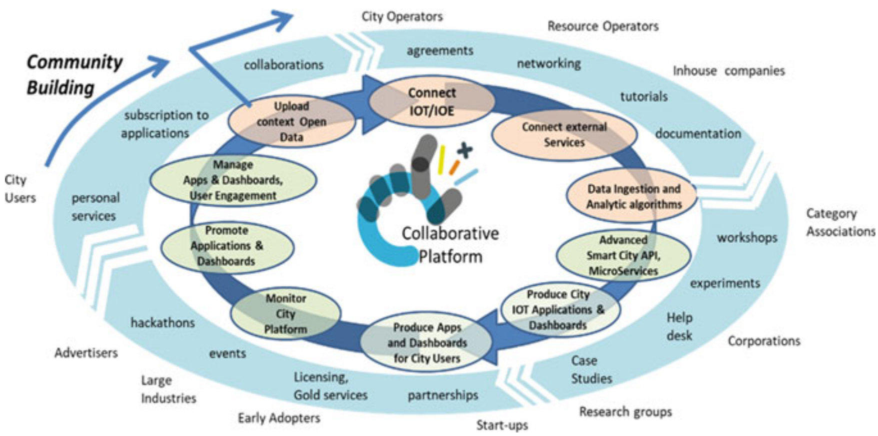

Fig. 1 Snap4City collaborative workflow process

3 Snap4City Architecture

Most of the smart city solutions must cope with big data volumes, variety and veracity (Bellini et al. 2014). Open data as static data (street graph, point of interest, etc.) are not the only data sources needed for the city SCCR: most of the big data ingested and managed periodically or in real time comes from public transport/vehicle and human mobility in city, events, energy, governance, IoT, etc. A smart city architecture should be capable of taking advantage of a huge amount of data coming from several domains, at different speed/rates for exploiting and analyzing them, for computing integrated and multi-domain information, making predictions, detecting anomalies and early warning, and for producing suggestions and recommendations for city users and operators. In this sense, the Snap4City architecture and the integrated semantic model, connected to the Km4City multi-ontology (Bellini et al. 2014), have been developed to collect, aggregate and manage these different kinds of data (see Fig. 2) to provide a set of services: dashboards, smart decision-support systems; social media-monitoring Twitter vigilance; statistics and prevision analysis, suggestions and recommendations for citizens, etc.

Snap4City consists of a set of modular tools accessible according to the user profile:

- **data registration, ingestion and publication**. Data connections are typically bidirectional. They can come from/to: (i) any kind of data source/collector, protocol and format from/to: open data, real-time data, GIS, IoT data, data stream, data driven, social media, Industry 4.0, etc.; (ii) IoT devices and networks, IoT edges, gateways, IoT brokers, via various protocols and formats; (iii) Web-scraping processes; (iv) dashboards collecting actions from the users via: buttons, dimers, time selectors, and showing them; (v) mobile applications collecting and presenting; (vi) results of data analytics, including personal data produced by users (Nesi et al. 2018).

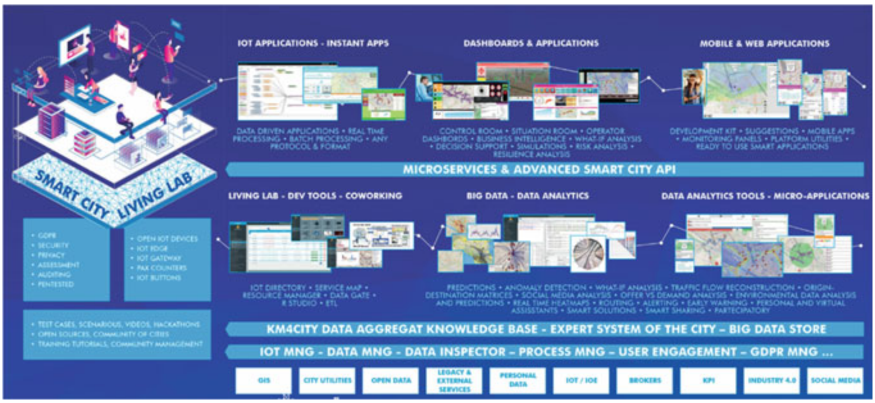

Fig. 2 Snap4City architecture and ecosystem

- **Storing and indexing of data** are performed via the Km4City smart city ontology and knowledge base on graphDB (Bellini et al. 2014); and big data store for data shadow, based on Elastic Search and/or Hbase noSQL database. The spatial, temporal and semantic indexes are created for fast and smart data retrieval with capabilities of inference, reasoning, faceted search, drill-down and extracting insights from the data and contexts.
- **Advanced Smart City API and Microservices** for accessing services and data. All the data collected and indexed can be accessed via APIs and/or Microservices to enable developers and operators to create in a simple manner: IoT applications, mobile and Web app, and dashboards, according to the GDPR (Badii et al. 2019).
- **Data analytics and data transformations processes and tools** can be created and shared as the smart core of the smart services, such as: making predictions, signaling early warnings, detecting anomalies, creating analysis, producing interactive heat maps, suggesting decision makers, supporting simulations, etc. Analytics and data processing exploit Smart City API, can be developed in R, Python, Java, IoT App Node-RED, ETL, etc., and can be executed on demand/on events, periodically and in real time. Resulting data are also saved and indexed into the platform.
- **Dashboards** can be created for various kinds of users, such as: the major decision makers, city operators, ICT operators and private users. They can be suitable for SCCRs with large video walls, large control rooms with tens of operators on desktops of multiple monitors, mobile operators and situation rooms with touch panels, as well as for virtual control room in which the controls are distributed and views are distributed among various locations.
- **IoT applications** are data-driven and/or periodic visually defined data-flow processes exploiting the suite of Snap4City Microservices (more than 150 nodes). They can be put in execution IoT edge, as well as on Cloud, and are based on Node-RED. IoT app also enables to perform business logic (i.e., the logic behind the applications which can be used to enforce the business rules and the application "intelligence"), smart interaction and data transformation behind the Snap4City dashboards, integrating ticketing, video wall dynamic re-configuration, etc. Microservices may also manage processes for data analytics, Web scraping, external services, data gathering and publication, etc. (Badii et al. 2018).
- **Web and mobile applications** can be created by developers exploiting Advanced Smart City APIs. The app may be managed by specific Snap4City tools to send engagements, surveys, stimulus and for understanding user behavior, creating origin-destination matrices, getting reactions from the users, informing of critical conditions, etc. (Badii et al. 2017a).
- **Living Lab support** makes possible creating a collaborative sustainable environment for smart city growth in which the city stakeholders can contribute, according to their skill and commitment. Snap4City provides an environment in which Living Lab users can exchange information, work on collaborative tools for data transformation and valorization, exploiting all the other tools.

The whole platform is GDPR-compliant and enforces privacy and security for data, dashboards, IoT devices, IoT applications, personal data, data analytics and processes, etc., which can be private or can be delegated to pass the ownership to other users.

4 Data Versus Services

The kind of services provided to the final users are strictly connected to the data in/out activities and the interaction among the data providers. Each data provider can have a different modality to expose, transmit and receive data, moreover the data can be formalized in various modalities (structured or non-structured information), formats (csv, Excel, XML, json, etc.), and protocols in push and/or pull, etc. This is the reason why a smart city big data platform, such as Snap4City, must be flexible and capable to ingest every various different kinds of data (see Fig. 3).

Once the data have been collected and integrated, the historical data and real-time data can be exploited by data analytics processes, IoT apps, dashboards and apps. The original data and results of the data analysis can be accessed for business intelligence tools and SCCR. The most relevant data available in the Florence SCCR, are described next and classified based on their context:

- **Mobility**: public transport operators schedule and paths, traffic-flow sensors, parking status, cycling paths, road graph, accidents and traffic events, ordinances, car-park occupancy prediction, what-if routing, quality of public transportation

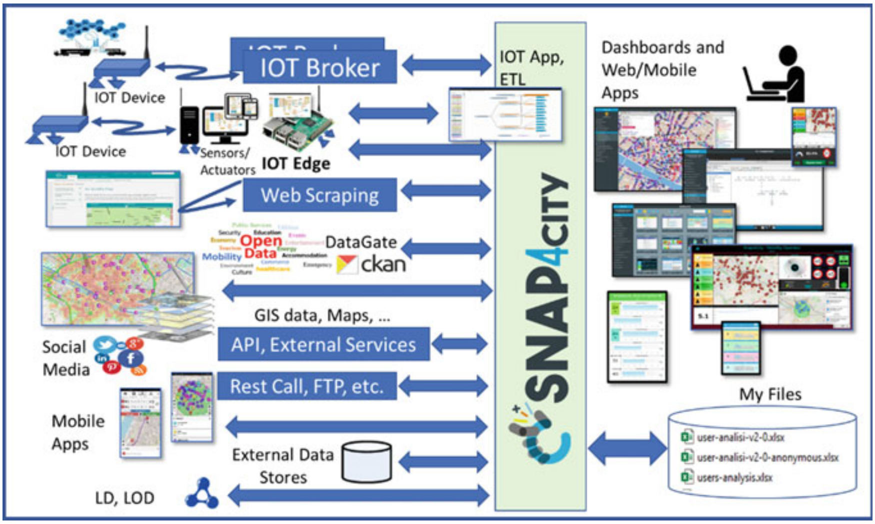

Fig. 3 Snap4City: data ingestion and final services

services, etc. The services produced, starting from those data are: KPI assessing quality of public transportation; routing and multimodal routing; real-time traffic-flow reconstruction (Bellini et al. 2018, results of the Sii-Mobility project https://www.sii-mobility.org); real-time status and predictions for parking, smart parking;

- **Environment**: (i) irrigators; (ii) smart waste; (iii) air quality sensors: PM10, PM2.5, CO, benzene, NO, NO_2, O_3, temperature, humidity, etc.; (iv) air quality heat maps for pollutants at point (iii); and (iv) pollination. As derived data, we can have NO_X predictions (as a result of the TRAFAIR CEF project, https://trafair.eu); air quality heat maps updated every hour, real-time status and trends related to air quality sensors and pollination, NO_X predictions for the next 48 h, with a resolution of 4×4 m and at two levels of height (at 3 and 6 m); and long-term predictions for pollutants' critical days;
- **Energy**: (i) recharging stations (fast and regular); (ii) consumption meters (smart info); (iii) smart light; monitoring consumption via smart meters, smart lights status and trends;
- **Weather**: forecast and actual (related to temperature, wind, clouds, sun, rain, etc.);
- **Social**: (i) smart benches; (ii) entertainment events; (iii) Twitter monitoring via Twitter vigilance (https://www.disit.org/tv), sentiment analysis, NLP text; (iv) TV-camera streams; and (v) triage status of major hospitals; also for early warning.
- **People Flows**: (i) Wi-Fi status; (ii) origin-destination matrices, people-flow analysis (as result of the EU RESOLUTE project, https://www.resolute-eu.org) from the Wi-Fi network of access points;
- **Governmental and Communications**: (i) KPI of the city, including COVID-19 data; (ii) digital signage (not directly included into the solution for Florence); (iii) civil protection, resilience guidelines and suggestions, KPIs (RESOLUTE project);
- **Tourism and Culture**: Points of interests (POI), cultural events, etc.;
- **Analysis**: (i) what-if routing; (ii) scenarios; (iii) traffic flow; and (iv) environmental predictions.
- **Video streams**: (not directly included into the Snap4City solution for Florence).

Starting from these kinds of data, reworking them (semantic aggregation in compliance with Km4City multi-domain ontology and data analytics) and thanks to the APIs presence, a set of services is available in the Florence SCCR. The series of dashboards designed to provide the services just described, a mobile app was created and called 'Florence where what…' (see next section) and are capable to send suggestions and recommendations based on location and the preferences expressed by citizens and tourists.

5 Smart City Control Room

A SSCR is a solution and structure in which all data and indicators of the city are collected and aggregated to produce summary visions, indicators, forecasts, precursors, anomaly indicators, etc. The results are produced through big data analytics to support decision makers and operators, so that they can quickly understand the situation in full and act, also through simulations for scenarios with what-if conditions. When the city grows, its systems become more complex. Moreover, some cities are morphologically complex during their histories, morphogenesis and structures, and it becomes important to:

- **manage the data** collection and integration, data analytics, prediction indicators (predictions, early warnings, anomalies), but also to carry out simulations and comparing them with the hypotheses on events, realized before the simulation and without the Snap4city tools.
- **Activate** and run data-analytic algorithms that can produce systematic or, if necessary, real-time forecasts, identifications of anomalies, and the ability to communicate them to operators and from an early warning and study perspective. Therefore, they are able to generate reports even in advance.
- **Visualize** the state of the city and its evolution and critical aspects for the different operators (in a common operating room, as in the situation rooms), allowing also some remote operators in their offices to access some summary information, prediction, service status, etc.
- **Enable the carrying out**, directly on the dashboards, the necessary **in-depth analysis** with drill-down techniques (time space and for reports), with: What-if simulations on problems and solutions, routing algorithms, predictive models and in-depth analysis tools. On these, it must be possible to **open discussions/chats** with other operators, even remote ones (via radio, voice and chat), and to bring the attention of all operators to support decisions.
- **Manage events and reports** that may arrive from various operators: mobility, transport, waste, energy, social media, highways, public transport, etc., in various standards and through various communication channels. Managing in these cases means: coordinating possible joint actions between several operators, acting, following their evolution, and keeping track of events, until their conclusion/resolution, to take them into account for the next actions.

5.1 A Set of Connected Views and Tools

The SCCR is a decision-support tool that is able to provide evidence of the arrival/occurrence of critical conditions in real time and/or precursors of such conditions and offer solutions (decision support, e.g., by proposing multiple choices on evacuation plans, routing and activation of implementation plans). Following these guidelines, the Florence SCCR has been realized with a series of ad hoc dashboards connected each other:

- **Main dashboard**, 'Firenze Oggi' (Florence Today), contains a set of KPIs monitored in real time: a number of users connected to the public Wi-Fi, civil-protection messages, weather forecasting, recharging stations statuses, state of road maintenance and accidents, public transport lines; but also statistical data such as: census numbers (births, deaths, marriages and civil unions) and analyses of: traffic, pollution and what-if analysis. It has links to the following dashboards.
- **Energy**: position on the city map, real-time status and historical trends of: fast and normal recharging stations, ZTL gates, Wi-Fi, smart irrigators, smart lights, statistics on residential smart energy meters. KPIs: monthly cumulative energy consumption, average weekly consumption of each fast recharging station, number of users connected to the mobile app, eEnergy consumption via mobile app, accumulator status (used), etc.
- **Environment**: position on the city map, real-time status and historical trends of: air quality stations and low-cost sensors (PM10), weather sensors, pollen monitoring, Florence weather for today and for the next two days (clouds, rain, sun, wind), temperature, waste sensors, etc.
- **Mobility**: traffic events in Florence, traffic daily inflow/outflow trend, total number of inflow/outflow vehicles, car-park statuses and trends, etc.
- **Social**: Twitter sentiment trends in the city of Florence, natural-language processing and sentiment analysis on tweets (most used hashtags, statistics on Twitter citations), people flow.
- **Resilience**: civil-protection messages in real time, hospital first aid, evacuation paths, etc.

Moreover, other additional views can be opened. In Fig. 4, some of the connections are shown. Starting from the mobility dashboard and clicking on 'traffic daily inflow/outflow trend,' it is possible to see details regarding the traffic flow: statistic and trends, ZTL, comparison among actual and past values (Badii et al. 2017b).

6 Usage and Validation

The Florence SCCR development started on 2017 with the first dashboard, and since that time, the number of data has been increased with corresponding views and dashboards of various kinds. Most of the data are public and accessible on dashboards from the Web site of Snap4City.org, while a number of dashboards are private to the municipalities. In Fig. 5, we have reported an aggregated view of the usage and attention that dashboards have received from the users. The views are classified basing on number of accesses and minutes of usage for the 2019. The dashboards describing the general view and the traffic aspects were the ones on which users spent the most time on viewing. While the dashboards that have received the most access are those related to general and the environment aspects. To measure how those data

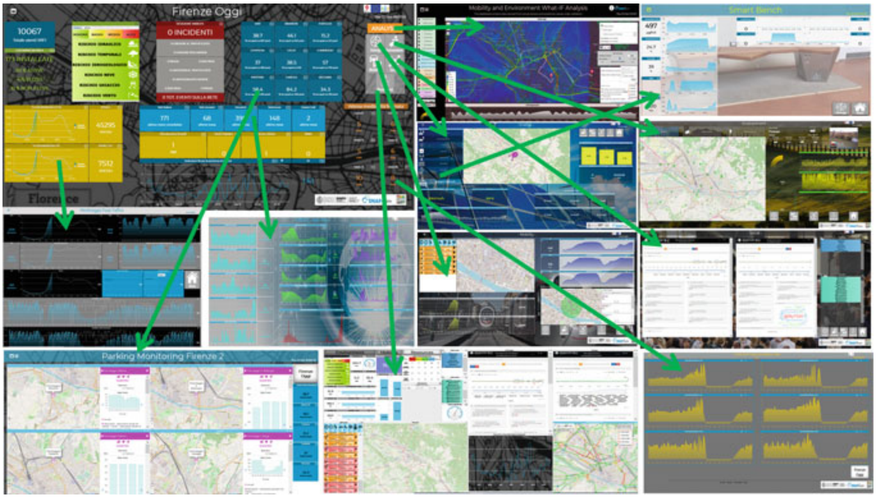

Fig. 4 Florence Smart City Control Room: connected views and tools

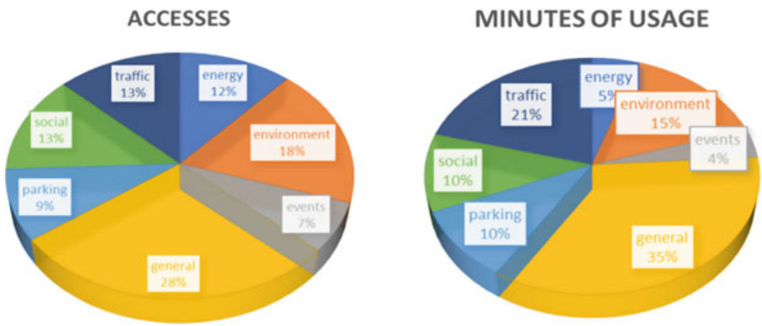

Fig. 5 View on the usage of the dashboards related to the major topics for the area of Florence

have influenced the policies of the municipality is not addressed, while it is evident which are the major topics of interest in the area.

The attention on general aspects, mobility and environment are a confirmation of the effective usage and need of an instrument such as an SCCR for monitoring the city. In summary, a total of more than 6000 accesses have been made and 340,000 min have been spent on the major dashboards for the major areas in the year 2019, which is an average of 57 min per access. On the other hand, there are dashboards that are typically accessed 24H/7D, and those that are only sporadically used.

7 Conclusions

Smart City Control Rooms, SCCRs, are getting strong attention at this time for their capability of reporting in real time the status of several city aspects, thus creating a strong and effective tool for decision makers. This paper presented Snap4city as a Big Data Smart City Platform to support the city decision makers by means of a SCCR. The solution is adopted in different degrees of diffusion in European cities such as Antwerp, Florence, Lonato, Pisa, Santiago de Compostela, etc. In this paper, the Florence SCCR has been analyzed as a major use case describing the data, the services and the workflow. For data aggregation, the Km4City multi-ontology and tools have been used to collect data from GIS, utilities, open data, IoT networks, external services, social media, etc. The first Florence SCCR dashboard appeared in 2017 as a prototype, and, since that time, a great evolution has been occurred and the amount and type of data have increased. Most of the data are public and accessible on dashboards from the Web site of Snap4City.org, while a number of dashboards are private to the municipality. The results presented have shown the data regarding the last year of high usage of the platform. During this period, a particular attention by the users, on general overview aspects, mobility and the environment have been registered. In summary, a total of more than 6000 accesses have been made and 340,000 min have been spent on the major dashboards for those major areas in the year 2019, which is an average of 57 min per access.

Acknowledgements The authors would like to thank the European Commission for funding the REPLICATE SCC1 H2020 project (which exploits Km4City/Snap4City framework) under grant agreement No. 691735, and all the companies and partners involved. Snap4City and Km4City are 100% open-source technologies and the platform of DISIT Lab can be accessed at https://www.snap4city.org.

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New Value Propositions in Times of Urban Innovation Ecosystems and Sharing Economies

Public Research and Development Funding for Photovoltaics in Europe—Past, Present, and Future

Simon Pezzutto, Juan Francisco De Negri, Sonja Gantioler, David Moser, and Wolfram Sparber

Abstract The use of photovoltaic technology is crucial to meet Europe´s ambitious climate and energy objectives set for 2030. To facilitate this shift, technological innovation is a key prerequisite, and the provision of public funding for related research and development is an important trigger. For this study, a vast set of data has been collected to explore how the EU and its Member States, plus Norway and Turkey, have so far invested in photovoltaic research and development. Based on historic values and actual trends, the authors additionally outline the possible future evolution of the investigated public funding. The study aims to shed light on the development of funding from the early 1970s until 2017 (most recent data available) and provide a forecast for 2030 (based on a business-as-usual scenario). According to results, at the national level, public funding had a considerable and steady rise after the OPEC´s oil embargo in 1973, reaching a first peak in the mid-1980s. The authors predict that, according to the most recent trends, by 2030, these will surpass 200 million € annually. In comparison, EU funding has steadily increased since its inception in the late 1980s up until 2007, but its evolvement is distinctively different, evidencing high fluctuations. The cumulative stock is also examined. National sources outweigh EU programs by a factor of almost five, and the stock should surpass 7 billion € by 2030. Based on the analysis and related insights, recommendations are elaborated on how the development of funding could inform policy strategies and actions to support research and development for photovoltaic technology.

Keywords Research and development · Public funding · European Union · Photovoltaics · 2030

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_8

1 Introduction

Why is facilitating investment into research and development of the photovoltaics (PV) sector important for the EU? Renewable energy sources have an important role to play at the global level—not only in Europe. This refers first to the positive effect they have on lowering CO_2 (and other greenhouse gas) emissions, which in turn then has a direct effect on fighting global warming, and second to the contribution they make to a more diversified energy mix, as well as energy security and independence (El-Agraa 2017). The EU has set ambitious climate and energy targets to be achieved by 2030 (EC 2018a), and electricity generation through PV can help in meeting those targets by contributing attributes like: scalability of solar parks; vast availability of raw materials; easy installation; simplicity of operation; and the low maintenance costs of PV plants (Twidell et al. 2006).

Europe has been at the top in terms of technology innovation for PV for decades (EC 2017a), providing important support for creating the necessary conditions that make PV nowadays a feasible electricity production alternative (Popp 2006; Gallaher et al. 2012). The combination of cost reduction, increased international competitiveness and continuous technological innovation (IRENA 2017) has enabled the accelerated growth of PV capacity in the EU since 2007 (Fig. 1). This growth coincided with a growing market and an increase in electricity consumption in the EU of about 24% from 1990 to 2016 (EC 2018b), resulting in a year-over-year increase of approximately 0.84%. The trend is in part driven by the growing appetite of the European population to increase its level of comfort by using electrical devices, which at the same time can be highly energy intensive (Pezzutto et al. 2016) and to partly offset energy efficiency improvements (EC 2012a).

To enable the transition to a higher use of PV, public investments in research and development (R&D) is a priority. The resulting innovation also contributes to the affordability and access to critical technologies (Mission Innovation 2015) and helps to bridge the gap between theoretical studies and commercial deployments and attracts private investments by de-risking technology (EC 2019a). Exemplary

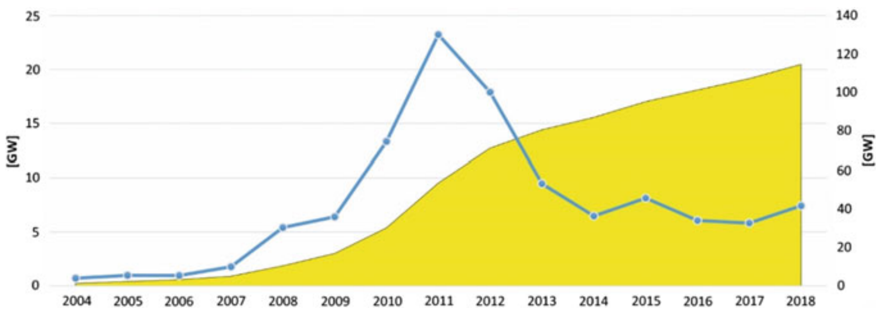

Fig. 1 Installed PV capacity (GW) in the EU, yearly (blue) and accumulated (yellow) (IRENA 2019)

publications that emphasize the importance of R&D toward the development of renewable energy sources (RES) and thus meeting named targets until 2030 are among others: the Energy Roadmap 2050 (EC 2012b); the European Strategic Energy Technology Plan (SET-Plan 2017); and the European Energy Security Strategy (EC 2014). Except for the Mission Innovation initiative, which specifically stipulates that members will double their clean energy R&D investment by 2021, other publications do not provide any specific quantitative targets on PV R&D in order to meet the 2030 climate and energy targets. To potentially inform the development of such targets, as an initial step, this study focuses on tracking all public investments made in the EU, plus Norway and Turkey (Iceland and Switzerland have not been taken into consideration because they are not members of the SET-Plan PV Temporary Working Group (Hünnekes et al. 2017), aiming to address these research questions:

1. What level of PV R&D funding has been provided so far by countries covered by the study, and how much is expected in the next decade?
2. What is the difference between the national and European level of funding?
3. What level of cumulative funding stock can be expected by 2030?

2 Materials and Methods

At the beginning of this study, a thorough analysis of the sources of public funding for PV R&D provided by Member States (MS), plus Norway and Turkey and by the EU, has been carried out, to answer the research questions just listed. With regard to questions 1 and 2 on funding at the national level, the International Energy Agency's (IEA) database was used as the main source (IEA 2019a). A comprehensive database including nominal values of PV R&D funding was then assembled, including inputs that date back to 1974. To adjust these values to 2018 prices, EU inflation values from the International Monetary Fund (IMF 2018) have been applied to ensure consistency throughout the analysis. To gain further input to question 2, a considerable number of EU funding programs were screened. However, when analyzing those more in depth, immediately a highly unequal distribution of share became evident. The European Framework Programs for Research and Innovation have historically represented the largest individual sources of funding. The most recent one—Horizon 2020—provides for approximately 85% of PV R&D funding. Accordingly, the Community Research and Development Information Service (CORDIS) database was used as the main source of information for EU funding (EC 2019). Using all the historical data collected with regard to questions 1 and 2, adjusted to 2018 prices, a future scenario (Business as usual (BAU), please see Sect. 2.2) for each case (national and EU funding) was produced, to answer question 3. These scenarios estimate both the annual and accumulated funding stock until 2030.

It needs to be noted that, according to metadata specifications provided by the IEA (2020), the possible overlap between national and EU R&D funding is reduced to a minimum. Data are submitted by national institutions, such as ministries and agencies, which in dedicated country notes outline related considerations and measures to avoid double counting. However, overlaps cannot be completely excluded.

The following sections provide further insights into methodological considerations with regard to data sources, scenarios development and cumulative funding stock calculations.

2.1 Photovoltaic Research and Development Funding at National and European Union Levels

The IEA R&D data service provides data on funding from EU MS, plus Turkey and Norway, provided in real values from 1974 onwards (IEA 2019b). The EU Research and Innovation funding programs—FP1 to H2020, spanning from 1984 to 2020—are the main arm of funding for R&D, in the respect that they provide the largest share of resources (Bointner 2016a). Analysis of historic R&D funding can be found in multiple publications and reports such as the World Economic Council's (WEC) Annex I (Valdalbero 2010) and from the EU/EC (EC 2009; EC 2015a; European Parliament 2015; EC 2017b).

The database constructed is vast, enabling the quantification of public PV R&D funding of the parties under scrutiny, and it appears to be the single source comprising a time series since the 1970s. Individual project information is available for FP6, FP7 and H2020.

2.2 Scenarios for Public Research and Development Investment Until 2030

The BAU scenario presumes that the ongoing trend of R&D funding based on historical values will continue its performance in the coming years. This entails that no major changes that could have an important impact on the estimations, especially those related to energy policy, will occur in the near future. The reason for creating a BAU scenario is to anticipate future R&D developments taking into consideration the current situation in Europe. The BAU scenario results are likely to be suitable also because the probability that all participants under examination radically change their energy R&D policies is very low, and, even if one contributor does indeed make important changes, the impact this may have on the overall picture is of minor consequence.

2.3 Cumulative Funding Stock for Photovoltaics

To neutralize the fluctuating nature of R&D funding, the cumulative funding stock is introduced, ensuring more stability and predictability and also enabling the possibility to calculate a highly reliable linear-regression equation based on historic data. It contains the year-to-year sum of R&D funding from 1974 to 2017. As in the other cases, a forecast represented in an accumulated form until 2030 is presented.

2.4 Literature Appraisal and Methodology Review

By using the IEA R&D database, some limitations arise, starting with the fact that not all EU MS participate in the IEA (Croatia, Bulgaria, Lithuania, Cyprus, Latvia, Romania, Malta, and Slovenia do not), and those that actually are a part do not always provide annual data (EC 2015b). There were no adjustments made to the original database for missing entries in the form of 'gap filling' or similar methodologies. Nevertheless, according to Wiesenthal et al. (2012), out of the entirety of R&D funding, IEA member countries account for almost 100%, so the missing MS contribution is safely considered as negligible. As for the EC, since funding is done through programs, the earliest data available is from 1987.

3 Results

The outcomes are divided into four sections: (Sect. 3.1) funding provided at national level; (Sect. 3.2) funding provided by the EU; (Sect. 3.3) the sum of both sources; and finally (Sect. 3.4) a snapshot of the cumulative funding stock.

As for going beyond the scope of this paper, the results are presented at an aggregated level and not at national/regional levels and have not been indicated as a percentage of GDP. A more in-depth discussion is expected to occur in any follow-up publications.

3.1 National Level: European Union Member States Plus Norway and Turkey

Figure 2 shows the annual investments made in PV R&D at the national level (EU MS plus Norway and Turkey) from 1974 to 2030. From 2018 to 2030, the expected BAU scenario is based on historic data. In the aftermath of the Yom Kippur war (1973), the Organization of Petroleum Exporting Countries (OPEC) proclaimed an oil embargo that abruptly disrupted the global price of oil, which subsequently skyrocketed.

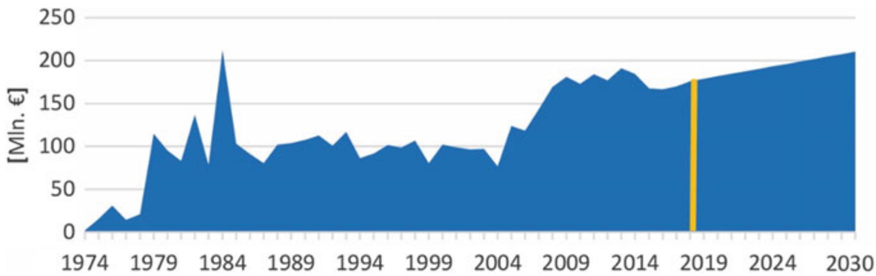

Fig. 2 Photovoltaics research and development investment of the European Union Member States plus Norway and Turkey. Period: 1974–2017 and projected funding until 2030 (million. €, BAU scenario, 2018 exchange rates and prices). The orange vertical line indicates the year from which the forecasted values are displayed—the same applies to following charts

Consequently, European countries found themselves very much exposed reliance on foreign supplies, and new and alternative ways of securing the much needed energy resources had to be procured. This marked the beginning of PV R&D funding in 1974. Not long after that, in 1979, another oil crisis took place with the advent of the Iranian revolution, mirrored by a subsequent spike in funding (as seen in Fig. 2) reaching more than 200 million € in 1984. The initial years of PV R&D funding are characterized by their high volatility, very much like oil prices. So, it is not surprising that the following period up until the early 2000s has shown greater stability, similar to the performance of oil prices. A second distinct period becomes apparent from 2005 onwards. It is characterized by a strong and sustained increment in funding, also linked to a lesser correlation and decoupling from oil prices and increasingly influenced by stricter policies to comply with climate and energy targets (Bointner 2016b).

3.2 *European Union*

Figure 3 shows the annual investments made in PV R&D at the EU level from 1987 until 2030. From 2018 to 2030, the expected BAU scenario is based on historical data. At first glance, it is discernible that the scale of investments is much lower than at the national level. The accumulated values are almost five times lower, averaging in the same timeframe around 25 million € at the EU level and 125 million € at the national level. Another clearly distinctive characteristic is the constant fluctuation of investments across the years (Baccini and Urpelainen 2012). The funding scheme of the EU is based on the implementation of FPs, which have short durations and whose objectives are rethought and reshaped at the beginning of each cycle, meaning there is a natural progression within each program's duration from less to more. This situation explains why, in the years 2003 and 2014 (each time at the beginning of a new FP), funding drops to almost 0 € and then quickly recovers. Funding is expected

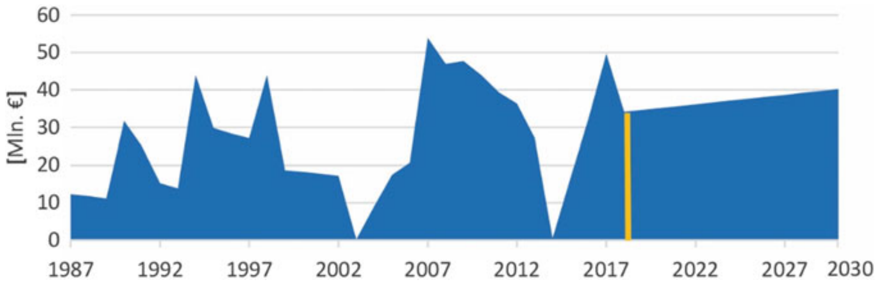

Fig. 3 Photovoltaics research and development investment of the European Union. Period: 1987 to 2017 and projected funding until 2030 (million €, BAU scenario, 2018 exchange rates and prices)

to remain constant at 2017 levels until 2030—around 35 million € a year, though it can be assumed that a funding drop will occur linked to the duration of the next program, Horizon Europe (2021–2027).

3.3 National and European Union Levels

When both values for Figs. 2 and 3 are summed up, a set of data emerges as displayed in Fig. 4.

As previously mentioned, since the national funding is almost five times larger, when adding the funding amounts coming from EU programs, there is not much divergence from what Fig. 2 displays. Moreover, less fluctuations occur from one year to the next, progressing in a smoother way. The year with the highest peak of funding is 2009 (nearly 230 million €), though a new record is expected for 2030, reaching a maximum of 260 million €.

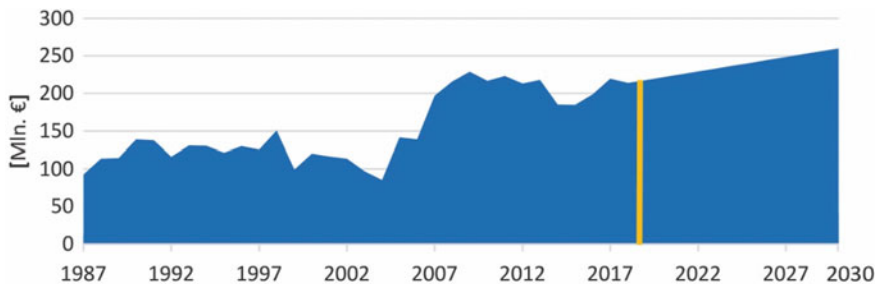

Fig. 4 Photovoltaics research and development investment of the European Union Member States plus Norway and Turkey and the European Union. Period: 1987–2017 and projected funding until 2030 (million. €, BAU scenario, 2018 exchange rates and prices)

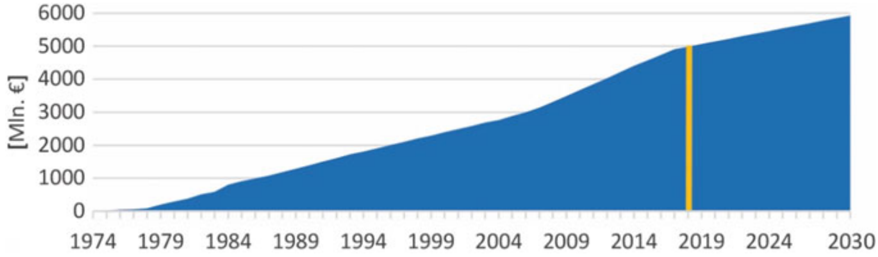

Fig. 5 Cumulative funding stock for photovoltaics originated from research and development investment of the European Union Member States plus Norway and Turkey (million €, BAU scenario, 2018 exchange rates and prices)

3.4 Cumulative Funding Stock

Results regarding the cumulative funding stock until 2013 are provided in Figs. 5, 6 and 7.

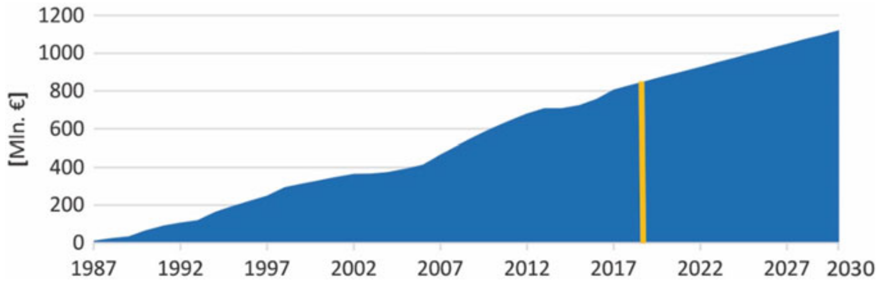

Fig. 6 Cumulative funding stock for photovoltaics originated from research and development investment of the European Union (Mln. €, BAU scenario, 2018 exchange rates and prices)

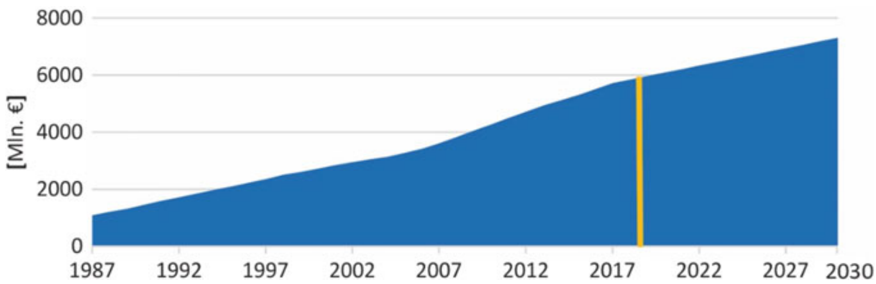

Fig. 7 Accumulated funding for photovoltaics originated from research and development investment of the European Union Member States plus Norway and Turkey and at the European Union level (million €, BAU scenario, 2018 exchange rates and prices)

Figure 5 shows data of PV R&D funding in 1987 to amount to 1 billion. €, taking into consideration historic funding at the national level starting more than a decade before. Since then, the cumulative funding stock has grown steadily at almost the same pace until 2004. Afterward, the figure shows an accelerated growth, and an all-time maximum of 4.9 billion € is achieved in 2017, paving the way to the expected mark of 5.9 billion € by 2030.

Figure 6 shows the cumulative funding stock induced by R&D expenditures at EU level until 2030.

The chart follows a different pattern than Fig. 5. Due to the highly fluctuating nature of the EU R&D funding, two distinct flatter areas can be identified at the beginning of the 1990s and during the mid-2000s, which match the periods of funding lack seen in Fig. 3. In 2017, the funding stock reached 800 million €, and by 2030, it is expected to surpass 1.1 billion €.

Finally, Fig. 7 displays the sum of monetary indications given in previous Figs. 5 and 6.

The situation is similar to the one in Fig. 4, where the resulting trend is highly influenced by the higher relevance of national investments. Also, in this case, the higher fluctuations are softened, and the trend is shaped more linearly, but still an inflection point can be noticed in 2004, just as in Fig. 5. The year 2017 totals 5.7 billion €, while the expected amount of accumulated funding is 7.3 billion € by 2030.

4 Discussion

The provided results over three to four decades indicate how PV R&D funding has been highly sensitive to world events with an impact on the energy markets, resulting in the exploration of alternative means of production. Originally forced by the energy crises in the 1970s, the EU quickly sought alternative sources to achieve energy security and found a momentarily effective solution in nuclear power (Bointner 2016b). However, as the market cooled down in subsequent years and the cold war came to an end, a lower necessity to explore substitutes to traditional energy sources emerged, as the world economy thrived thanks to cheap and abundant fossil fuels from new markets. Thus, the political will to advance on the subject dwindled down. During this period, a stagnation in PV R&D occurred, so when a policy shift started in the EU in the 1990s, the funding had to be considerably increased. Largely due to the signing of international agreements (Rio ’92, Kyoto ’97, Cancun ’10, Paris ’15), a growing number of natural disasters linked to a changing climate (Fang et al. 2019) and later on fueled by Fukushima’s 2011 nuclear disaster in Japan (Goebel et al. 2015), the notion of energy security became more renewable energy inclusive, encompassing also climate change and security concerns. Furthermore, a growing population with an appetite for energy intensive devices that provide higher living comfort (Pezzutto et al. 2019) create pressure on demand that is only partly offset with increasing efficiency levels for buildings and appliances. RES and as such PV technology partially provide a solution to these problems, particularly, as the EU agreed to comply with stricter climate and energy targets for 2030 and 2050 and their likely upward revision due to a dire necessity to keep global warming at lower values (EC 2019c).

Since the late 2000s, PV has experienced a dramatic price drop to date (Wang and Barnett 2019), but it has been largely due to economies of scale. Installed capacity grows by giant leaps each year (IRENA 2019), so PV R&D has become fundamental to enable developments that make possible fully unleashing the potential of the technology. To accomplish an efficient allocation of resources and prevent the duplication of research, the EU should take a comprehensive approach to fostering knowledge transfer and joint initiatives, as well as developing policies that make financing provided for the sector more transparent.

5 Conclusions

The results illustrate how, within the past three to four decades, PV R&D funding from the MS, Turkey and Norway is almost five times higher than that provided at the EU level. Considering the size of the EU budget and its approach to technological neutrality, this is not surprising, although it highlights the importance of improving the effectiveness by combining EU and Member State efforts. More importantly, in contrast to national funding, EU expenditures are characterized by high and repeated fluctuations. This makes it difficult to forecast annual values—especially when the ending of the funding program occurs. It also puts into question whether the investments can be considered sufficiently steady. Overall, national and EU R&D funding for PV are expected to reach an all-time maximum value of about 260 million € in 2030.

In light of growing PV R&D funding (national and at EU level) over the past 30–40 years, the expected importance of this type of RES in contributing to climate and energy objectives set for 2030 becomes evident. Sufficient public expenditures for PV will be fundamental to preserve and increase the impact of such a crucial technology. In this sense, a constant and less fluctuating funding provision for PV R&D would be of advantage, lowering the possibility of knowledge loss, as well as achieving innovation more efficiently and effectively.

Finally, it has to be highlighted that R&D is key to the generation of innovation, which in turn nourishes economic and social growth. Hence, in light of potential upcoming economic crisis, an adequate funding provision for such a relevant RES sector can be considered of high importance to the EU and its MS.

Acknowledgements The research leading to these results has received funding from the Horizon 2020 program, under Grant Agreement number 842547; Project name: Actual execution of the Implementation Plan for Photovoltaics and monitoring the Implementation Plan's delivery; Acronym: PV Impact. Moreover, we are thankful to our colleague Amy Segata (Eurac Research) for the elaboration of this study's figures.

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Urban Density and Household-Electricity Consumption: An Analysis of the Italian Residential Building Stock

Valentina Antoniucci, Adriano Bisello, and Giuliano Marella

Abstract The influence of urban density on household electricity consumption is still scarcely investigated, despite the growing attention to building energy performance and the electrification of heating systems advocated at the European level. While the positive correlation between urban sprawl developments and the increasing of marginal costs of public infrastructures, services, amenities, public, and private transports are known, there has been little research on the relationship between urban form and electricity consumption in residential building stock. The present work aims to contribute to filling the gap in the existing literature, presenting the early results of ongoing research on the role of urban form in the household electricity consumption in Italy and, consequently, the related energy costs. The building typology and, in general, the structure of urban dwellings, is crucial to forecasting the electricity requirements, taking into account single housing units and their spatial composition in multi-family homes and neighborhoods. After a brief literature review on the topic, the contribution presents empirical research on the electricity consumption at the municipal level in 140 Italian cities, analyzing the diverse consumption patterns under different conditions of urban density to verify whether there exists a significant statistical correlation between them. The analysis confirms that there is a statistically negative correlation between urban density and the log of electricity consumption, even if its incidence is very limited. Further investigation may highlight whether there exists a threshold for which this relationship would be reversed, explaining the higher electricity consumption in dense metropolitan areas.

Keywords Energy sprawl · Housing market · Electricity consumption · Household behavior · Urban density

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_9

1 Introduction

The relationship between energy consumption and urbanization is contentious. In his chapter in the Oxford Handbook of Energy and Society (2018), Peter Sadorsky states (p. 181): "[…] Urbanization leads to more economic activity and energy use. Economies of scale and energy-efficient transportation and infrastructure can reduce energy use, which makes it difficult to predict what the overall impact of urbanization is on energy intensity." The present contribution focuses on the role of urban morphology on energy consumption and electricity consumption, specifically in Italy. While the topic of energy consumption, and energy-saving mostly, is nowadays widely studied at the building level from a technological perspective, the role of the urban environment is far less analyzed. Nevertheless, it is known that the organization of infrastructures, housing, commercial dwellings, and industries has a significant consequence of global energy consumption. As Gago et al. state: "Cities occupy 2% of the earth's surface, but their inhabitants consume 75% of the world's energy resources" (Gago et al. 2013). An in-depth analysis of energy and electricity consumption may be helpful to support public policies both at the municipal and regional levels (Keirstead et al. 2012; Grilli et al. 2018; Moroni et al. 2019).

In the last decade, most of the literature focuses on the forecasting of electricity consumption (Marvuglia and Messineo 2012; Hernandez et al. 2013) and on the innovation of devices help to reduce the consumption (Verbong et al. 2013; D'Oca et al. 2014; Park et al. 2014). Nowadays, several studies approach the relevance of urbanization processes and urban structure in energy consumption, including electricity. But the empirical analysis is focused on analyzing various sectors or the overall energy intensity, mostly concentrating on Anglo-Saxon countries (Larivière and Lafrance 1999; Lenzen et al. 2004; Howard et al. 2012) and in the Far East (Holtedahl and Joutz 2004; Liu 2009; Cui et al. 2019), given the several issues on the environment caused by the continually growing population and urbanization in the latter mentioned countries. The excessive consumption of electricity has become a problem also in the West, which more and more often are experiencing blackouts and electricity shortages at the metropolitan and even the regional level (Moroni et al. 2018). As will be discussed more deeply in the next paragraphs, the relationship between electricity consumption and spatial structure concerns various features (Li et al. 2018).

On the one hand, high population density reduces the electricity consumption for transportation and infrastructures (Morikawa 2012). Still, on the other hand, the high differential between metropolitan cities around the world in electricity consumption's efficiency (Larivière and Lafrance 1999) has been demonstrated. Lastly, another gap in the current literature is the absence of empirical analysis of medium and small towns. If the higher relevance of electricity issues for metropolitan areas and megalopolis (Zhang and Lin 2012) is understandable, on the contrary, it is not possible to generalize conclusions from these kinds of studies to sprawling settlements, both in North American or in Europe. Consequently, policy suggestions may be misleading if based on results related to just one kind of urban form. The present paper provides an empirical analysis of the features affecting electricity consumption in the residential sector with a focus on the urban form. We adopt traditional variables such as population density to describe cities' morphologies (Burton 2002; Del Giudice et al. 2019b), and also recently added indicators related to the built environment already tested in Italy (Antoniucci and Marella 2016; Bisello et al. 2020). Moreover, we test our analysis with economic variables relevant to the energy consumption, according to the existing literature on the topic (Bianco et al. 2013; Giuffrida et al. 2018; Bencardino and Nesticò 2019), and we add other variables helpful in defining the consumption of residential building stock. We also decided not to include in the model any variable or proxy related to space heating (e.g., natural gas, biomass, or liquefied petroleum gas consumption).

The remainder of the paper is structured as followed: the next paragraph summarizes the electricity consumption in Italy, while Sect. 2 describes the methodology and the sample of data adopted for the statistical analysis; Sect. 3 presents the results of the multivariate regressions; and Sect. 4 discusses it. Finally, Sect. 5 provides the conclusion, policy implications, and suggestions for further research.

1.1 Electricity Consumption in Italy

Beginning in 1963, gross domestic electricity use increased until 2008, when consumption began to decrease (Torriti 2012). In recent years, electricity consumption in Italy (for all sectors) has been about 331 TWh/y (Data source: Terna a). In 2018, 57.3% of energy came from traditional sources, while 31.3% came from renewable ones. The production from renewable sources is highly diversified across regions, and it is slowly but consistently increasing.

The remaining 11.4% streams from abroad. Italy is the second country in Europe, after Germany, for imported volumes of energy with an energy-dependency rate of more than 75% (Source: Eurostat). The residential sector comprises just 21.5% of the overall electricity consumption. In comparison, the greater part is consumed by the industry sector (41.7%), followed by services (34.9%). Agriculture is less than 2% of total electricity consumption (Data: Terna 2018). In respect to 2017, only agricultural and residential use is decreasing, while other sectors present a slight increase. The per capita residential average consumption is 1.078 kWh/in (Source: Tern a, b).

Competitiveness in the Italian electricity market is highly limited by the dominant position of the former public electricity company, Ente Nazionale per l'Energia Elettrica (ENEL), which is present in all the stages of the production process. It has a dominant position also in the distribution market that was opened in 2001 to other companies. The experiences of small-scale production and distribution of electricity from renewable sources are still few and vary greatly across countries. Regions such as Trentino, South Tyrol, Emilia Romagna, and Tuscany have a tradition of local cooperatives that have contributed to the development of energy communities at the municipal and territorial levels (Moroni et al. 2018). Nevertheless, the adoption of

RES coupled with the governance model of the energy community is still related to specific experiences, not pervasive at the territorial level, nor primarily supported by National and Regional legislation. National laws promote incentives for renewable resources for several years. However, their effects are still not robust enough to support the expansion of micro-grids and substantially change household behavior (Mangialardo and Micelli 2018; Massimo et al. 2018).

2 Methodology and Sample Data

We adopt this general form of multivariate linear model according to (Rosen 1974) and already tested for similar empirical research (Larivière and Lafrance 1999):

$$(\log)Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_n X_{in} + \epsilon_i$$

where y is the dependent variable and the (log) is annual city electricity consumption per inhabitant in the residential sector. The independent variables are $\beta_0, \beta_1, \beta_2, \ldots, \beta_n$ related to two diverse groups of characteristics: the socioeconomic features and the building stocks features (see Table 1): These parameters are estimated with the method of least squares, while ϵ_i is the statistical error. The observations in the sample (n) are 140, which are all the Italian cities with more than 50,000 inhabitants. All the data refer to 2012 because, for most of the cities, this is the last year of release of the per capita electricity consumption, provided by the

Table 1 Variables

	Variables	Measure unit
Dependent variable	Per capita electricity consumption	(kWh/year)
(Log) Dependent variable	(Log) Per capita electricity consumption	(no.)
Socioeconomic features (independent variables)	Per capita income	(€/year)
	Employment rate	(%)
	GDP	(€)
Urban features (independent variables)	Population density	(inh/km^2)
	Urban density	(no.)
	Residential buildings with just one level	(no.)
	Residential buildings	(no.)
	Housing units	(no.)
	Degree days	(no./year)

Covenant of Mayors for Climate and Energy. According to the dependent variable, all the independent ones are related to this year.

The socioeconomic features represent mostly the spending capacity of households and the wealthy of the cities and territories, in general (Bianco et al. 2013; Nesticò et al. 2018; Bencardino and Nesticò 2019). Employment rates and GDPs are available only at the provincial and regional levels, while per capita income is at the urban scale (Del Giudice et al. 2019a). The data related to the first two variables are provided by the Italian National Statistics Institute (ISTAT). At the same time, per capita income is gathered from the Open Data of the Department of Finance of the Italian Ministry of Economy and Finance.

Six variables represent the urban features: Urban density, which is the focus of the empirical research, is represented by two diverse variables. The first one is the population density, which is traditionally the most-used data to express this feature (see, among others, Brueckner and Fansler 1983; Burton 2002; Galster et al. 2001; Holden and Parr 2013). The second is the urban density, designed as built density and already tested by other empirical research in Italy (Antoniucci and Marella 2016, 2017a, b). It is measured as the ratio between the number of housing units per residential building at the city level. Thus, we also tested the number of housing units and the number of residential buildings: these figures are all provided by ISTAT. They were collected during the 2011 National Census of Population and Buildings. The data is also reliable for 2012, given the small time shift and the scarce activity of the construction industry in Italy at the time (Ance 2019). Lastly, we consider the number of single-storey buildings, which helps to identify the urban-sprawl phenomenon, where the villas and semi-detached houses are more frequent than in high-density cities. These typologies mostly have one or two floors. Conventionally, the variable called degree-days represents the number of days on which the heating system is used. By law, they are calculated from the first three days when the temperature is under 12 °C to the first three days when the temperature is above this threshold.

Descriptive statistics summarized in Table 2 are coherent with the national indicators, even if some data such as employment rate and the GDP are slightly lower than the national average (56,4% and 25,700 €, according to ISTAT). The sample represents low-density cities, with 3.8 units per residential building on average, with a maximum of 14 units in the denser metropolitan areas.

3 Results of the Model

We tested for a diverse combination of variables, and the model results for the log of annual electricity consumption, with a sample of 140 observations, is described by the following empirical equation:

$$\begin{aligned}&\text{Log annual city electricity consumption per inhibitant} = 2088255\\&\quad + 0.00000487 * \text{population density}\end{aligned}$$

$$+ 0.00000723 * \text{per capita income} - 0.00003977$$
$$* \text{degree days} + 0.00171222 * \text{employment rate}$$
$$- 0.00565515 * \text{urban density} + 0.000005328$$
$$* \text{single} - \text{storey buildings}$$

Table 3 presents the regression analysis of the model, and it explains the 29.46% of the residential urban electricity consumption. This percentage is not particularly high, but it is anyway satisfactory considering the number of factors involved.

To increase the adaptability of the model, we reduced the sample to the provincial capitals, and we reduced the number of variables. The best model presents an R^2 adjusted of 37.7%, as summarized in the following Table 4, which is also coherent with similar statistical analysis on the topic (Lasarte Navamuel et al. 2018).

Table 2 Descriptive statistics of tested variables

Variables	Mean	St. dev.	Minimum	Maximum
Per capita electricity consumption (kWh/year)	1,130	143	841	1,604
(Log) Per capita electricity consumption (no.)	3.05	0.05	2.92	3.20
Degree days (no./year)	1,796	641	707.00	3,043
Per capita income (€/year)	20,453	3,250	11,094	30,798
Employment rate (%)	55.26	10.55	36.6	69.00
GDP (€)	24,500	6,390	16,369	37,316
Population density (inhab/km^2)	1,355	1,678	787	10,508
Urban density (housing units/residential building) (no.)	3.80	2.10	0.97	14.06
Single-storey buildings (no.)	2,105	3,054	25	18,009
Residential buildings (no.)	13,786	13,894	2,869	137,021
Housing units (no.)	58,643	11,7422	8,351	1,137,391

Table 3 Multivariate regression results with a sample of 140 observations

Variables	Coeff.	*T* Statistic
Constant	2.88255	103.58
Degree-days (no./year)	−0.0000398	−3.84
Per capita income (€/year)	0.0000072	3.91
Employment rate (%)	0.0017122	2.67
Population density (inhab/km^2)	0.0000049	1.76
Urban density (no.)	−0.0056552	−2.43
Single-storey buildings (no.)	0.0000053	3.70
N. observation		140
R^2 adj.		29.46%

Table 4 Multivariate regression results with a sample of 111 observations (provincial capitals)

Variables	Coeff.	*T* Statistic
Constant	2.89325	92.11
Degree-days (no./year)	−0.000067	−3.35
Per capita income (€/year)	0.0000078	2.09
GDP (€)	0.0000041	3.80
Urban density (no.)	−0.0067500	−3.35
Single-storey buildings (no.)	−0.0000049	3.17
N. observation		111
R^2 adj.		37.7%

Two variables have been changed, but the meaning of the results is confirmed by the previous model. Moreover, the incidence of urban density slightly increased. The scale of coefficients depends on the form of the dependent variable as a natural logarithm.

4 The Relevance of Urban Density

The model confirms the correlation between the urban density, meaning urban built environment, and the residential electricity consumption: the higher is the urban density, the lower is the electricity consumption (0.067%). The relevance of the number of buildings with just one level, moreover with the same sign of urban density, increases the robustness of the correlation described. As already demonstrated in the literature (see, among others, Chen et al. 2018; Wang and Yang 2019), per capita income and GDP have a positive correlation with the energy consumption. The wealthier is a city, the higher are the consumption of energy and electricity specifically.

We tested further the model's specifications, sub-dividing the original sample on the average urban density (3.8 residential units per residential building), but the statistical elaborations did not provide satisfying results. Examining the low-density cluster, urban density should not be relevant to explain electricity consumption (Sadorsky 2018).

These results are not incoherent with considerations related to the so-called "urban heat island" phenomenon. Since the pioneering studies of Oke (1982, 1973), it is well-known that a high density of population increases the overall energy consumption because urban structures "consume and re-radiate solar radiations" (Rizwan et al. 2008). The temperature increase in metropolitan areas is the result of several conditions and their interlinkages such as environmental features (climate and weather, topography, etc.), human activities (public and private transports, industries, etc.), and physical and morphological features (spatial distribution and density of the buildings, the materials of surfaces, the presence of green areas, etc.). The present analysis does not intend to dispute the higher electricity consumption in metropolitan areas and megalopolises compared to less dense urban settlements. Our results fit with the Italian urban morphology that, as the previous descriptive statistics demonstrate, are characterized by a dense constellation of small towns. Thus the overall urban density is anyway less than big metropolitan areas, even in other European countries. It is worth mentioning, for instance, that Rome is the most extensive city in Europe, so given its three million inhabitants, it is a low-density city considering other capitals such as London, Paris, or Berlin. No Italian cities have the morphology, population, and building density of the European metropolitan areas but if we will conduct the same analysis not at the municipal level but at territorial level, we would probably find that the whole Po Plain territory gather together all the features of an "urban heat island".

5 Conclusion

The present contribution presents the early results of ongoing research on the incidence of urban form in electricity consumption. The electricity savings are more and more important for the overall reduction of energy consumption and meeting the current climate and energy targets. The topic is mostly analyzed from a technological perspective in a twofold way: looking at the end-user side, the focus is on the improvement of building performance (Canesi and Marella 2017) and the increase of innovative devices to save energy. Moreover, on the supply side, the research is concentrated on the production and distribution of electricity at buildings and neighborhood scale (Moroni et al. 2016).

The relevance of urban form is scarcely analyzed even if the relationship between the costs of infrastructures and public services and the urban density is long since demonstrated (see, among others, Brueckner and Fansler 1983; Liddle and Lung 2014). To investigate this, we perform several multivariate regressions on a sample of 140 Italian cities with more than 50,000 inhabitants; then, we reduce the sample to the provincial capitals (111 cities) to refine the results. To measure urban density, we adopted the traditional indicator of population density (inhabitants per square kilometer) and an original indicator of building density (number of housing units per residential buildings). Moreover, we control for socioeconomic variables and other building stock features helpful to describe the urban structure of Italian cities.

Our tests demonstrate that the lower is the density, the higher is the electricity consumption. The early results here provided may help to design better public policies. This result is consistent with the existing literature on the topic, investigating similar urban contests in Southern Europe (Lasarte Navamuel et al. 2018) on one side but contradicts the literature on the so-called "urban heat islands", in which the denser is the urban structure, the higher are the temperature and electricity consumption. This is contradictory only apparently, and it should be explained by looking at the urban structure of Italian cities. Italy has across its territory a high density of small and medium cities, that anyway does not reach the density of metropolitan agglomeration of other European countries and much less than American cities. From this perspective, there is room for further research. Additional analysis may be performed comparing cities, at the European level at least, by density. We subdivided our sample by the average density, defining two clusters below and above the average building density. Still, the analysis does not provide significant results, given the low average density of Italian cities. This kind of investigation, on the contrary, may let to identify a threshold of density for the electricity consumption in denser contexts. Above this threshold, the meaning of the urban density would be reversed, explaining the "urban heat islands". Moreover, to reach more robust results, additional explanatory variables should be found—we suggest avoiding those potentially highly correlated with electricity consumption, as the use of gas or oil. Also, the spatial specification of the model may help detect hidden variables or heteroscedasticity (Anselin 2001). In Italy, it will be of particular interest to better understand the future development of the electricity consumption in the residential sector after the forthcoming national law, which will make possible for the first time small scale energy sharing among prosumers.

The goal of energy savings should also be reached considering the development of new urban dwellings and the re-development of brownfields. It is a critical issue in countries such as Italy, whose territory is already mostly built and characterized by an old and low performing building stock (Mangialardo and Micelli 2019; Bisello et al. 2020). Densification contributes to reducing the collective costs of infrastructures, public services, and as we demonstrated at least partially, it also may reduce electricity consumption, up to a certain threshold value. Even if in comparison to heating and cooling needs, electricity consumption is less affected by the features of building stock (such as age and maintenance status) the form and structure of urban settlements may be highly relevant.

Acknowledgements We thank Andrea Lorenzin for the collaboration in the elaboration of data.

The present contribution is partially funding by the Department of Civil, Architectural and Environmental Engineering of the University of Padova, Italy, contract of research fellowship rep. no. 205/2019, prot. 2982, date 2019 Nov 14th.

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Circular Economy in Poland: Main Achievements and Future Prospects

Anna Avdiushchenko

Abstract Circular economy (CE) is a new development strategy adopted by the European Union (EU) authorities in 2014, aiming to boost global competitiveness, foster sustainable economic growth, and generate new jobs. The CE approach maintains the added value in products for as long as possible and eliminates waste; moreover, it implies totally systemic change and innovation not only in technologies, but also in organization, society, finance methods, and policies. Such an approach leads to a new model of production and consumption and a new relationship between stakeholders at the local, regional, national, and EU levels. The first consideration of CE priorities in Poland started in 2016 when the Inter-ministerial Committee for Circular Economy was established. Representatives from nine ministries became committee members, and the chief document they prepared was the Roadmap for Circular Economy Transition. The document proposed an action plan for CE implementation and focused on increasing resource efficiency and waste reduction in Poland. Prepared with the active involvement of all possible stakeholders—businesses, NGOs, the academic and research community, and local and regional authorities—the Roadmap can be seen as a quick and effective guide. In addition to national government initiatives, there were numerous attempts to implement CE principles at the local and regional levels. The main goal of the current research was to examine the effectiveness of such national, regional, local, and business CE projects for influencing Poland's CE transition during the past three years. This study reviews the main policy documents, reports, and expertise of national, international, regional, and local organizations and NGOs involved with CE in Poland. The research is also supported by a review of the relevant academic literature. As a result, it was possible to estimate the current level of achievement, as well as future prospects for CE in Poland. Moreover, this research identifies potential opportunities for updating existing planning policies and tools related to CE-based development in Poland.

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*,
Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_10

Keywords Circular economy · Roadmap · Local and regional initiatives · Transition process

1 Introduction

According to the European Commission, the circular economy (CE) is an economic model based *inter alia* on sharing, leasing, reusing, repairing, refurbishing, and recycling in an (almost) closed loop that aims at retaining the highest utility and value of products, components, and materials over time (Commission of European Communities, Communication No. 398, 2014). In the last few years, numerous researchers have endeavored to define and apply the main concepts of the CE approach in business and public administration strategies for sustainable development. However, the CE model often has differing meanings among the various stakeholders involved in this transition. That is why the CE approach has recently become a popular topic of academic discussion from the perspective of engineering, natural, and social sciences (Schulz et al. 2019). Moreover, CE has gained popularity as a core idea for development strategies at the national, regional, and municipal government levels (Alaerts et al. 2019).

There are numerous examples of national CE strategies, roadmaps, and action plans in EU countries, including a circular economy in the Netherlands by 2050 [10]; Finland's National Circular Economy Roadmap (Sitra 2016); ProgRess II—German Resource Efficiency Programme (Federal Ministry for the Environment, Nature Conservation, Building, and Nuclear Safety 2016); leading the transition: a circular economy action plan for Portugal (Ministry of Environment 2017); Towards a Model of Circular Economy for Italy—Overview and Strategic Framework (Ministry for the Environment, Land and Sea Ministry of Economic Development 2017); France Unveils Circular Economy Roadmap (The French Ministry of Ecological and Solidarity Transition 2018); Roadmap towards the Circular Economy in Slovenia (Circular Change and other consortia of partners 2018).

At the same time, a few initiatives were introduced at the regional and local levels, such as Promoting Green and Circular Economy in Catalonia: Strategy of the Government of Catalonia (Government of Catalonia 2015); Brussels Region—*Programme Régional en Economie Circulaire* (2016); Scotland—Making Things Last: A Circular Economy Strategy for Scotland (The Scottish Government 2016); Circular Amsterdam (City government of Amsterdam 2016); White Paper on the Circular Economy of Greater Paris (City government of Paris 2016); Extremadura 2030: Strategy for a Green and Circular Economy (Regional government of Extremadura 2017); London's Circular Economy Route Map (London Waste and Recycling Board 2017); and the Circular Flanders kick-off statement (Vlaanderen Circulair 2017).

The first steps toward CE implementation in Poland were made at the end of 2015. During the public consultation titled Closing the Loop—An EU Action Plan for the Circular Economy with EU Member States, Poland presented its main national priorities for CE transition as follows:

- innovation, strengthening cooperation between industry and the scientific community, and effective implementation of innovative solutions in the economy
- the creation of a European market for secondary raw materials and facilitating their flows
- ensuring the high quality of secondary raw materials through sustainable production and consumption
- development of the services sector.

From 2016–2019, the Polish CE approach was developed and supported by numerous activities of governmental and non-governmental organizations, businesses, and research and educational institutions. The main goal of the current research was to determine the effectiveness of such CE initiatives in Poland at achieving CE model transition during the past three years. The findings of this research also made it possible to estimate the future prospects for CE in Poland.

2 Concept and Method of Research

This research examined the main policy documents, reports, and expertise of national, international, regional, and local organizations (including governmental, non-governmental, and business) addressing CE in Poland. The research was also supported by a review of the academic literature on the subject. In the final stage of the analysis, the main achievements and future directions for research were identified. The concept for the current research is presented in Fig. 1.

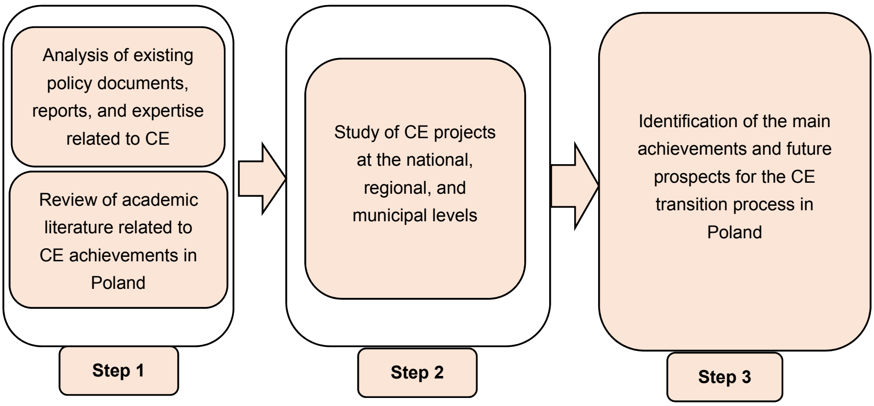

Fig. 1 Concept for investigation of CE in Poland from 2016–2019

3 CE Development in Poland

The first work on CE Roadmap priorities in Poland started at the beginning of 2016. The Inter-ministerial Committee for Circular Economy was established in June 2016. Representatives from nine ministries became committee members, drawn from the Ministry of Entrepreneurship and Technology; Ministry of Environment; Ministry of National Education; Ministry of Energy; Ministry of Infrastructure and Construction; Ministry of Science and Higher Education; Ministry of Family, Labour, and Social Policy; Ministry of Agriculture and Rural Development; and Ministry of Health (Order No. 33 of the Minister of Development 2016). The Ministry of Entrepreneurship and Technology was the main state body responsible for the organizational issues and effectiveness of the inter-ministerial committee's work.

The composition of the committee shows the strategic importance and interdisciplinary nature of the circular economy concept in Poland. The Committee worked to define the strengths, weaknesses, opportunities, and threats of transition toward a CE model in Poland, expressing opinions regarding European Union initiatives for transition to CE, developing an action plan for the implementation of a circular economy in Poland specifying, in particular, the objectives and priorities of the actions along with their time horizons and the institutions responsible for their implementation, and lastly monitoring of CE action-plan implementation. The main document prepared by the committee was the Roadmap for Circular Economy Transition, the first draft of which was presented in December 2016. Its main goal was the preparation of an action plan for increasing resource efficiency and waste reduction in Poland. Four main avenues were proposed as follows: (I) Sustainable industrial production; (II) Sustainable consumption; (III) Bioeconomy; and (IV) New business models.

Further work on finalization of the Roadmap for Circular Economy Transition was prepared with the active involvement of all possible stakeholders (Fig. 2).

The CE concept has a broadly interdisciplinary character and covers not only changes in technological processes but also implementation of the extended responsibility of producers in the whole value chain. This demands a paradigm shift in consumption, establishing new patterns of production and consumption to create in Poland a CE society. That is why the business sector, NGOs, the academic and research community, and local and regional authorities were invited to work together on developing the roadmap for fast and effective transition to CE.

Four thematic working groups were created, taking into account key priority areas proposed in the Draft Roadmap—waste, bioeconomy, business models, and promotional and educational activities. As a result of intensive interdisciplinary and intersectoral work, the final version of the roadmap was presented at the end of 2018 and adopted in September 2019 (Roadmap 2019). More than 200 partner organizations participated in its preparation.

The roadmap includes a set of legislative, analytical, conceptual, informational, and promotional coordination tools for the main avenues identified. Moreover, as a result of the committee's work, the process of implementation, monitoring, and funding for CE actions was added to the CE Roadmap.

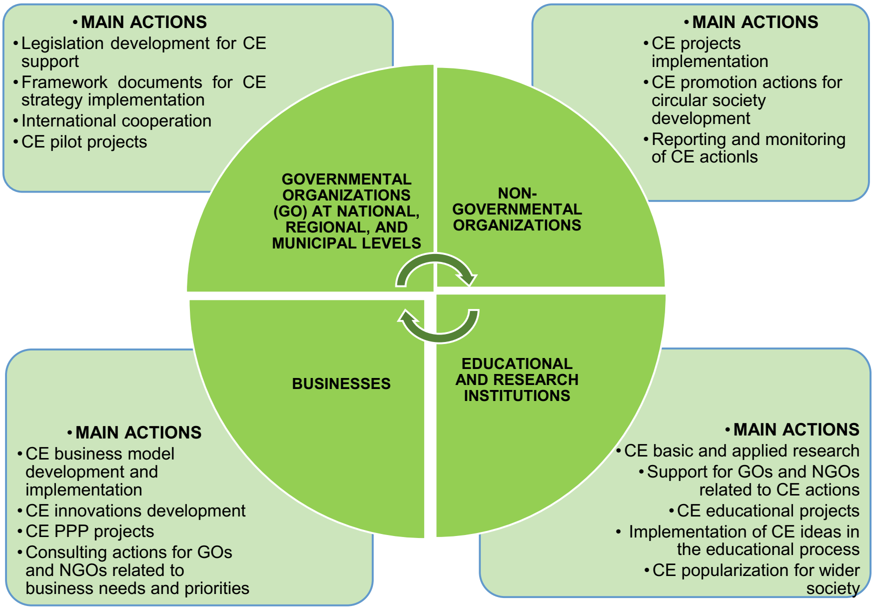

Fig. 2 Main stakeholders of CE transition process in Poland

The Roadmap for Circular Economy Transition is also one of the elements of successful realization of the Poland Strategy for Responsible Development for 2020 (with the perspective to 2030), where the Strategy of Transformation to Circular Economy was mentioned as one of the strategic projects (Poland Strategy for Responsible Development for 2020, 2019) (Fig. 3).

Another Polish national-level document that has already accounted for the recommendations and assumptions of “Towards a circular economy: A zero waste programme for Europe” (Commission of European Communities, Communication No. 398, 2014) and Closing the Loop—An EU Action Plan for the Circular Economy (Commission of European Communities, Communication No. 614, 2015) is the updated National Plan of Waste Management 2022 adopted by the Council of Ministers of Poland in July 2016 (Resolution No. 88 of the Council of Ministers 2016). The document set new waste management targets to be met and the possible means by which this could be achieved, taking into account a nationwide CE-supportive environment.

One of the most fundamental reports examining the Polish path to CE was prepared as part of a research project conducted at the Institute of CE in Poland (Bachorz 2017). The research was focused on raw materials policy, design, production and distribution, consumption, recycling, and residual waste, and on the economic and social system and its readiness for CE transformation. The authors of the report made detailed analyses of the most important aspects for CE, supported by individual, in-depth interviews with representatives of the academia and industrial R&D. That

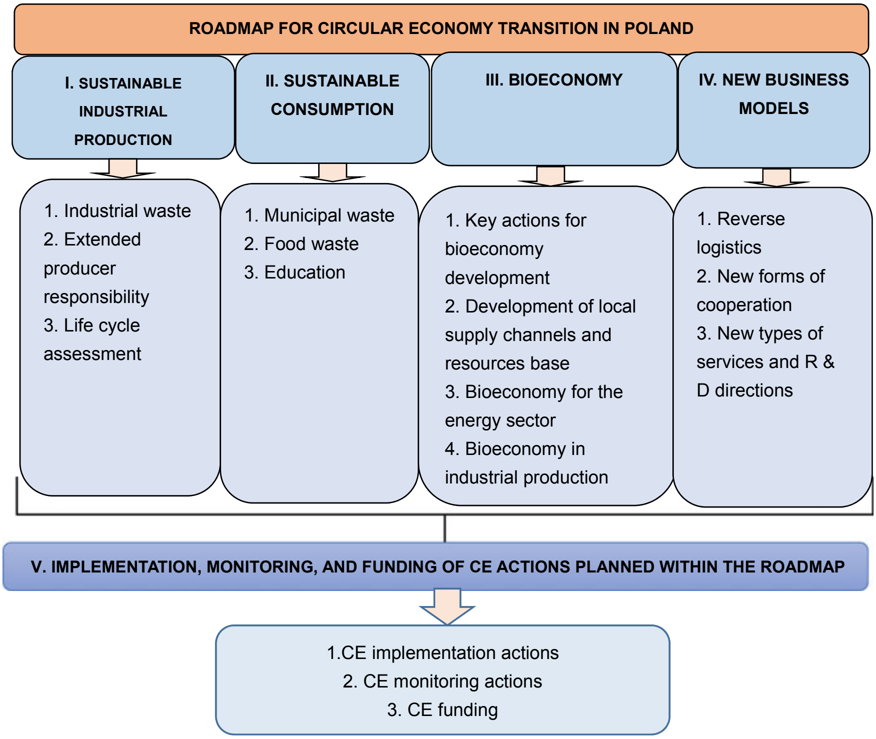

Fig. 3 Poland's roadmap for circular economy transition

analysis led to recommendations for the development of a CE action plan. Some of the recommendations were even used in the development of the CE Roadmap for Poland.

One additional report was focused on CE in Poland, prepared by the Deloitte company with the cooperation and support of the Ministry of Entrepreneurship and Technology, Ministry of Environment, and Ministry of Investment and Economic Development. The report presented possible ways of boosting CE development from a business and consumer perspective, as well as possible supporting actions on the side of the public administration (Deloitte 2018).

Recently, CE issues in Poland have become a mainstream topic of research (Baran et al. 2016; Smol et al. 2018; Woźniak and Pactwa 2018; Woźniak and Twardowski 2018; Seroka-Stolka and Ociepa-Kubicka 2019). The results obtained are helpful for understanding Polish realities and opportunities for successful CE transformation. Moreover, such research has identified numerous challenges associated with the transformation process.

4 CE-Related Projects

In addition to CE-related documents and initiatives at the conceptual level, there are numerous practical projects and initiatives led by local and regional authorities, the business sector, research and educational institutions, NGOs, and intersectoral coalitions working on effective implementation of CE ideas. Only a reasonable combination of conceptual and practical CE approaches can yield tangible results for the Polish economy and social transformation. The following section of the research will present examples of CE-related projects in Poland in 2016–2019.

4.1 Pilot CE Project in Polish Municipalities

One more national level initiative related to CE transition is a planned CE pilot project for five rural and urban-rural municipalities in Poland, though only three of them ultimately confirmed participation: Łukowica (Kraków Province), Tuczno (Szczecin Province), and Wieluń (Łódź Province).

The main purpose of the project was to develop good practices for circular-economy implementation at the local level, with special focus on non-urbanized areas. This pilot project is coordinated by the Ministry of Environment and financed by the National Fund of Environmental Protection and Water Management.

Municipalities, as well as business owners and individuals operating within a given municipality, could apply for as much as 45 million złoty in non-refundable grants or preferential loans to be used for investment projects involving the following (Appendix 1 to Resolution of the Management Board of National Fund of Environment Protection and Water Management, May 2017; Deloitte 2018):

1. systems for separate collection and prevention of municipal waste
2. local waste-recycling facilities
3. development of infrastructure supporting waste prevention
4. environmentally friendly transport, with a focus on public transport
5. energy efficiency (with respect to heat or electricity)
6. circular economy in households
7. circular economy in agriculture or agricultural product processing
8. saving water as a resource in households, municipalities, and businesses
9. resource-efficient economy in local business, with a focus on:
    - reducing per-unit consumption of primary raw materials, including water, in manufacturing processes
    - reducing per-unit waste generation in manufacturing processes
10. rational management of land by reversal of anthropogenic land degradation or finding new uses for land degraded by human activities.

Among the participating municipalities, Wieluń stands out for its innovative approach and variety of initiatives. The ambitious plan committed to by the municipality includes the following (Concept of Implementation CE in Wieluń 2017; Deloitte 2018):

- construction of underground containers for separate collection of municipal waste in places where conventional containers cannot be placed
- setting up several dozen (about 30) reverse vending machines for separate collection of PET plastic bottles and aluminium cans, in exchange for which residents may receive discount vouchers for services provided by the municipality, including discounts on water and sewerage charges, cinema or swimming pool tickets, or a pass for free use of paid parking zones
- construction of solar panel shelters over public car parks and covering the roofs of buildings owned by the municipality (schools, gym facilities, community centres, etc.) with photovoltaic panels
- construction of a geothermal heat and power plant, a biomass thermal power plant, and a biogas plant
- replacement of public transport buses with a fleet powered by biogas or electricity from renewable generation in the municipality.

The program is expected to bring benefits at multiple levels—from environmental to economic and societal. The municipalities are to deliver on their commitments by 2020. After 2020, the deliverables will be evaluated in order to select model projects that could be replicated by other municipalities, and the program launched on the total, nationwide scale (Deloitte 2018; Appendix 1 to Resolution of the Management Board of NFWP and WM 2018). In 2019, the National Fund for Environmental Protection and Water Management already announced a new call for proposals for CE implementation in municipalities, taking into account the experience obtained within the cited CE pilot project.

4.2 Polish Circular Hotspot

Polish Circular Hotspot is a public cooperation platform based on networking among partners from various sectors for the purpose of introducing innovative, comprehensive, practical, and scalable solutions in all sectors of the economy. It is not the only circular economy networking platform in Europe. Similar initiatives in the Netherlands, Slovenia, Scotland, and Norway have already been successful for years.

The partners of the Polish Circular Hotspot are represented by local and national governments, universities, and scientists from a wide range of disciplines. They cooperate with various industries, including construction, food, packaging, electronics, plastics, logistics, transport, energy, and textiles.

The main activities of the partnership include work on:

- strategies and roadmaps
- database of innovations and programs
- new business support models giving local authorities and businesses access to circular economy innovations, databases, and CE programs used in Poland and abroad
- business networking (study visits and B2B matchmaking sessions with the support of the Dutch, Swedish, German, French, and Danish embassies)
- workshops about circular economy and circular procurement for public institutions
- circular cities—support for cities to implement circular economics by identifying problems and helping to create solutions/projects for CE changes in their city
- educational activities—workshops and trainings for anyone interested in the circular economy concept.

One more initiative led by the Polish Circular Hotspot is Polish Circular Economy Week. It is a nationwide social campaign to create awareness and encourage the Polish people to change consumption habits and to make them conscious of the use of resources (Polish Circular Hotspot 2019).

4.3 Circular Cities Program

The Circular Cities Program is an initiative implemented jointly by the Polish Circular Hotspot and Metabolic Group with co-financing by the MAVA Foundation. As part of the Circular Cities project, Polish cities are invited to join the national circular cities program, starting with developing practical zero-waste strategies.

The purpose of this program is to help prepare an analysis of the current waste flow in a city and to build a transformation strategy towards circular economy. Through the program, cities build sustainable strategies that change waste policy—reducing waste, but also utilizing upcycling and reuse of raw materials. These jointly developed circular strategies work not only to eliminate negative impacts on the environment but also to achieve financial profits and generate new business opportunities, as well as new professional and training prospects. Throughout the process, the participating cities will have the opportunity to exchange experiences with both national and international partners thanks to cooperation within the network of Polish cities and cities gathered in the Circular cities network (covering Europe and North America).

Joining the Metabolic network creates the opportunity for Polish cities to conduct in-depth analysis of value chains, sectors of the economy, and the flow of raw materials for circularity features. Usually, such analyses are implemented in four stages:

- analysis of the socioeconomic and political situation
- researching the flow of raw materials in the city

- analysis of the impact of innovation on development and the functioning of the city
- strategy preparation (action plan).

As a result of such analysis, a CE roadmap can be created that identifies the possibilities of implementing circular economy solutions in a particular city, and ultimately facilitates the creation of practical and scalable solutions.

To date, reviews of 15 cities including Amsterdam, Rotterdam, Glasgow, and Barcelona have been carried out. This process proved extremely helpful in bringing about effective implementation of circular solutions for these cities and their surrounding regions (Polish Circular Hotspot: Cities and Regions 2019).

4.4 Reconomy Coalition

"Reconomy"—the Coalition for Circular Economy—is an association of companies and institutions involved in the promotion of the concept of a sustainable economy and implementation of the principles of circular economy at every stage of business operations.

As part of its activity, the Reconomy Coalition inspires businesses to undertake innovative actions that bring Poland closer to the circular-economy model. The coalition's activities included, among other things, preparing publications and expert studies on the circular economy, disseminating information demonstrating the profitability of GOZ best practices and business models, creating a Polish knowledge base on circular economy, and co-organizing the Polish Circular Economy Week.

The Coalition's activities contribute to increasing environmental awareness and raising the level of managerial education, as well as providing readymade solutions to build a competitive circular economy in Poland. Enterprises joining the project gain expert support and the opportunity to develop business plans in accordance with the objective of the rational use of resources (Reconomy Coalition 2018).

5 CE Future Prospects in Poland

Future prospects for CE development in Poland are dependent on the main achievements related to CE model implementation. Given that, during last three years, there was much activity supporting the CE transition process, the foundation has been laid for the future development of the CE model in Poland—for scaling up the obtained experience, replicating good practices, and continuing to create favorable conditions for future changes. Such progress could be focused on:

- identification of the exact directions for effective implementation of CE Roadmap activities
- more involvement of a wider part of society in CE implementation

- increasing the level of public and business awareness regarding the advantages of CE solutions
- setting up dedicated stimulation tools for boosting CE at all possible levels of implementation
- increasing the level of international cooperation on CE projects
- increasing funding for CE basic research and applied research projects
- broader inclusion of CE in formal and non-formal educational programmes and projects
- developing the potential of CE priority sectors in Poland—bioeconomy, transport, and construction
- further incentivizing CE aspects in the Polish energy sector in order to increase energy efficiency.

6 Conclusions

This study has examined the recent achievements, trends, and future prospects of the Polish CE model of development. Its findings are intended to help CE stakeholders to realize the full potential of CE to improve competitiveness and to make use of all relevant opportunities for smart and sustainable growth at the national, regional, local, micro, and individual levels.

The research shows that significant CE support activities have been carried out during the past three years, but this is not enough to take advantage of the full potential of the CE model. That is why this research was also focused on identification of future prospects for this new model of economic and social development. One of the key aspects for successful integration of CE ideas in all areas important for sustainable development is the greater involvement of a wider part of society—increasing the level of public and business awareness.

One of the main tasks for authorities is therefore popularization of, and increasing support for, CE through financial and non-financial instruments. Public cooperation platforms have also demonstrated their effectiveness in developing CE stakeholder networking. The main criteria of effectiveness, in this case, included the number of projects, networking development, thematic areas covered by the project, involvement of representatives from the various stakeholders group, the level of project internationalization, and public-private partnership development.

Special attention should be paid to CE priority sectors identified in the Polish economy to increase material and energy efficiency and to develop secondary raw-materials markets. Lastly, wider CE implementation could be achieved by scaling up pilot projects in Polish municipalities to the level of other municipalities and the largest cities with the Circular Cities Program.

Acknowledgements This project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement no. 665778. The project has also received funding from the National Science Centre, Poland, POLONEZ funding program (project registration number 2015/19/P/HS4/02098).

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A Possible Circular Approach for Social Perception of Climate Adaptation Action Planning in Metropolitan Cities

Alessandro Scuderi, Luisa Sturiale, Giuseppe Timpanaro, Giovanni La Via, and Biagio Pecorino

Abstract One of the factors that will affect the livability of cities and the overall citizens' quality of life in the future is certainly climate change. Urban areas will play a fundamental role in the commitment against climate change and will have to develop appropriate adaptation actions, in accordance with the European Strategy against climate change, including the planning and implementation of Green Infrastructures (GIs). They produce various environmental and social benefits in the urban context. Various studies have shown that citizenship involvement at all levels is necessary for the evaluation of the sharing of the proposed projects. The research proposes an innovative methodological model to support administrations in the strategic planning choice of GIs according to a shared and circular approach. To perform a multi-layer assessment, the multi-criteria evaluation will be combined with the circular evaluation model called Green City Circle. The evaluation is set up as a circular process, followed by a first investigative phase, followed by a proactive phase of solutions and an implementation phase up to a final stage of evaluation of the results and strategies for long-term sustainability. The study was carried out in the city of Catania to test a planning and management tool for GIs envisaged by the administration as win–win climate adaptation measures.

Keywords Green infrastructure · Social perceptions · Green public management · Participatory decision support systems · Green city circle

1 Introduction

Climate change is both a threat and a new challenge for twenty-first-century cities, projected into a scenario of uncertainty, with repercussions from the complex environmental system perspective (Haaland and van Den Bosch 2015; Hunt and Watkiss

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_11

2011). In this arena, the management of city areas could contribute both in terms of developing proposals to reduce emissions and in terms of integrating adaptation actions aimed at specific territorial contexts (Gill et al. 2007; Matthews et al. 2015). It is now widely acknowledged by the international scientific community that the cyclical natural changes in environmental systems that have always been happening have been superimposed by the decisive and invasive contribution of human activity (Evans and Schiller 1996; Werguin et al. 2005). Human activities have impacted both in terms of an increase in emissions and of a lack of, and, above all ineffective, territorial planning (Alpert et al. 2017; Wei et al. 2018). Over recent years, there has been an increase in temperature, with an upheaval of the rainfall regime and a rise in sea level, as well as an increase in the frequency and intensity of extreme weather events that multiply numerous risks at the local level, for the territories and cities (Bulkeley 2010; Moughtin et al. 2009; Tzoulas et al. 2007).

In this scenario of possible changes, there are urban systems in which the negative effects of the climate are more impactful on the prevalence of the human influence over the natural one (Oke 2006). The identification of the risks to which the inhabitants are exposed, the assessment of the urban vulnerability as a whole and the formulation of strategies to counteract the problem of local impacts of external events represent an important test for planning oriented to the growing consideration of climate change (Gómez-Baggethun and Barton 2013).

Cities play a central role as motors of the global economy, and they could be uniquely positioned to drive a global transition from a linear economy (based on the linear 'take-make-dispose' model) towards a circular economy (Ellen MacArthur Foundation 2017; Lindner et al. 2017). Local governments have a large and direct influence on urban planning (from mobility to grey and green infrastructure planning, labor policy, business, and social and inclusion policies). Therefore, local governments can play an important and active role by developing the principles of the circular economy across a coordinated set of policies and instruments (C40 2017; Petit-Boix and Leipold 2018; UNEP 2017).

Italian institutions have shown interest in the new orientation, as evidenced by the broad adherence to the Covenant of Mayors and the definition of the recent National Strategy for Adaptation to Climate Change (SNAC) and the consequent adoption of the Adaptation Plans (De Gregorio Hurtado et al. 2015; Spanò et al. 2017; Sturiale and Scuderi 2018).

By placing climate change and the related policies to counteract it at the center of urban policies, a scenario opens up that must question the disciplines of territorial governance with respect to its role, the way in which the city is designed and managed, and its ability to adapt to the changing climate scenario. In this context, cities will be called upon to use innovative urban planning tools capable of responding to the uncertainty imposed by climate change. Nevertheless, the involvement of stakeholders and citizens will be necessary to verify, on the one hand, the degree of perception of climate change issues and, on the other hand, to undertake participatory planning of adaptation measures to be taken.

As several studies have shown, it is now necessary to test innovative tools that can support local governments in the process of acquiring in-depth knowledge of the territory, from economic, environmental, and social points of view, according to a vision of a sustainable, resilient, inclusive and circular city. In particular, among many aspects, the following (Caspersen and Olafsson 2010; Langemeyerab et al. 2016) deserves in-depth analysis (Demuzerea et al. 2014; Kabisch 2015):

- sociality, including inclusion, multiculturalism, the presence of cultural-creative districts and innovative services;
- resilience and adaptation to climate change, i.e., the energy and environmental performance of the city and climate adaptation strategies;
- technological innovation, which, on the one hand, provides tools to achieve energy and resource savings and, on the other hand, enables reaching more citizens and ensuring better, customizable, and more attentive services to individual needs.

These are the main questions to which the public administrations should try to respond in the immediate future, using innovative and participatory methodologies. In this work, a methodological approach is proposed aimed at implementing bottom-up planning considering the needs of the environment and the local community, as well as economic activities.

2 The Role of Nature-Based Solutions in Urban Planning

The climate protection planning in Europe is absolutely heterogeneous (COM 2013). Each country has developed national mitigation plans and strategies and local initiatives in terms of climate plans and local authority instruments (DG 2013).

The different urban contexts are subject to very different consequences, resulting from the various combinations of the structure of the territory, resulting from climate change with specific dimensional, localizing, social and productive characteristics (European Commission 2016). For the definition of exposure, the downscaling of climate forecasts and analyses is of central importance. The current climate models operate mostly on a large scale, offering several indications but, for planning on a local scale, it is fundamental to use specific indicators for the understanding of local impacts and vulnerabilities and supporting tools for formulating strategies (Hunt and Watkiss 2011; Sturiale and Scuderi 2019).

The scientific scenario and international relations (IPCC—Intergovernmental Panel on Climate Change; EEA—European Environmental Agency; European Union (EU) White Paper) (EU 2009) consider spatial planning as a basic paradigm to address both the causes and consequences of climate change: the translation of these issues into policies and processes of ordinary land management is not done explicitly.

The implementation of policies and action plans varies according to the national context and the mode of urban governance, and there is a growing amount of experience, programs, and projects that directly link local realities to the European Community, creating new networks (Covenant of Mayors, GRaBS) or relying on associative relationships already established in Italy and internationally (Italian National Coordination Local Agenda 21, ICLEI—International Council for Local

Environmental Initiatives, C40 CITIES, the Clinton Foundation, the Rockefeller Foundation's Resilient Cities program, etc.).

Local, regional, and national authorities have defined, in many cases on an experimental basis, a series of plans aimed at climate protection, which, depending on the level or type, have assumed different names, not to mention that different names do not always correspond to substantial differences in content if not different levels of attention to mitigation and adaptation. Climate strategy plans, national mitigation, climate action/protection plans, and climate mitigation plans are names of some of the tools and strategies built on the European and international scene, with the aim of introducing climate protection into spatial planning, both on a large and local scale (Benedict and McMahon 2002; Depietri and McPhearson 2017).

The latest report of the European Environmental Agency (2016) defined the main impacts that climate change has on urban centers:

- worsening of extreme climate-related events, both in frequency and in intensity, with consequent economic impacts;
- increased climate-related health problems;
- increased rainfall, storms, and sea levels in the coastal areas;
- increase in heat waves and extreme cold, both in time and intensity;
- increased energy demand, both in winter and in summer.

The strategies that aim to contribute to the subject of climate change, therefore, tend to be aligned on two main actions: mitigation and adaptation to climate change. Mitigation is aimed at progressively reducing emissions of gases responsible for global warming; adaptation to reduce environmental, social, and economic vulnerability and to increase climate resilience.

The integration of Green Infrastructures (GIs) in urban planning is considered to be one of the most appropriate tools to improve the microclimate and address the impacts of climate change (in particular UHI—Urban Heat Island, microclimate improvement, pollution control, etc.) (European Commission 2012).

Green Infrastructures, according to the E.U. definition, "*… are networks of natural and semi-natural areas planned at strategic level with other environmental elements, designed and managed in such a way as to provide a wide spectrum of ecosystem services. This includes green (or blue, in the case of aquatic ecosystems) and other physical elements in areas on land (including coastal areas) and marine areas. On the mainland, green infrastructures are present in a rural and urban context…*" (Environment Directorate 2013).

The types of GI are different and among the most common are: green roofs, green walls, urban forest, bioswales, rain gardens, urban agriculture (urban gardens; community gardening; collective greenery; peri-urban agriculture, agricultural parks), river parks, local product markets, built wetland areas, alternative energy farms and nature conservation areas.

The GIs and all nature-based solutions are important for promoting climate resilience in urban areas (Chang and Li 2014; Moreno-García and Serra-Pardo 2016; Raymond et al. 2017). The urban green areas have significant effects on the urban microclimate because they enable reductions of solar radiation input due to the trees and produce lower temperatures that mitigate heat islands, as reported in several studies conducted in various cities (Georgi and Zafiriadis 2006; Bowler et al. 2010; Armaghan Ahmadi et al. 2017; Potcher et al. 2006; Moreno-García 2019; Zinzi and Agnoli 2012).

The importance of GIs and of nature-based solutions to mitigate the negative impacts of climate change in urban areas is recognized at the scientific and political levels. It is clear that the mere presence of urban green spaces is not the global solution, while the structure, composition, and management of specific vegetation is essential to improve the capacity of green spaces to provide ecosystem services (air purification and climate regulation).

The ecosystem services are the indirect and direct benefits provided by urban green areas for human health and the environment and the welfare of the community. The ecosystem services "… *consist of material flows, energy, and information from natural capital stocks, which are combined with the services of anthropogenic artifacts to generate well-being and quality of life* …" (Costanza 1991). They may perform the following functions: as environmental regulators; protection from hydrogeological instability; social, recreational, and therapeutic assets; cultural and educational benefits; and aesthetic-architectural features. Moreover, they can contribute to adapt cities to climate change because they help to purify the air, to regulate the urban microclimate, and to reduce noise (Hansen and Pauleit 2014; Lovell and Taylor 2013; Seppelt et al. 2011).

Some studies (e.g., Vieiraa et al. 2018) have, in fact, shown that vegetation consisting of a more complex structure (trees, shrubs, and herbaceous layers) and the absence of agronomic practices (pruning, irrigation, and fertilization) had a greater capacity to provide the ecosystem services of air purification and climate regulation.

The management of the contemporary city provides the answer to several complex situations that, on the one hand, are linked to environmental, social, and economic problems and, on the other, to the coordination of projects and actions that often develop to solve yet more emerging issues.

Therefore, it is necessary to evaluate the needs of the city in a transverse, stratified way and on a plurality of themes, focusing the research on the following points (Demuzerea et al. 2014; Jayasooriya et al. 2017; Sturiale et al. 2020): socializing; sustainability and adaptation to climate change; resilience; innovative technologies; and resources.

3 Methods

Into this scenario, one may insert the methodology called Green City Circle (Boulanger and Marcatili 2018), which is configured as a circular process, in which a first investigative phase is followed by a phase of proposed solutions and a phase of implementation up to a final phase of evaluation of results and strategic for long-term sustainability. The effort that this model makes is to coordinate the specific interventions at the territorial level within a wider framework, defined by the multi-criteria analysis that aims to help in the construction of a long-term vision for the territory.

The multi-criteria evaluation (Munda 2008) will be combined with the circular evaluation model called the Green City Circle (Boulanger and Marcatili 2018) for a multi-layer assessment. The evaluation is set up as a circular process, followed by a first investigative phase, followed by a proactive phase of solutions and an implementation phase up to a final stage of evaluation of the results and strategic for long-term sustainability. This is a decision-making process that could be adopted as a tool operational and supportive of urban planning sustainable and resilient, with the aim of responding to European demands to facilitate the transition of cities to the circular-economy approach (Calabrò et al 2019; De Marchi and Ravetz 2001; Matthews et al 2015).

One of the principles on which the circular economy of cities is based is the regeneration of the urban natural system, which enhances the natural capital and provides for the planning of urban green areas (Qian and Wang 2016). The objectives to be achieved are: to adopt a circular use of the components of the natural ecosystem; to reduce the negative effects of pollution; and to combat the effects of climate change (Christisa et al. 2019).

The methodology applied the integration of the Green City Circle into the multi-criteria analysis. During the first phase, defined as cognitive, there is an analysis of the context through:

- documentary analysis through the examination of documents, reports, and historical data;
- urban and relational analysis of the context, internally related to a larger scale;
- analysis of the social, cultural, and informal creative dimension, also through innovative cognitive strategies, such as those of the Participant observation;
- compilation of a preliminary check-list, proposed by the tool enabling identify the main stresses that the context has.

The proposed model integrates the Green City Circle (based on the establishment of the Focus Group with the various stakeholders) and the NAIADE method (Novel Approach to Imprecise Assessment and Decision Environments), for the Social Multi-Criteria Evaluation (SMCE) of the "complex" information collected (quantitative and qualitative data) (De Marchi and Ravetz 2001; Munaretto et al. 2014; Munda 2006, 2016; Oppio et al. 2018; Scuderi and Sturiale 2019).

SMCE accomplishes the goals of being inter/multi-disciplinary (with respect to the research team), participatory (with respect to the community), and transparent (since all criteria are presented in their original form without any transformations in money, energy or whatever common measurement rod) (Greco and Munda 2017).

The methodological approach is applied to the metropolitan city of Catania to evaluate the planning of Green Infrastructures (GIs), and, in particular, the experimentation of new participatory approaches for the definition of green urban strategies. The information and results obtained can be used to develop guidelines to support local planning policies and tools to identify climate-adaptation measures in the urban environment according to a circular economy model for three scenarios.

Three hypotheses/scenarios of green recreational strategies are envisaged:

- hypothesis 1—GARDEN: creation of parks and gardens with tree bushes and meadows (with high impact on the micro-climate)
- hypothesis 2—PLAYGROUND: creation of areas for play and socialization (with limited impact on the micro-climate)
- hypothesis 3—AGRI-URBAN: creation of areas for the creation of vegetable gardens and orchards cultivated by citizens (with medium impact on the micro-climate).

The model provides for a first phase of execution of focus groups with the identified stakeholders, with the administration of customized questionnaires prepared to acquire the main information. In particular, the following stakeholders have interviewed: citizens, pensioners, cultural associations, schools, trade unions, public institutions, scientific institutions, and tertiary sector companies. The meetings were held at public social gathering places present in the area concerned, in the presence of a sociologist who was able to guide the conversation, structured by the properly prepared questionnaire.

The second phase involves the application of multi-criteria analysis using the NAIADE method, in which the basic input consists of hypotheses of alternative scenarios to be analyzed and identification of the different decision-making criteria for the relative evaluation and meetings with the various stakeholders, who express opinions on the scenarios in question.

According to this method, two types of analysis can be performed:

- multi-criteria analysis: contributes to the definition of the priorities of alternative scenarios with respect to certain decision criteria, based on the impact matrix;
- equity analysis: analyses possible alliances or conflicts that may arise between the interests of the various actors involved in relation to the proposed scenarios, based on the equity matrix.

The impact matrix (criteria/alternative matrix) is the basis of the NAIADE method, built with scores that can take the following forms: stochastic elements, sharp numbers, fuzzy elements, and linguistic elements (such as “very poor”, “poor”, “medium”, “good”, “very good”, “excellent”). The comparison between alternative scenarios is performed through the concept of distance. When operating with sharp numbers, the distance to a given evaluation criterion is calculated by subtracting the sharp numbers of the two alternative scenarios.

The classification of the alternative scenarios is performed on the basis of the impact matrix data used for:

- comparing each individual pair of alternatives with all the assessment criteria considered;

- calculating a credibility index for each of the above comparisons, using a relationship of preference between '… alternative scenario a' and 'is better/worse, etc.' alternative scenario 'b' … ;
- aggregating the credibility indices into a preference intensity index μ * (a, b) of an "a" alternative to another "b" for all the evaluation criteria (associated with the concept of entropy H * (a, b), as an indication of the change in the credibility indices);
- classifying the alternative scenarios on the basis of information obtained from the previous steps.

The intersection of the "classification $\Phi +$" (a) (based on preference relationships 'better' and 'definitely better') and the "classification $\Phi -$" (b) (based on preference relationships 'worst' and 'definitely worse') determines the final classification of alternatives.

4 Results

The model was tested in a suburb of the city of Catania, but it is designed to be used in feasibility studies in larger contexts, by adapting it to territorial specificities, present resources and urban planning priorities according to the principles of resilience and circularity.

The first phase, consisting of the development of focus groups with the interaction of the identified subjects, arises from the need to implement urban strategies with the involvement of potential stakeholders, including not only the resident population, but also the production and financial system, as well as associations and the cultural and creative world. The study was supported by the City of Catania, which provided images of the green areas present and the areas likely to be transformed in GIs, in the urban and peripheral environment, and often located in degraded contexts. The analysis focused on a peripheral area, where the objectives of green planning combine environmental, climate, economic, and, above all, social aspects.

In particular, respondents were asked which scenario, among those proposed, was preferred to meet climate change adaptation needs and economic and social needs.

The three scenarios proposed can be considered climate-adaptation actions, although with different microclimatic impacts, in relation to the vegetation structure foreseen in their design. However, this aspect, in particular, will be subject to further verification at another point in the research, as the priority was to verify the model of evaluation of the social perception expressed by the local community.

To evaluate the three scenarios assumed in the survey, twelve evaluation criteria (or variables) were identified, defined by the basis of the objectives set in the analyzed case, which can be considered representative of the reality of the Municipality of Catania but, overall, very similar to other metropolitan areas.

The objectives chosen to characterize the various scenarios are environmental quality, sociality, climate adaptation, economy, urban green area, and health security. For each objective, the relative evaluation criteria are defined, as listed here:

1. Environmental quality: air quality; human settlement.
2. Sociality: usability, multi-functionality.
3. Climate adaptation: reduction of temperatures, creation of accessible shaded areas, thermal excursion.
4. Economy: cost of realization.
5. Urban green areas: quality of the landscape, biodiversity.
6. Health safety: pollution, use of pesticides and fertilizers.

The equity matrix (Table 1) summarizes the framework of the stakeholders' views on the three scenarios. As highlighted in the methodology, in the multicriteria evaluation, the opinions expressed by the stakeholders are of a qualitative nature. Therefore, the following linguistic expressions are used: very poor, poor, medium, good, good, very good, and excellent (Table 1).

The results show the clear preference of the stakeholders for the Garden scenario, followed closely by the Playground scenario and, finally, the Agri-Urban scenario, which revoked the lowest reported evaluations (Fig. 1).

Table 1 The equity matrix—stakeholder opinions of three hypotheses

Typology of stakeholder	Group	Scenario Garden A	Scenario Playground B	Scenario Agri-urban C
Citizens	A1	Excellent	Excellent	Poor
Pensioners	A2	Very good	Good	Good
Cultural associations	A3	Excellent	Excellent	Poor
Schools	A4	Very good	Excellent	Very good
Trade unions	A5	Good	Good	Good
Public institutions	A6	Very good	Very good	Good
Scientific institutions	A7	Excellent	Good	Good
Tertiary sector companies	A8	Very good	Very good	Poor

Source Our elaboration

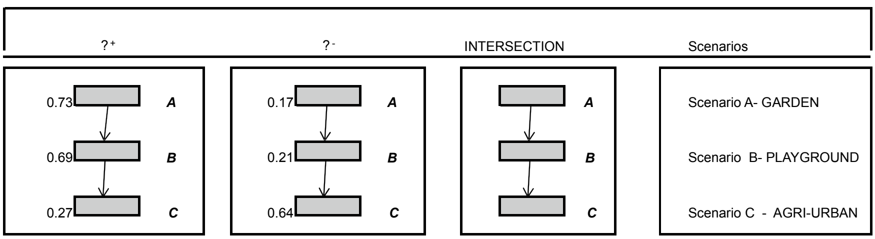

Fig. 1 Intersection and final classification of the three hypotheses scenarios. *Source* Our elaboration

Table 2 Consensus levels and relative definition of the priorities of scenarios

Classification scenarios	**Consensus levels**					
	0.7312	0.6934	0.7136	0.5235	0.6239	0.7089
	A	A	A	A	A	A
	B	B	B	B	B	B
	C	C	C	C	C	C
Groups with alliances and each level consent	All groups	All groups except A1	All groups except A2	All groups except A6	All groups except A2–A6	All groups except A4

Source Our elaboration

The results obtained through the equity analysis were used to examine possible alliances or conflicts among the opinions expressed by stakeholders on the three scenario hypotheses. The information reported in Table 2 shows the values attributed to the classification of the corresponding scenarios based on the relative level of consensus. These results show that a large number of stakeholders agree on the final classification of the three scenario hypotheses and, in any case, the Garden hypothesis is the preferred one, as it is the one with the highest consensus.

In the following phases, consistent with the methodological aspect, we will have to make some drawings of the garden and a metric calculation which will be followed by a business plan. To evaluate the best design solution, a cost–benefit analysis will be made. This phase will have to be shared with the population also attracted through social media to continue the participatory planning of the area. The project after completion must be monitored, through the indicators provided in the design phase, linked to climate change, as well as an overall assessment of the project to assess the benefits and losses that have emerged, as a source of experience for future planning activities.

The proposed evaluation approach, based on the integration of multi-criteria analysis and participatory planning, applies to a complex urban reality from an environmental and social point of view, making it possible to acquire useful information and to reach the choice of the preferred scenario for the local community.

5 Conclusion

In the last decade, cities have shown growing awareness of climate issues and a greater need for involvement in government activities, especially those concerning the design and management of public green spaces and environmental improvement projects (Baró et al. 2014).

Current environmental legislation gives a particularly significant role to municipalities in terms of actions and responsibilities (Bekessy et al. 2012). This evolution has helped local administrations to gradually assume environmental responsibilities, thus shortening the distance between the citizen and the administration, generating greater mutual responsibility (Escobedo et al. 2011).

The experience conducted in the city of Catania, as a model of city and scenario of surveys and concrete applications, has also represented a moment of verification of the opening of an institution to tackle issues not yet fully included in the practices of the public administration. The willingness shown by the administrators and citizens who participated both in the survey phase, through the questionnaire, and in the collection of information, has shown that the actors involved are beginning to be aware of environmental issues. Moreover, the sharing of the project proposals, i.e., the three scenarios to be evaluated, leads to the objective of making the adaptation actions foreseen by the administration accepted and re-appropriating parts of cities that could guarantee better climatic and environmental conditions.

The approach of the proposed method proved particularly appropriate to achieve the result that the administration wanted to achieve. A concrete process of improvement of the urban environment will have to start from the involvement of all the social and economic actors who live and know the city, its potential, and, above all, the needs of the community.

This work in its proposal offers a series of ideas aimed at introducing, into the tools for urban planning, measures to adapt to climate change, and to promote innovative choices that can be useful for the future of our cities based on economic, social, and environmental sustainability. The tool adopted have proven to be innovative and useful as a support to strategic policy choices for the sustainable development of the city according to a resilient and circular model.

Funding This work has been financed by the University of Catania within the project "Piano della Ricerca Dipartimentale 2016–18 of the Department of Civil Engineering and Architecture".

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A Spatial Multi-criteria Decision Support System for Stress Recovery-Oriented Forest Management

Irene Capecchi, Gianluca Grilli, Elena Barbierato, and Sandro Sacchelli

Abstract A solution to cope with chaotic urban settlements and frenetic everyday life is refuging in nature as a way to reduce stress. In general—in recent years—it has been scientifically demonstrated how natural areas are an important environment for psycho-physiological health. As a consequence, it is important to plan dedicated spaces for stress recovery in order to increase the well-being of people. With respect to forests, there is a growing interest in understanding the marketing and tourist potential of forest-therapy activities and policies. This paper develops a decision support system (DSS) for decision makers, based on geographic information system to define the suitability of forest areas to improve psychological and physiological human well-being. Innovative technologies such as electroencephalography (EEG) and virtual reality (VR) are applied to test human status. The DSS combines four sets of indicators in a multi-attribute decision analysis and identifies the areas with the largest stress-recovery potential. Two multi-attribute model—one in summer and one in winter—are elaborated to obtain a dynamic evaluation of suitability. Results show significant differences among forest type, forest management, altitude range, and season in terms of stand suitability. EEG and VR seem to be promising technologies in this research area. Strengths and weaknesses of the approach, as well as potential future improvement and implications for territorial marketing, are suggested.

Keywords Regional planning · Smart living · Territorial marketing · Socio-ecological dynamics · Ecosystem services

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_12

1 Introduction

There is an increasing trend for people to live far from natural environments, which is caused by urbanization and loss of green areas. This situation increases people's need to spend their free time in nature to recover from stressful city routines. A meta-analysis carried out by Bowler et al. (2010) found that all primary studies detected an association between health and exposure to natural environments, in particular with respect to stress relief. A Finnish study concluded that even short-term visits to natural areas are beneficial to reduce perceived stress and cortisol levels (Tyrväinen et al. 2014). Forests play a central role with respect to stress recovery, in fact several studies show that spending time in forests has psychological and physiological benefits. Hansmann et al. (2007) detected positive effects of forest visits on self-assessed measures of well-being, headache, and stress. Other studies demonstrated that forest visits contributed to reduced cortisol levels, cerebral activity, and heart beat (Jin et al. 2010; Park et al. 2008). The positive effects of forests are now widely recognized, so that terms like "forest bathing" and "forest therapy" are often used to refer to restoration effects provided by forest visitation (Bielinis et al. 2018a, b; Ochiai et al. 2015; Ohe et al. 2017).

The emerging topic of stress relief supported by natural resources has gained interest in recent years. A typical "cultural ecosystem service" (CES) (MEA 2005) is characterized by a high degree of intangibility and incommensurability. In addition, the valuation, as well as quantification of CES, in dynamic environment such as forests suggests how standardized decision support systems (DSS) for provisioning of information for management are needed (Inostroza et al. 2017). Currently available DSS applied to CES are mainly focused on trade-off analysis among ecosystem services (including CES) and aesthetic/landscape perception. Pang et al. (2017) applied the Landscape Simulation and Ecological Assessment tool to assess synergies and trade-offs among provisioning of biomass for energy and timber production, forest carbon storage, recreation areas, and habitat networks. Dynamicity of economic value of ecosystem services throughout rotation period is considered in Sacchelli (2018) by means of Trade-off of Forest Ecosystem Services model. It considers raw material, carbon sequestration, habitat for species, and touristic and recreational value of *Abies alba* Mill. stand. The spatial dimension of CES are often explored: in this sense—among several DSS—participatory Geographic Information Systems (Brown and Fagerholm 2015), models applying social media (Langemeyer et al. 2018; Bernetti et al. 2019) or techniques based on a multi-method approach (Rovai et al. 2016; Saeidi et al. 2017) can be mentioned. While the association between forest visit and stress are extensively studied, to the best of the authors' knowledge it is still not clear whether forests are all equally effective or if some forest types are better than others for stress relief. Forests differ based on tree species and density and across seasons, therefore stress relief potential may also be different. Understanding which forests are suitable for therapy is useful information for forest management, as specific areas with high potential for forest therapy and stress recovery can be designed. In addition, the cited literature review lacks user-friendly and open-source DSS for dynamic stress-recovery assessment of forest areas. Within this framework, the aim of the work is to implement a spatial-based DSS centered on multicriteria analysis to provide information to forest managers about the perspective of stress-recovery-oriented forest management. The model will be able to classify forest compartments according to their suitability in CES provisioning for both winter and summer seasons. Innovative technologies such as electroencephalography (EEG) and virtual reality (VR) are applied to test psychological and physiological status of those interviewed. These techniques—as described in Sect. 2.3.1—seem to be promising in this research area.

The work is structured as follows. In the second section, we briefly describe the general framework of the study and the examined area, as well as methodology. The third section is dedicated to results and discussion of them. The final chapter suggests potential policy and practical implications of the method and offers additional conclusions.

2 Material and Methods

2.1 General Framework

The applied method provides a geographically-explicit DSS based on GRASS GIS v. 7.6 (https://grass.osgeo.org/) and multicriteria analysis. As reported by Comino et al. (2014), a multicriteria spatial DSS follows a flow of activities classifiable in three phases: (i) Intelligence, (ii) Design, and (iii) Choice. Specifically, "*data acquisition, processing, and examining are done in the intelligence phase; formal modeling/GIS interaction in the design phase, in which a solution set of spatial decision alternatives are developed; and the choice phase involves the evaluation of alternatives*" (Comino et al. 2014: 382–383) as described below. The DSS combines four criteria—each characterized by a set of indicators—in a multi-attribute decision analysis and identifies the areas with the largest stress recovery potential. The first criterion considers variables describing the degree of usability of the forest, while the second is dedicated to risk analysis for potential visitors. The third set considers psychological factors. Finally, the fourth set includes physiological features. Some indicators are computed for both summer and winter seasons to include dynamicity of CES. Each indicator is normalized in the range 0–1 to be processed with the multi-attribute technique. The normalization is based on a literature review if information was available; otherwise, a focus group involving researchers and local experts was carried out. For some indicators, normalization comes from laboratory experiments involving psychological and neuroscientific tests as subsequently described. Eventually, indicators are aggregated and constraints (mandatory conditions to be reached) are included in the analysis.

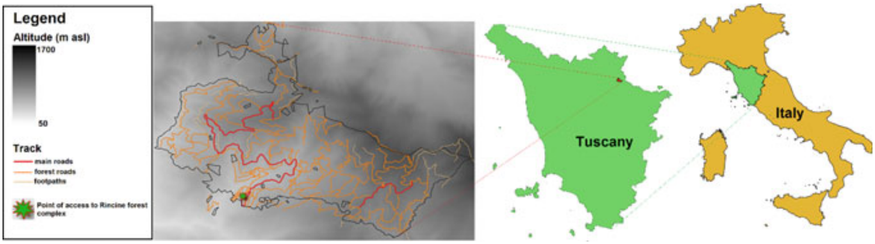


Fig. 1 Localization of study area

2.2 *Study Area and Territorial Informative System*

The case study is located in the Municipalities Union of Sieve and Arno Valleys (province of Florence, Tuscany region—Italy). Specifically, DSS is tested in the regional forest complex of Rincine (Fig. 1).

Rincine forests have a total extension of 1448 ha. This territory is currently the operational center of the Forestry Activities Service of the Municipalities Union. It is the site of numerous scientific researches and recently achieved the certification of international FSC® and PEFC™ standards. From a vegetation point of view, the prevailing forest typology is European beech (365 ha), followed by Turkey oak (290 ha) and artificial planted conifers (187 ha). Fifty-three percent of the woodland is managed as coppice; 47% are high forests.

The elaboration starts from the Territorial Informative System (TIS) reported in Table 1.

2.3 *Modellization*

2.3.1 Identification of Criteria and Measurement

All geodata are imported into GRASS GIS platform and—if vectorial—converted in raster format.

The criterion *usability* of forest includes four indicators: slope (%, from DTM), accessibility and water uptake degree (derived from Rincine Forest Plan and experts' attribution as reported in TIS), as well as distance from access point. The latter parameter is computed by means of *r.cost* operation in GRASS GIS to quantify the cumulative distance from a starting point (preliminary set at point of access of Rincine forest complex) and one or more *stop* points (forest compartments). The distance—expressed in meters—is quantified considering a potential trail on main roads, forest roads, and footpaths. For each trail typology, a *cost* value (weight) is given to express the relative difficulty (time) in crossing the pixel.

Table 1 Territorial informative system

Variable	Format/value/(U.M.)	Source[a]
Forest management	Vectorial/high forest: 1, coppice: 2, no-forest: 0	Rincine forest plan
Aspect	Vectorial/N: 1, NE: 2, E: 3, SE: 4, S: 5, SW: 6, W: 7, NW: 8	Rincine forest plan
Stoniness	Vectorial/absent: 0, low: 1, 2: medium, 3: high	Rincine forest plan
Rockiness	Vectorial/absent: 0, low: 1, 2: medium, 3: high	Rincine forest plan
Flammability	Vectorial/low: 1, 2: medium, 3: high	Rincine forest plan
Accessibility	Vectorial/0: not accessible, 1: easy, 2: medium, 3: difficulty	Rincine forest plan
Water uptake	Vectorial/0: not easy, 1: easy	Rincine forest plan
Ornithic richness	Vectorial/1: medium, 2: high, 3: very high	Rincine forest plan
Forest density	Vectorial/1: low, 2: medium, 3: high, 4: very high	Rincine forest plan
Forest coverage	Vectorial/range 0–100/(%)	Rincine forest plan
Tree height	Vectorial/top height/(m)	Rincine forest plan
Broadleaf	Vectorial/range 0–100/(%)	Rincine forest plan
Conifers	Vectorial/range 0–100/(%)	Rincine forest plan
Forest function	Vectorial/1: protective, 2: other	Rincine forest plan
Hydrogeological risk	Vectorial/1: compartments at risk[b], 0: no risk	Rincine forest plan
Digital terrain model (DTM)	Raster/(m a.s.l.)	Tuscany region opendata (https://www502.regione.toscana.it/geoscopio/cartoteca.html
Forest roads	Vectorial	Rincine forest plan

[a]Variables from Rincine Forest Plan refer to compartments
[b]Hydrogeological risk is defined for compartments with medium or high risk for rockfall and/or landslide

The criterion *risk for visitors* is composed of two indicators: rockiness and flammability already described in the TIS. The hypothesis is that rockiness makes more difficult the walking capacity in forest compartments, increasing the risk of injury. Flammability depends on vegetational and climatic characteristics: its normalization is in fact evaluated for various seasonal conditions related to literature data.

The third criterion (psychological aspect) analyzes six indicators, i.e., ornithic richness, dendrometric variables (forest density, forest coverage, tree height), and other forest characteristics (forest management and percentage of broadleaf/conifers). The ornithic variable, and—specifically—species richness, is directly correlated to psychological improvement (Edwards et al. 2012). Dendrometric parameters have a more fluctuating trend. Their normalization derive from both the scientific literature and the focus group (Table 2). The importance of species categories (broadleaf and conifers) was analyzed in a laboratory experiment where interviewed were asked to indicate their willingness to visit (WTV) the forest in a VR environment. We used an HTC Vive headset, which provides the subjects a 360° view and to be fully immersed in the place. Immersion is also emphasized using videos with audio. The use of VR has two main strengths: (i) it reduces the cost and time of questionnaire administration because all subjects can view the stimulus without needing to move outside; (ii) it removes time differences because the scene freezes at precise times, and all subjects can see the scenes in the same situation and weather conditions. The videos were recorded through a spherical camera (Nikon keymission 360). The urban video was recorded in a Florence suburb while the eight forest videos were recorded in a Rincine forest. The videos were recorded both in the winter season (at the end of February) during the vegetative-rest condition, and in the summer season (July) during vegetative conditions. The forest videos present four different forest types (Turkey Oak, Black pine, European Beech, and Douglas fir) and two different forest density (high and low). The sample is composed of selected subjects in the millennial generation who did not attend forestry science classes because this can alter the emotional perception of the forest. We interviewed 20 subjects (60% female and 40% male), between 21 and 28 years of age and studying in the Territorial, Urban and Environmental Planning course of the University of Florence.

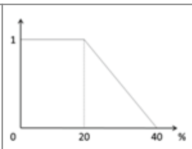
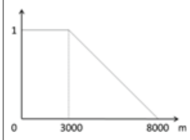
The sample was split into two gender-balanced sub-samples (T1 and T2) characterized by equal numbers of individuals. After viewing each 30-s video, the subjects were queried concerning their WTV the place, based on a five-point Likert scale. To avoid distortion in responses due to different sequences, the order of videos (videos of urban scenes were also included to compare the effects of artificial vs. natural locations) was the following:

- T1: urban, Turkey oak (high density), black pine (low density), European beech (high density), Douglas fir (low density);
- T2: European beech (low density), Douglas fir (high density), Turkey oak (low density), black pine (high density), urban.

The entire survey takes approximately 15 min. The questionnaire was administered in a neutral place (room) to guarantee both full immersion and reduction of potential external disturbances.

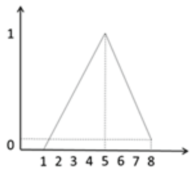
The last set of criteria (physiological responses) comprises three indicators: aspects of the forest compartments, the altitude, and EEG trends of the subjects of the lab experiment. Aspects and altitude are strictly related to climatic conditions, as well as the subjects' temperature perception of people. Thus local analysis and adaptation of literature are carried out to define the variables. Concerning EEG trends, the first step involves comparing subjects' stress level in forest and urban environments; the second step concerns analyses of stress levels in winter and summer season. The EEG equipment employed was the MUSE Brain, a wearable

Table 2 Normalization of indicators and definition of constraints

Indicator	Normalization	Source
Criterion: usability		
Slope		Chiou et al. (2010)
Accessibility	Value 1 = 1; value 2 = 0.66; value 3 = 0.33	Focus group
Distance from access point		Focus group
Water uptake degree	Value 1 = 1; value 0 = 0.33	Focus group
Criterion: risk for visitors		
Rockiness	Value 0 = 1; value 1 = 0.66; value 2 = 0.33; value 3 = 0	Tomczyk (2011)
Flammability[a]	Summer scenario: value 1 = 1; value 2 = 0.66; value 3 = 0.33 Winter scenario: all value = 1	Tomczyk (2011)
Criterion: psychological		
Ornithic richness	Value 3 = 1; value 2 = 0.75; value 1 = 0.5	Edwards et al. (2012)
Forest management	Value 1 = 1; value 2 = 0.5	Riccioli et al. (2019); Focus group
Forest density	Value 1 = 0.5; value 2 = 0.75; value 3 = 1; value 4 = 0.5	Pelyukh et al. (2019), Chiang et al. (2017)
Forest coverage	Linear normalization on maximum value according to the following formula: $N_i = (\max_m - v_i)/(\max_m - \min_m)$ where $\max_m$ and $\min_m$ are respectively maximum and minimum value in the map, v_i is the value for the pixel ith	Focus group
Top height	Linear normalization on maximum value according to the following formula: $N_i = (\max_m - v_i)/(\max_m - \min_m)$ where $\max_m$ and $\min_m$ are respectively maximum and minimum value in the map, v_i is the value for the pixel ith	Focus group

(continued)

Table 2 (continued)

Indicator	Normalization	Source
WIllingness to visit[a]	Summer scenario: if broadleaf = 1; if conifers = 0.73 Winter scenario: if broadleaf = 0.59; if conifers = 0.78 (weighted on broadleaf/conifers percentage)	Laboratory experiment
Criterion: physiological		
Aspect		Focus group
Altitude[a]	Summer scenario: linear normalization on maximum value according to the following formula: $N_i = (\max_m - v_i)/(\max_m - \min_m)$ where $\max_m$ and $\min_m$ are respectively maximum and minimum value in the map, v_i is the value for the pixel ith Winter scenario: linear normalization on minimum value according to the following formula: $N_i = (v_i - \min_m)/(\max_m - \min_m)$ where $\max_m$ and $\min_m$ are respectively maximum and minimum value in the map, v_i is the value for the pixel ith	Boori et al. (2015)
Electroencephalographic trend[a]	Summer scenario: if broadleaf = 0.96; if conifers = 1 Winter scenario: if broadleaf = 0.85; if conifers = 0.87 (weighted on broadleaf/conifers percentage)	Triguero-Mas et al. (2017); Laboratory experiment
Constraints	*Definition*	*Source*
Forest area	If forest management is 0, then = 0, 1 otherwise	Focus group
Accessibility	If accessibility is 0, then = 0, 1 otherwise	Focus group
Forest function	If forest function is 1, then = 0, 1 otherwise	Focus group
Hydrogeological risk	If hydrogeological risk is 1, then = 0, 1 otherwise	Focus group

[a]indicators with summer and winter scenario

four-channel EEG, which measures brain activity. This device analyzes signals from four electrodes [TP9, AF7, AF8, TP10 scalp positions according to a 10–20 system classification (Klem et al. 1999)] located in the frontal and temporal lobes of the brain. The outputs of MUSE Brain are raw EEG data, raw accelerometer, raw Fast Fourier Transformation (FFT) coefficients, relative, and absolute band powers for waves and blink-and-jaw-clench detection that can be re-elaborated with available algorithm for several platforms (R-cran, Matlab). Five waves (measured in hertz) are derived from outputs: alpha, beta, theta, gamma, and delta. Each wave or the combinations among them can be related to the emotional status of individual (Norwood et al. 2019). Beta waves are generally associated with awake people in a condition to alert consciousness, thinking, and excitement. On the other hand, alpha waves are considered as a proxy of physically and mentally relaxed status. In the case study, as done in previous scientific works (Sacchelli et al. 2020), we concentrated on beta waves because they are more reactive to short videos, while alpha is more sensitive to the dose–response effect (Chiang et al. 2017). The time series of beta waves were compared using ANOVA and OLS regression to identify statistically significant differences originated from different forest types.

2.3.2 Normalization of Criteria

Indicators were normalized as reported in Table 2. Suitable areas for stress-recovery in all indicators have value 1; the value decreases to zero in a non-suitable area. Normalization is developed through fuzzy logic by means of both functions (Cheng 1999) and a linguistic evaluator (Chen and Hwang 1992). The aggregation of indicators is performed as total compensatory approach (i.e., average of normalized value). Constraints were included as Boolean factors (Table 2) to be aggregated at suitability maps with logic operator "AND" (Larson et al. 1991).

3 Results and Discussion

Results are elaborated through zonal statistics operation to compute an average suitability score at the Rincine forest-complex level, and for different variables. The stress recovery potential is assessed for summer and winter seasons separately.

The average score for the total forest surface in the district is 0.56 in summer and 0.59 in winter. This difference is probably caused by the absence of weights in the multicriterial model. In particular, the flammability indicator seems to negatively affect the summer scenario more than other indicators, due to the higher probability of fires.

Table 3 reports average scores for forest type and forest management.

The deciduous category has a lower suitability value than conifers, in particular in winter time, when the gap increases. That assertion highlights the importance of usability and psychological criteria for the comparison of broadleaf and conifer forests. In fact, dendrometric, managerial, and logistic characteristics of compartments as well as the WTV the forest could represent influential indicators. Conifers

Table 3 Average suitability scores for forest variables and season

		Summer	Winter
Forest type	Broadleaf	0.50	0.52
	Conifers	0.66	0.74
Forest management	High forests	0.65	0.71
	Coppices	0.48	0.49

are generally higher than deciduous stands, and they can be more accessible because they can be part of reforestation process (mainly adopted—in the case study area—near to roads). In summer, WTV is higher in broadleaf stands due to vegetative conditions and subsequent positive perception. Eventually, coppices are perceived worse than high forests, and this aspect has a negative (average) repercussion on broadleaf evaluation.

An interesting suitability trend is highlighted for the altitude range (Fig. 2). The value is indirectly proportional to altitude in both winter and summer. The usability criterion influences the suitability trend because higher altitudes are characterized by longer walking distances and steeper slopes. In summer the average suitability tends to be greater than in winter for the importance of physiological criterion.

A final aspect to stress is the appropriateness of DSS for visualization and presentation of results to the various stakeholders. In this respect, Fig. 3 shows the main output of the DSS model, i.e., a suitability map with scores for each forest parcel. This map may be the starting point for forest management that aims at maximizing the stress-recovery potential of local forested areas.

The research into natural areas for stress recovery has led to the creation of healing gardens inside hospital open areas and to nature-based activities to help solve neural

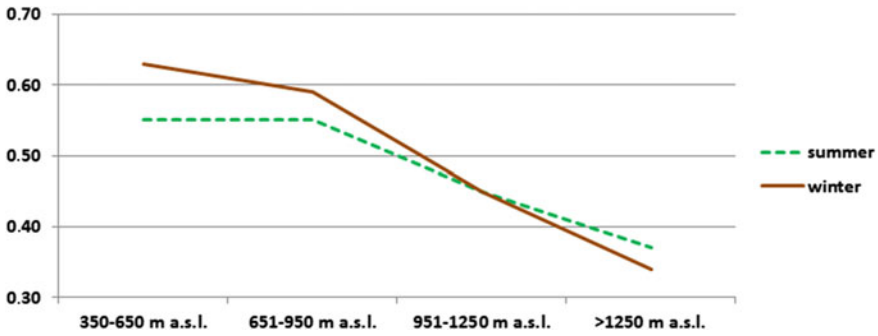


Fig. 2 Suitability score (0–1) based on altitude range in summer and winter

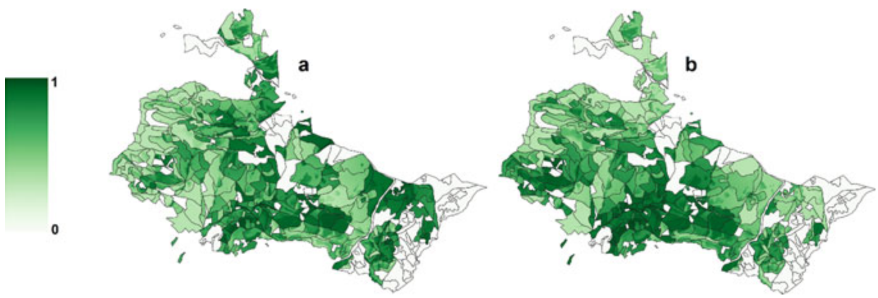


Fig. 3 Suitability score (0–1) in summer (**a**) and winter (**b**) at compartment level

problems, such as horticultural therapies (Cervinka et al. 2012; Jiang 2014). However, reproduced natural environments are not as effective as wild natural ones. In Nordic countries, in fact, it was found that the sounds of nature are associated with increased levels of restoration and well-being, which can hardly be reproduced in hospital gardens (Konu et al. 2017). For this reason, therapy-oriented management of forests is very important to provide spaces for individuals seeking restoration.

4 Conclusions

The present study follows recent trends in natural-resource management that highlight how natural environments are very effective for stress recovery and for the general psycho-physiological health of individuals. Dedicated spaces for stress recovery increase the well-being of people and a territorial balance between urban and natural environments; as a consequence, larger recreational opportunities are beneficial for marketing, in terms of increased numbers of potential tourist segments to attract, and for their potential spillovers to local economies. The literature suggests that people do not exhibit a unique response to all natural settings, but some environments are more effective than others for restoration.

Within this framework, the paper provides a geographically explicit DSS that could assist decision makers in planning dedicated forest areas for stress recovery. The DSS applies a user-friendly approach based on multi-criteria analysis. The inclusion of people's psychological and physiological responses to different forest types and density represents a novelty within the forest DSS literature. New technologies such as EEG, VR, and the combination of their results in a spatial model furnish more insight in respect to currently available techniques. Results confirm that all forest types provided lower stress levels compared to the urban environment. In addition, effectiveness of forest for well-being improvement is strongly affected by the season, suggesting how the temporal variable must be taken into account for a correct valuation of the topic.

Future development of DSS should be focused on the application of weights to criteria or indicators to balance local peculiarities and stakeholders' perceptions. In this sense, sensitivity analyses (e.g., "what-if" scenario) based on variation of weight should be developed to validate the results (Capolongo et al. 2019). An integration of physiological indicator could be performed that considers not only EEG responses to various stimuli but also additional parameters (e.g., heart rate, blood pressure, salivary cortisol). Outputs of the model can be easily presented to policy- and decision makers to create a basis for future marketing-oriented local activities for stress relief and human well-being.

Acknowledgements This study was conducted in the frame of the "Pianificazione strategica di impresa per la valorizzazione sostenibile delle filiere e dei servizi ecosistemici forestali" project, co-financed by Fondazione Cassa di Risparmio di Firenze.

The authors would like to thank A. Ventre and I. Battaglini for their valuable help in field investigations.

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Rural-Urban Relationships for Better Territorial Development

Institutional Methods for the Identification of Urban and Rural Areas—A Review for Italy

Valentina Cattivelli

Abstract Recent economic, demographic, and spatial changes have profoundly modified urban and rural areas and generated new territories, characterized by varying degrees of urbanity. The classification methods traditionally used to identify them are based on the distinction between urban and non-urban areas and are no longer functional to describe the territorial outcomes of these transformations. New methods have therefore been formulated and implemented in recent years to replace them. EUROSTAT has developed and updated periodically its own methods, intended to methodologically support scholars to read territorial diversities and transformations. Being the basis for the production of official statistics and data comparison between regions, these methods have fully replaced all the other methods that singular statistical offices of European countries had previously developed. Several government institutions began adopting specific territorial classifications in their strategic planning documents. These methods differed from those implemented by statistical offices, providing a more accurate and detailed framework for national and regional policies. This also happened in Italy, with ISTAT (Istituto Nazionale di Statistica—National Statistical Office) and many governmental institutions (e.g., National Government Institutions, Department for Economic Development and Cohesion, Ministry for Agricultural Policies, National Rural Network), experimenting with their own urban–rural classification methods to map all or part of the Italian territory. This paper offers an overview of the methods formulated and implemented in Italy over the last 15 years by ISTAT and governmental institutions. During this time, these institutions have developed six different methods to define urban and rural territories and to delimit territories with several degrees of urbanization, such as peri-urban areas. Specifically, ISTAT uses the EUROSTAT method to produce international and national statistics. Governmental institutions adopt methods based on economic and demographic data, which identify various territorial categories in addition to urban/rural ones, in their strategic planning documents. These findings result from desk research based on an analysis of official documents and scientific papers.

Keywords Urban–rural typologies · Territorial mapping · Italy

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*,
Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_13

1 Introduction

Urban and rural areas have changed profoundly in recent decades and have lost their clear and defined connotations (Cattivelli 2011, 2012, 2018; Hugo 2017; Dijkstra and Poelman 2017; Arellano and Roca 2017). This has occurred due to demographic dynamics, changes in settlement intensity and economic specialization, which have followed different paths from those traditionally defined by urbanistic literature (e.g., Wandl et al. 2014; Dymitrow and Stenseke 2016).

Urban peripheries and fringes grow more rapidly than core areas since population and economic activities are reversed in such contexts (EUROSTAT 2017). Relocation of people and economic activities leads to an explosion of the cities into the countryside, with the consequent conversion of agricultural land for productive and residential purposes in nearby rural areas. This, in turn, generates a sort of territorial *continuum* with no precise geographical identity, giving rise to peri-urban territories that are incredibly challenging to govern. Such territories are located within the urban fringes, on the edges of the built-up areas and close to rural areas, and tend to comprise a scattered pattern of lower density settlements and production zones around the main infrastructural hubs (Donadieu 2012; Wandl and Magoni 2017). Their spread creates urban conurbations with nearby small-medium cities, while also encompassing nearby rural areas (Simon et al. 2006; Simon 2008). Here, the characteristics of urban and rural zones merge in a disorderly, unplanned way, which can sometimes give rise to land tenure-related conflicts (Dadashpoor and Somayeh 2019). Investments in transport infrastructure reduce distances among urban fringes, peri-urban areas and nearby rural areas, and increase accessibility to work opportunities and services located in core urban areas (Accetturo 2018). This in turn intensifies commuting flows and requires spatial reorganization of public spaces and services (Timberlake 2017).

Changes in rural areas, where agriculture remains the most practiced economic activity (EUROSTAT 2017), are partly dictated by variations in production specialization. Due to the relocation of many industries, however, the secondary sector is growing, which in turn also attracts many companies from the tertiary sector, particularly in rural areas closer to urban centers (Cattivelli and Iuzzolino 2014). The latter territories are very dynamic, including from a demographic perspective, and enjoy economic benefit arising from their proximity to urban areas. Conversely, remote rural areas continue to suffer from depopulation, population aging and lack of job opportunities (ESPON 2018).

Considering these transformations, traditional territorial methods based on the urban–rural dichotomy are no longer appropriate as a framework for considering. "Urban" and "rural" as well-identified territorial categories are assumed to exist only at the extreme ends of a territorial *continuum* (Davoudi and Stead 2002; Donadieu 2012; Mustafa et al. 2015). This continuum or peri-urban area is difficult to map due to its complexity. No classification method enables its inclusion in a well-defined category (Pagliacci 2017).

New urban–rural typologies are required, as are more appropriate definitions of the continuum between these two territories. Firstly, these new definitions could methodologically support scholars to investigate the current territorial configurations and different characteristics of urban and rural areas more accurately. Secondly, they could serve to steer the attention of local policymakers toward the implementation of more territorial-targeted policies to promote local development. Finally, they will also be of interest to those involved in local development policies and allocation of resources at a higher territorial levels (national and European governments), as well as journalists, researchers, and citizens interested in the classification and characteristics of urban and rural areas.

In response to these needs, 80 different methods have been developed in Europe over the last 15 years, which can be clustered into three well-defined categories, based on their originator (statistical institutions, government, or scholars) (Cattivelli 2018).

The first kind of method is used for statistical purposes and specifically to prepare reports and publications, including national statistical analyses. Formulated and implemented by national statistical institutes to map the entire national territory, these methods are based on administrative boundaries and generally use few variables (ibid.).

The second group consists of territorial-targeted methods, which are adopted by state and regional institutions as territorial frameworks for formulating measures and programs (e.g., Piano di sviluppo rurale—Rural development plan). The third and final group is much more heterogeneous, encompassing all the methods developed by scholars to support policymakers and to map territorial changes with greater precision. As such, these methods employ sophisticated statistical techniques to manage many indicators, particularly social, economic, demographic, and morphological ones.

All these methods differ depending on the choice of indicators, territorial unit of analysis, statistical method, and number of classes adopted (Cattivelli 2011, 2012, 2018).

2 Aims

The aim of this short paper is to illustrate the main characteristics of urban–rural classification methods adopted over the last 15 years in Italy by statistical and governmental institutions. The methods developed by scholars will be the subject of a later study.

According to the OECD methodology, 24% of the Italian territory consists of predominantly urban territories, 49.2% of intermediate territories, and 26.8% of predominantly rural ones (OECD-EUROSTAT 2011). This breakdown is the result of an intense process of urbanization (Romano et al. 2017), which has quickened considerably over the past 50 years. Even in the 1950s, buildings were distributed widely throughout the territory, but outside cities they were mainly used for agricultural purposes. The countryside only became urbanized later, when residential, industrial, and service buildings poured into areas apart from the most densely populated cities, in smaller urban centers or rural municipalities near larger urban areas. According to ANCI (2018), 1000 Italian municipalities (out of a total of 8000) grew by more than 160% demographically between 1971 and 2019. Their spatial distribution underlines a shift in part of the urban population: toward smaller municipalities on the one hand, and toward the countryside on the other. The countryside is becoming increasingly urbanized, thus influencing the expansion of peri-urban areas around the most important urban centers (Esposito et al. 2018; Caracciolo 2018). In contrast, population growth in urban centers during the same period was found to be stable, or even negative (ibid).

This process of urbanization and peri-urbanization has made the boundaries between urban and rural areas less defined, generating peri-urban territories. Their delimitation is an urgent prerequisite for local policies and studies. This requires new methods of urban–rural and peri-urban identification to be developed, as those currently used do not identify peri-urban areas or do not accurately describe the territorial heterogeneity because they are based on the urban–rural dichotomy. Attempts to formulate new, more precise identification methods have led to their proliferation across Europe. Several statistical and governmental institutions and scholars have developed numerous methods at municipal, regional and national levels, in addition to those applied at a European level. Italy is the European country that has developed the most urban–rural methods, together with France and Germany (Cattivelli 2018). This indicates a willingness to read and describe the territorial complexity of our country. However, it also requires reflection on existing methods and their ability to represent territorial peculiarities.

3 Methods

This short paper illustrates the results of a desk research analysis undertaken in 2017 and completed one year later. Adopting the categorization approach proposed by Cattivelli (2018) to group existing urban–rural classification methods depending on the subjects who developed them, the research analyzes the statistical methods introduced by statistical institutions and the territorial-targeted methods adopted by governmental institutions.

As such, it studies the official documents drawn up by statistical and government institutions to delimit urban and rural areas, as well as to identify peri-urban areas or other territories with varying degrees of urbanization. Specifically, it focuses on analyzing the documents draft by ISTAT (Istituto Italiano di Statistica—National statistical institute), with the aim of investigating which classification methods this institution adopted to identify urban and rural areas in Italy during the 2005–2020 period. Subsequently, the research focuses on a study of national strategic planning documents to identify the methods adopted in the context of territorial development policies over the last two periods (2007–2013; 2014–2020) (Piano di sviluppo Nazionale—Plan of national development; Strategie Aree Interne—Inner areas strategy; Rete Rurale Nazionale—Rural National Network and Ministero delle politiche agricole alimentari, forestali e del turismo—Ministry of Agricultural, Food, Forestry and Tourism Policies plans).

The documents considered were requested and obtained directly from ISTAT and the Italian government offices.

Each method identified is analyzed specifically according to certain characteristics, such as the statistical units of reference and methodologies adopted, as well as the territorial typologies identified. The main results are described in the following sections, while Appendix provides a synoptic table summarizing the main features.

4 Results

The study identified six different methods that distinguish urban and rural areas and delimit the emerging peri-urban territories by defining various degrees of urbanization.

Section 4.1 describes the method adopted by ISTAT while Sect. 4.2 explores the methods developed by national government institutions.

4.1 The Method Adopted by ISTAT

ISTAT has adopted the EUROSTAT-OECD method to produce official statistics at the national level. This method was developed in 2010 (EUROSTAT 2010) but has been adapted over time as appropriate to take into account the presence of peri-urban territories and the influence exerted by larger urban centers.

Currently, it refers to grids and uses demographic data (easy to collect and updated periodically) to map all European territories. Procedurally, it implements a simple two-step approach to identifying population in urban areas based on the calculation of:

1. the population density threshold (300 inhabitants per km^2) applied to grid cells of 1 km^2.
2. the minimum size threshold (5000 inhabitants) applied to grouped grid cells above the density threshold.

The population living in rural areas is calculated by considering the population located outside urban areas, identified using the method just described. Population size is determined through the grouping of cells based on contiguity. If the central square of this grouping is above the density threshold, it will be grouped with each of the other surrounding eight cells that exceed the density threshold. This procedure is performed for all grids within NUTS 3. Threshold percentages are then applied at NUTS 3 level for the calculation of population density. Population thresholds are similar to those of the original OECD[1] classification applied to NUTS 3 regions, with the exception of that used to distinguish predominantly urban from intermediate areas, which has been adjusted from 15 to 20%. Moreover, the same three urban–rural typologies are applied: predominantly urban regions, intermediate regions (which can be proxied to peri-urban territory or the urban–rural continuum), and predominantly rural regions.

The main difference from the original OECD classification is the statistical unit of reference. Instead of using LAU 2s, the OECD-EUROSTAT uses the population share of rural grid cells.

This method resolves two types of distortions. The first is connected to the large variation in terms of area of LAU 2 local administrative units in Europe. Some municipalities are too extended; others are too small. Moving straight from the grid to the regional level circumvents the distortion associated with the variable size of LAU 2s. The second distortion is due to the large variation in size of NUTS 3 regions, and the practice in some countries of separating a small city center from the surrounding region. This method proposes a different approach to resolve the problem of excessively small NUTS 3 regions, by combining those smaller than 500 km^2 with their neighboring NUTS 3 regions.

By resolving these two distortions, this approach can be applied uniformly to all NUTS 3 regions in the EU. Figure 1 here and Table 1 in the annex illustrate the characteristics of this new method and its application to European territory. The map that emerges from Italy is of a country characterized by the presence of intermediate and mainly rural territories, where urban areas are confined to a few territories around Milan, Turin, Rome, Naples, and Palermo.

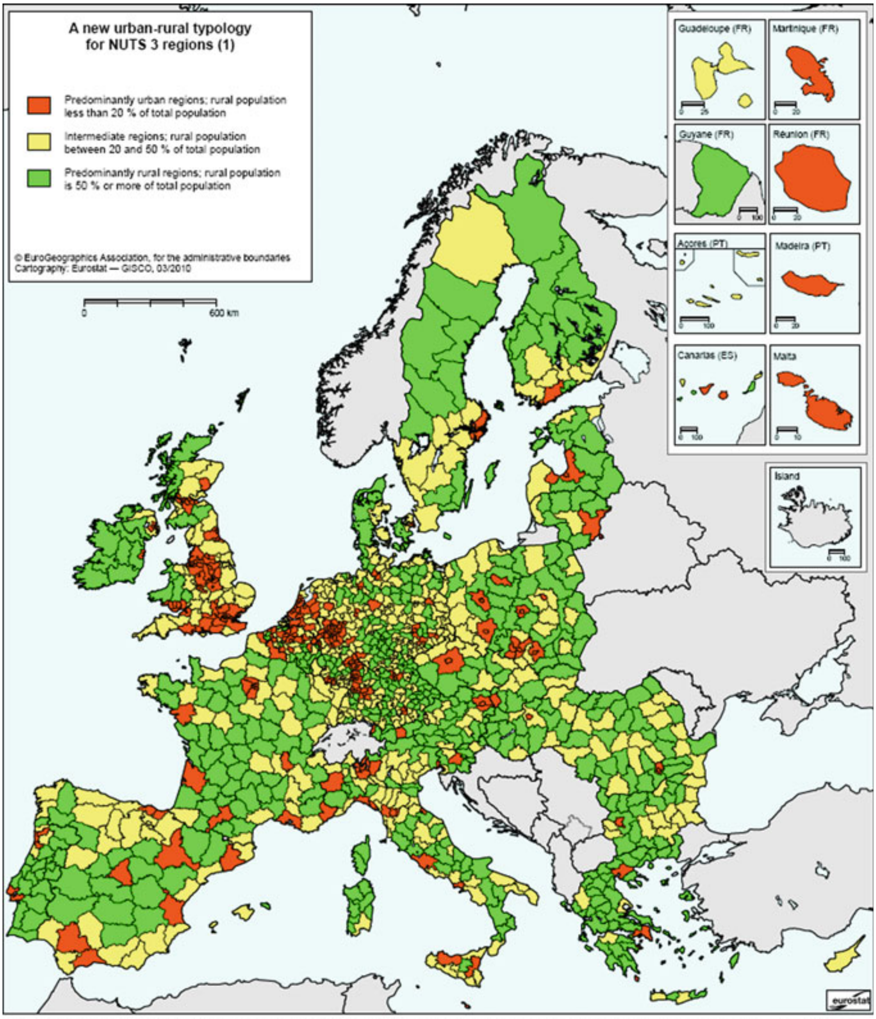
In this country, it has replaced a method that has been used for many years by ISTAT and that allowed Italian municipalities to be differentiated based on the degree of urbanization (ISTAT 2017). This previous method distinguished rural from urban municipalities based on population density. Municipalities with less than 100 inhabitants per km^2 were considered rural, while those with more than 100 urban inhabitants were classified as urban (ibid.).

[1]This classification involves two steps:

- defining rural local administrative units level 2;
- based on the population share in rural LAU 2s, classifying the regions.

It classifies LAU 2s with a population density below 150 inhabitants per km^2 as rural. Due to the heterogeneity of size in area of LAU 2s, some LAU 2s will be incorrectly classified. Subsequently, it classifies regions as predominantly urban, intermediate or predominantly rural based on the percentage of population living in local rural units. A NUTS 3 region is classified as:

- predominantly urban (PU), if the share of population living in rural LAU 2 is below 15%;
- intermediate (IN), if the share of population living in rural LAU 2 is between 15 and 50%;
- predominantly rural (PR), if the share of population living in rural LAU 2 is higher than 50%.



(1) This typology is based on a definition of urban and rural 1 km² grid cells. Urban grid cells fulfil two conditions: 1) a population density of at least 300 inhabitants per km² and 2) a minimum population of 5 000 inhabitants in contiguous cells above the density threshold. The other cells are considered rural. Thresholds for the typology: 50% and 20% of the regional population in rural grid cells.

For Madeira, Açores and the French outermost regions, the population grid is not available. As a result, this typology uses the OECD classification for these regions.

Fig. 1 A map of urban–rural typologies for European NUTS 3 regions according to OECD-EUROSTAT method. *Source* EUROSTAT (2018)

4.2 Methods Developed by National Government Institutions

In their National Strategic Plan for the 2007–2013 period, the Italian government adopted an urban–rural classification method like the original OECD method. It consists of four phases. The first involves the selection of all Italian municipalities with more than 150 inhabitants/km^2, which are considered urban poles. These municipalities represent the most important urban centers based on the concentration of non-agricultural activities and population. The second phase involves application of the OECD method to the remaining municipalities to identify those predominantly urban (population rural municipalities <15% of total population), significantly rural (population of rural municipalities >15% and <50% of total population), and predominantly rural municipalities (population of rural communes >50% of total population). In the third phase, the method rearranges these municipalities according to their altitude and the incidence of the importance of agriculture. Specifically, it differentiates municipalities within each province, by altitude zone and, for each of these three zones (plains, hills, and mountains), calculates the incidence of population municipalities classified as rural in the overall population. This is a novelty compared to the OECD method and others previously adopted. At the end of the final phase, the method identifies four different typologies of territories (urban poles, rural areas specializing in intensive agriculture, intermediate rural areas and rural areas with development problems). Figure 2 demonstrates the cartographic application of this method.

For the subsequent 2014–2020 programming period, the Italian Government refined this classification. Specifically, it has continued to consider the three different areas in terms of altitude (mountain, plain, and hill) with the four categories of territories obtainable by applying the OECD methodology. Unlike in the previous period, however, it now performs a fine-tuning process at a regional level with local administrations following the matching procedure. This process involves bilateral negotiation with local administrations to finalize and refine the territorial classifications resulting from application of the matching procedure, so that it more accurately describes the diversity of the local urban and rural areas. Figure 3 illustrates the result of applying this method, which does not produce a map not dissimilar to the previous one. Some differences do exist, however, particularly in Calabria and southern Italy, more generally.

In the same period, the Department for Economic Development and Cohesion developed the Strategy for Inner Areas, containing a series of measures for the promotion of territories defined as inner areas based on certain economic criteria. The method for identifying inner areas is based on the belief that these territories are characterized by inadequate supply of public services, but extensive availability of natural assets (water resources, forests, natural landscape, etc.) and cultural resources (craft centers, archaeological settlements, etc.). It applies a two-step approach that does not use demographic criteria.

First, it identifies single or multi-service centers as those municipalities that offer an exhaustive range of secondary schools, at least one highly specialized hospital and a "silver standard" (not small) railway station. Secondly, it defines the remaining municipalities according to their distance from these centers as:

- Belt areas—up to 20 min from the centers.
- Intermediate areas—between 20 and 40 min away.
- Remote areas—between 40 and 75 min away.

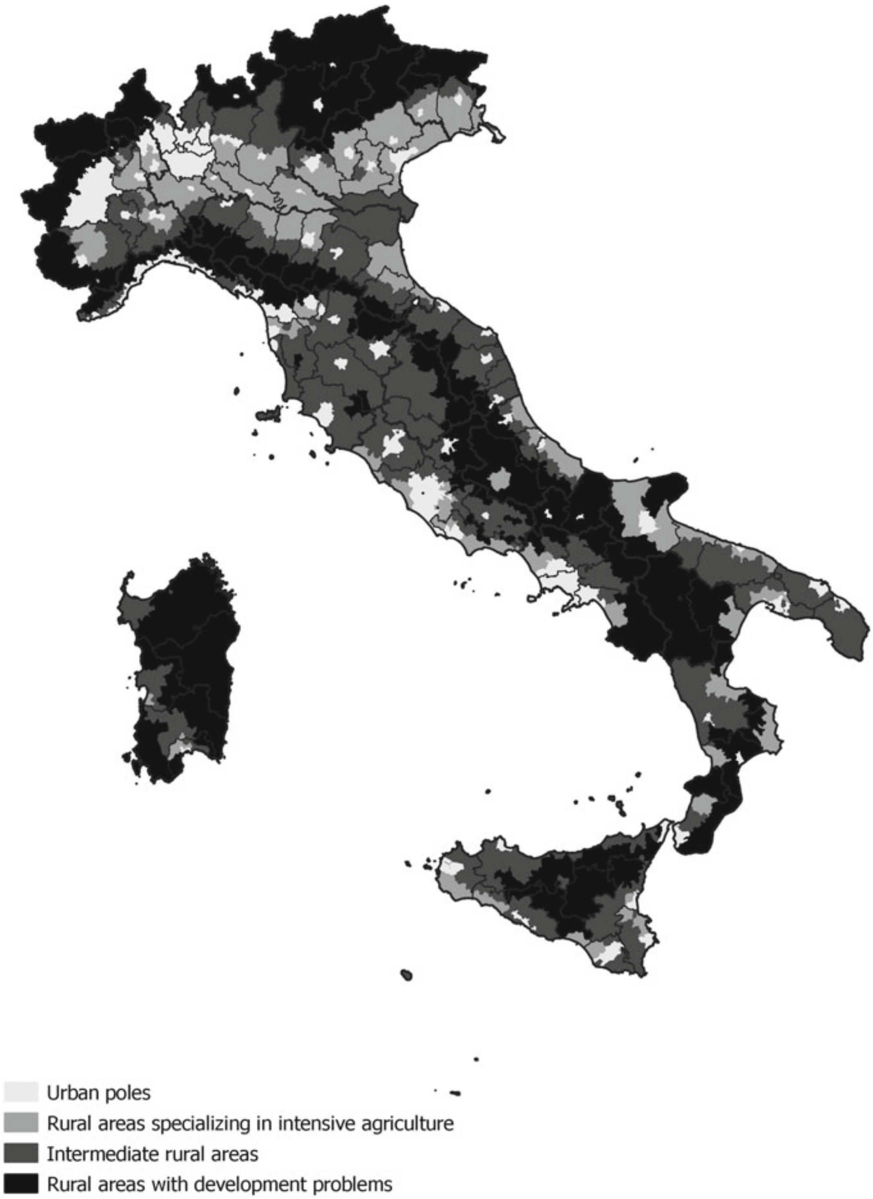


Fig. 2 A map of Italy according to the PSN 2007–2013 method. *Source* Italian Government (2007)

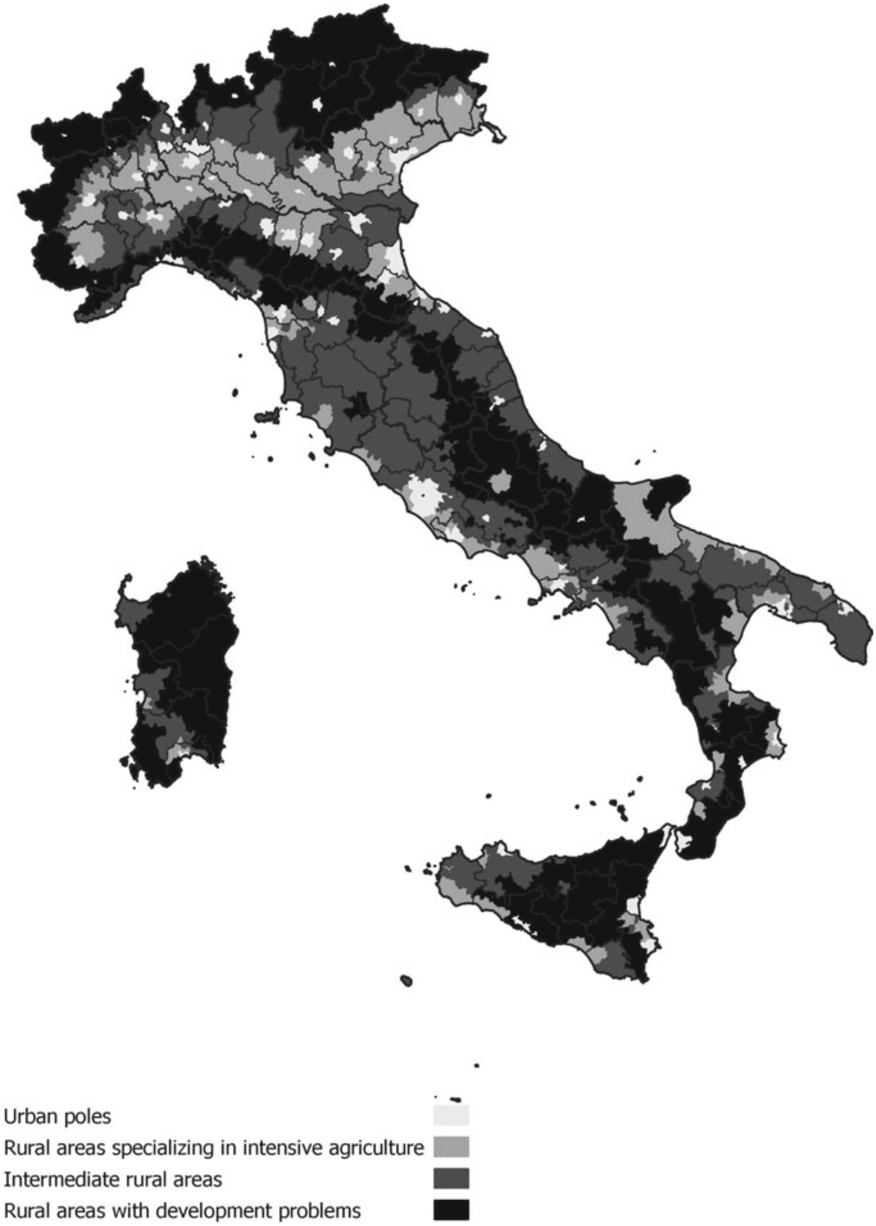


Fig. 3 A map of Italy according to the PSN 2014–2020 method. *Source* Italian Government (2014)

- Ultra-remote areas—over 75 min away.

The last three categories constitute the inner areas and are mapped in Fig. 4.

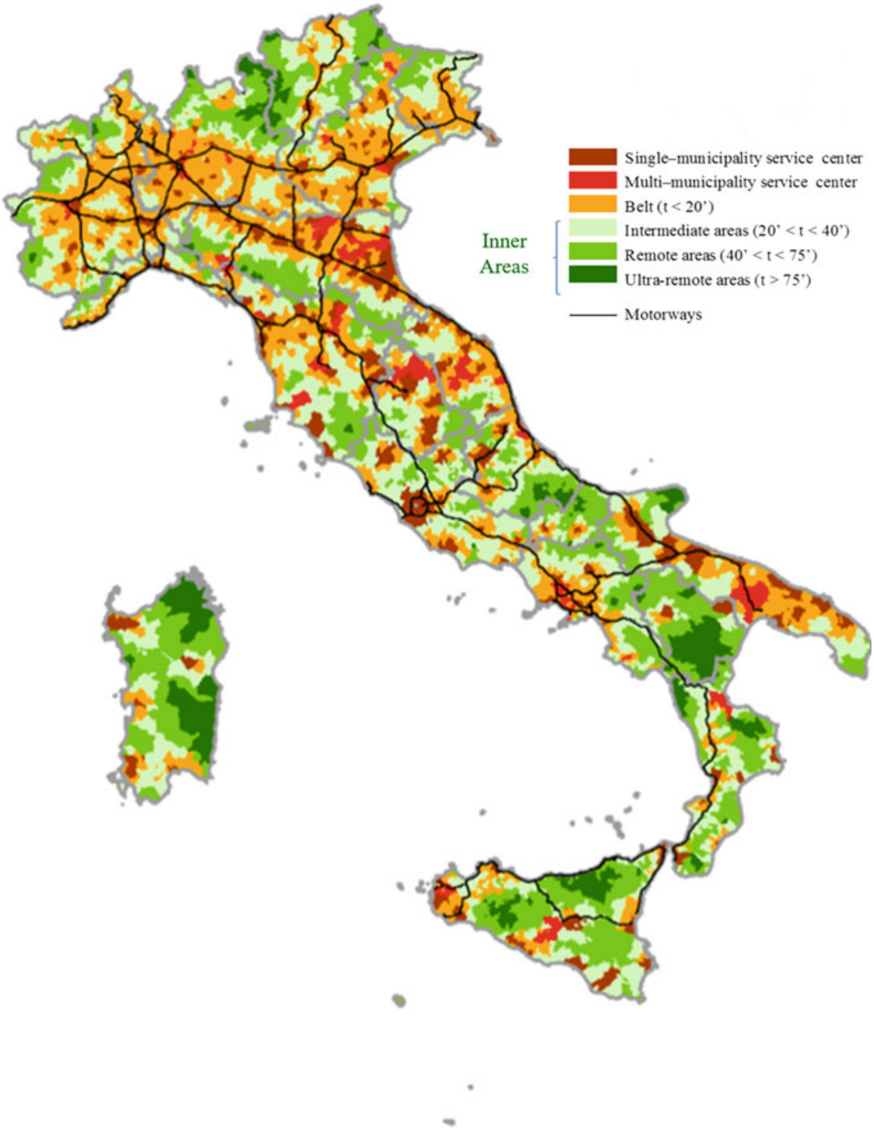


Fig. 4 A map of Italy according to the inner areas approach. *Source* Dipartimento per lo sviluppo e la coesione economica (2013)

Most mountain areas are considered inner areas and, specifically, remote and ultra-remote areas. The Po valley is mapped more accurately than other territorial representations.

In 2014, the Ministry for Agricultural Policies, together with the National Rural Network, developed a method for defining rural territories, which would form the basis for defining the Leader strategy for start-up programming. This method does not consider the grid or the municipality as a reference statistical unit, instead considers the Gruppo di Azione Locale—Local action group GAL/LAG. LAGs are inter-institutional groups to which all the public and private actors in a group of contiguous municipalities belong. The method combines indicators concerning morphological, sociodemographic, and economic dimensions and clusters each municipality in the corresponding GAL/LAG. The morphological dimension is measured by some indicators related to the physical-territorial system, such as the municipal average size and the percentage of protected area in the total regional protected area. The sociodemographic dimension is defined by indicators related to the sociodemographic system, such as the average population size, the percentage of the population present in the total regional population, the aging index and the depopulation measure (1997–2007). The economic dimension is structured around some indicators like the employment in the most important economic sectors (agriculture, industry, and services ones), the dependency ration, the firms' average size, and the average size of a utilized agriculture area. Figure 5 here provides a more comprehensive graphic explanation of this method.

This method does not replace the territorial distinction applied in the 2010 National Atlas of Rural Territory, based on demographic dynamics and travel distances. Specifically, this distinction identifies two main categories (urban and rural areas) and other specific ones, such as metropolitan areas, important cities and local systems of cities with at least 250,000 inhabitants, other central municipalities, intermediate areas and internal and outermost areas. Compared to other methods, it very accurately details the territorial diversity of central Italy, as well as the urban structure and system of inner areas in the rest of the country. Figure 6 displays a graphical representation of this method.

5 Discussion

Urban–rural typologies represent an important means of categorization to methodologically support scholars to read territorial diversities and transformations and provide a framework for national and regional policymakers to target economic and social policies at a territorial level. Due to their importance, there have been many attempts in recent years to define them more accurately. This has also happened in Italy, where the highest number of methods have been developed in the 2005–2020 period. Here, however, research was fruitful in the earlier years of that period, while work in later years was limited to adapting or revising the methods tested in previous years.

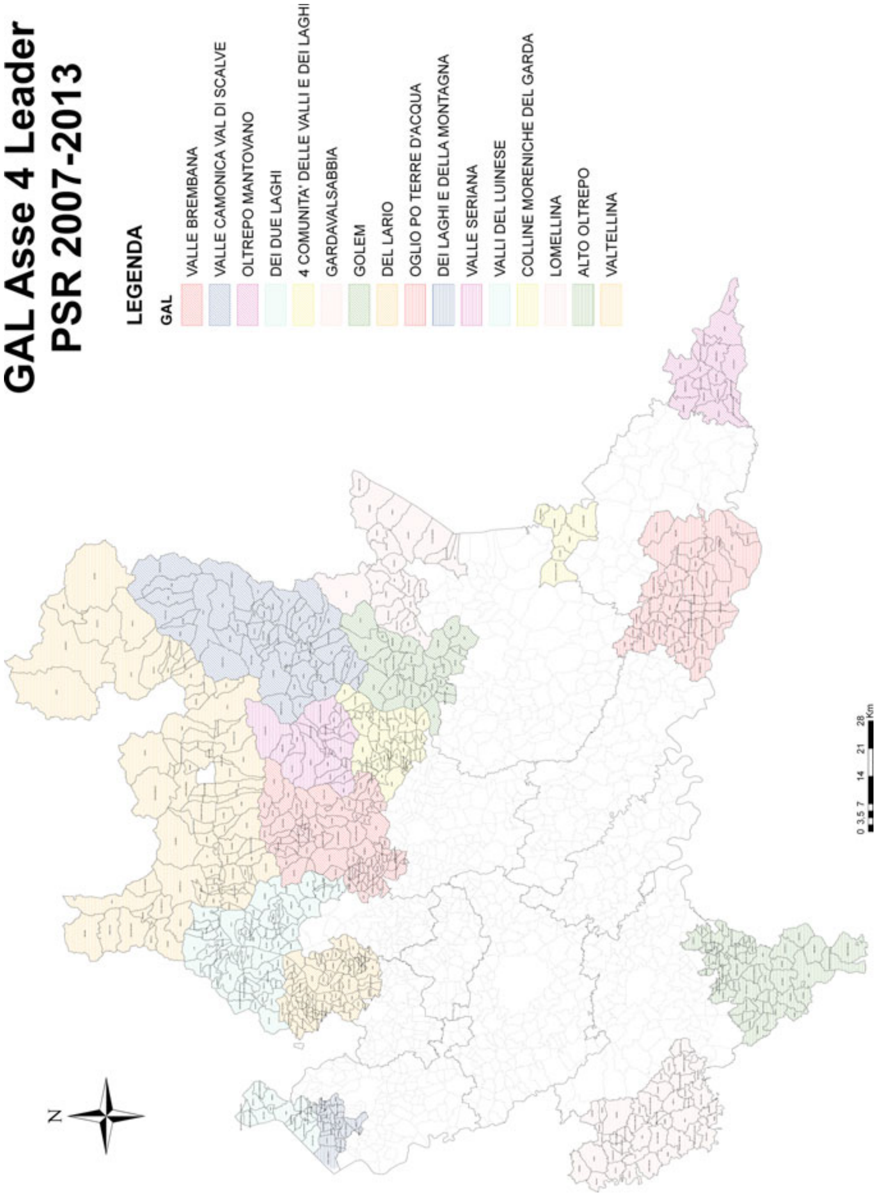


Fig. 5 A map of Lombardy according to the GAL/LAG leader approach. *Source* Regione Lombardia (2014)

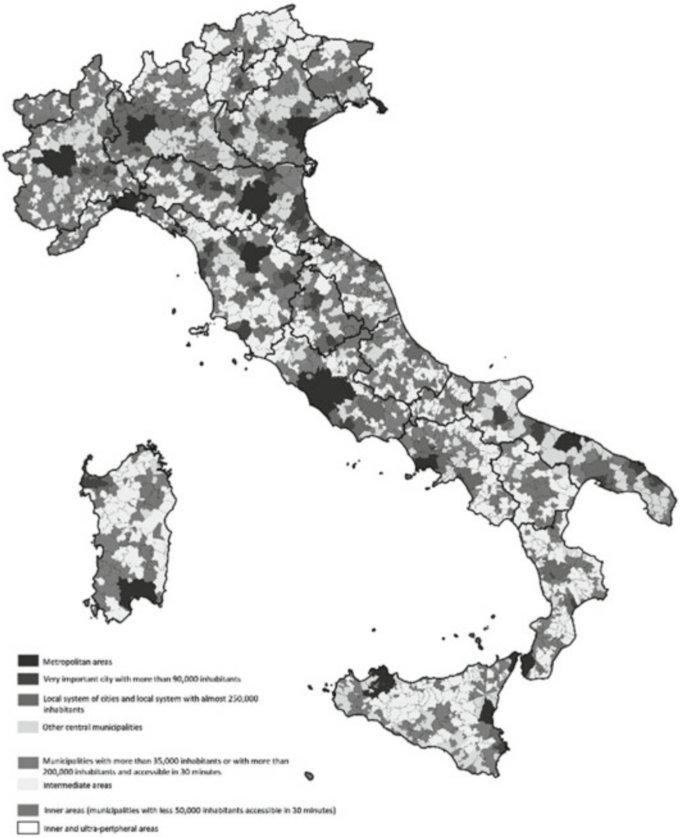


Fig. 6 A map of Italy according to Rete rurale nazionale. *Source* Rete rurale nazionale 2010

The obligation to adopt the OECD-EUROSTAT method to produce official statistics has certainly discouraged the development of new methods. In addition to being compulsory, this method is easily applicable across Europe and resolves distortions linked to the size of the various administrative units thanks to recent corrections. The method is, in fact, based on elementary statistical units (grid and municipalities) and map territories at the lowest possible territorial level, while only partially considering administrative boundaries (through the reaggregation of grids according to administrative boundaries). This approach reveals an aspiration to describe territories and their dynamics beyond their administrative boundaries. To this end, it abandons the traditional dichotomous categorization method of identifying just two categories of territories—urban and rural—and introduces a third category, which could be proxied to the intermediate territories or the continuum between urban and rural areas. The identification of these categories only involves applying demographic thresholds, while excluding other economic and morphological indicators. By only adopting three categories, the method offers a framework to produce uniform statistics and compare countries, but it is unable to accurately map territorial diversities. It is inspired by simplicity and comparable principles.

Although this method is mandatory, National Government Institutions have preferred to adopt specific and territorial-targeted methods to map their territories. The latter take a different perspective. While the statistical methods illustrated above are based on a dichotomous approach, the territorial-targeted methods are based on equality between territories or are built with the specific objective of mapping part of them and focusing mostly on rural (Ministry of Agriculture and National Rural Network) or inner areas (Strategy for Inner Areas). Consequently, instead of the traditional two, these methods identify four (PSN 1 and PSN 2), six (Inner Strategy), or eight (Atlas) territorial categories. Indeed, the specific distinction they adopt informs/influences policymakers' decisions as to which development policies to implement and how much funding to allocate to different territories. In this sense, territorial categorization is a prerequisite for proper decision-making as regards development policies and allocation of financial resources to territories lagging in terms of development. These methods offer more accurate territorial representations, above all concerning the mapping of the continuum, and use the municipality as a statistical unit of reference because more data are available at this territorial level. Only the Ministry of Agricultural Policy and the National Rural Network attempt to experiment with a new territorial unit, the LAG. This decision is motivated by the fact that rural policies, including European ones, are based on this unit. To offer accurate representations, these methods therefore employ a large variety of mainly economic, social, morphological, and accessibility indicators, and combines them with demographic ones. They then adopt more sophisticated statistical techniques, such as principal component analysis and multivariate analysis.

6 Conclusion

This paper offers an overview of the urban–rural methods formulated and implemented by statistical and governmental institutions over the last 15 years in Italy.

Some years ago, these actors began questioning the urban/rural dichotomy, proposing a multi-scalar approach and focusing on patterns of territorial continuity, thus challenging the framework based on traditional administrative boundaries. This led to an overproduction of classifications and definitions, which mapped the territories differently. Nevertheless, the OECD-EUROSTAT method remained the most widely used for official statistics and academic reports, and we are still far from the adoption of a single method of classification that describes all territorial diversities.

This has discouraged Italian scholars, who in recent years have stopped developing new methods. In order to relaunch the debate in light of the incessant peri-urbanization of the Italian territory, it is worth bearing in mind that each method offers a different territorial representation that depends, in turn, on the chosen statistical unit, the territorial categories defined and the methodology used. The choice of municipality or grid as statistical unit highlights a preference for simple, but accurate, representations, or the availability of data. Opting for others such as the LAGs reflects a desire not only to map the territories, but also to consider the economic relations between them. The definition of territorial categories is also crucial because the accuracy of the method depends on it. The adoption of a high number of categories is a sign of the capacity of the method to capture territorial diversity, while a low number indicates a desire to take a dichotomous approach. The choice of simple or complex statistical methods depends on the availability of variables and the degree of understanding of those who apply them.

Differences among methods depend on the combination of choices related to these three variables. It is not, however, possible to establish a priori which method is best or most representative of the territorial characteristics, but merely which is more in line with the objectives set by the experimenter.

When producing statistics or performing comparisons among territories, it is preferable to use a simple method, with few variables and territorial categories, as a basis. This is the case of ISTAT, which for these reasons favors the OECD-EUROSTAT method based on population density and includes just three categories. If the objective is to capture territorial diversity or develop territorial-targeted policies, however, then more complex methods, such as those adopted by government institutions or scholars, are more effective.

Future studies should investigate the differences between the various representations and calculate how much of the Italian territory is mapped differently. They could also extend the use of the grid to more complex methods or experiments with new statistical units, by regrouping different grids and municipalities. Finally, they should more accurately map the differences among peri-urban territories.

Appendix

See Table 1.

Table 1 A summary of the considered methods

Method	Spatial unit	Basic element of classification	Purpose	Territorial typologies	Bibliographical references
OECD-EUROSTAT method	Grid	Population dynamics	This method maps Europe to produce comparable statistics	• Predominantly urban regions • Intermediate regions (which proxied peri-urban or urban–rural continuum) • Predominantly rural regions	EUROSTAT, OECD (2011). *Urban–rural typologies*. Bruxelles: EUROSTAT
Italian Government—PSN 2007–2013 method	Municipalities	Population density, altitude, economic specialization	The method aims to produce a territorial classification for inclusion and use in the PSN draft	• Urban poles • Rural areas specializing in intensive agriculture • Intermediate rural areas • Rural areas with development problems	Italian Government (2007). *PSN Piano Strategico Nazionale*. Rome: Italian Government

(continued)

Table 1 (continued)

Method	Spatial unit	Basic element of classification	Purpose	Territorial typologies	Bibliographical references
Italian Government—PSN 2014–2020 method	Municipalities	Population density, altitude, economic specialization	The method aims to revise the previous classification included in PSN 2007–2013	• Urban and peri-urban areas • Rural areas specializing in intensive agriculture • Intermediate rural areas • Rural areas with development problems	Italian Government (2014). *PSN Piano Strategico Nazionale*. Rome: Italian Government
Inner areas approach	Municipalities	Population dynamics, commuting flows, distances and services availability	This method aims to map the inner areas	• Belt areas • Intermediate areas • Remote areas • Ultra-remote areas These last three categories constitute the inner areas	Website: programmazioneeconomica.gov
Italian Government—GAL/LAG leader approach	GAL/LAG	Morphology, socio-demographic and economic system	The method drafts a territorial map of areas eligible for inclusion in the leader program	Membership or exclusion to a particular LAG/LAG	Rete Rurale Nazionale, Ministero delle Politiche Agricole, alimentari, forestali e del turismo (2014). Approccio Leader Schede cartografiche e statistiche: modalità di elaborazione e di calcolo - fonti. Rome: Rete Rurale Nazionale, Ministero delle Politiche Agricole, alimentari, forestali e del turismo

(continued)

Table 1 (continued)

Method	Spatial unit	Basic element of classification	Purpose	Territorial typologies	Bibliographical references
Italian Government—Atlas for rural territory	Municipalities	Population dynamics and travel times	To build a new specific mapping method for Atlas for rural territory	• Metropolitan city • Very important city with more than 90,000 inhabitants • Local system of cities and local system with almost 250,000 inhabitants • Other central municipalities: municipalities with more than 35,000 inhabitants or with more than 200,000 inhabitants and accessible in 30 min • Intermediate areas • Inner areas (municipalities with less than 50,000 inhabitants accessible in 30 min) • Inner and ultra-peripheral areas	Rete Rurale Nazionale, Ministero delle Politiche Agricole, alimentari, forestali e del turismo (2010). *Atlante Nazionale del Territorio Rurale*. Rome: Rete Rurale Nazionale, Ministero delle Politiche Agricole, alimentari, forestali e del turismo

Source Own elaboration based on literature review 2020

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Diagnosis of the State of the Territory in Flanders. Reporting About New Maps and Indicators Differentiating Between Urban and Rural Areas Within Flanders

Ann Pisman and Stijn Vanacker

Abstract Within the several European analyses of spatial patterns, Belgium and Flanders take a specific position. The average 'settlement area percentage' (i.e., all land used beyond agriculture, semi-natural areas, forestry, and water bodies) for Europe is 4%, but 32% of the Flemish area is occupied with artificial land. Belgium has the highest score for urban-sprawl indicators, and within the European context, almost the entire area is considered urban. The aim of the research presented in this paper is to expand on the theme of indicators for spatial patterns by analyzing the Flemish area with detailed data across various scales. The results are collected in a report, the '*Ruimterapport*'— 'RURA', published in 2018. RURA is a bundling and compilation of research results from very diverse sources, amongst others studies from the Department of Environment and Spatial Development of Flanders and of Espon studies. This article presents the most important results from RURA and further positions them in international comparative literature. New maps and indicators are developed for the urban/peri-urban/rural dimensions of the human settlement area, urban sprawl, and settlement patterns by differentiating amongst others between urban centers, ribbon development, and scattered buildings. The paper gives a quantitative, methodological, and empirical contribution to the field of urban and regional development processes and contributes to conceptualizations of space. The case of Flanders, with its specific sprawl pattern, illustrates the difficulties spatial planning policy makers currently are facing, dealing with the complexity of space and society.

Keywords Urban/peri-urban/rural dimensions · Indicators · Land use · State report

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_14

1 Introduction

In international analyses of spatial patterns, Belgium and Flanders often stand out. A few examples to illustrate this follow. The average 'percentage of land take' in 2013–2015 [= all land used by man and thus not for agriculture, semi-natural areas, forestry or water-covered (European Commission 2012)] for Europe is 4% (Eurostat E4.LUCAS (ESTAT) 2015), but amounts to 32% for Flanders (Poelmans et al. 2016b). In various analyses, almost the entire Belgian and Flemish territory is considered urban (Copus and Hörnström 2011; ESPON 2013 Programme Coordination Unit 2013), despite the fact that there is also a lot of rural area in Europe and in Belgium. Moreover, because Flanders and Belgium have a limited surface area, much of the diversity within the territory is lost.

Because of the specific (average) characteristics of Flanders and Belgium and also to gain even more insight into the differences within their own territory, RURA, '*Ruimterapport Vlaanderen*', was developed in 2018 (Pisman et al. 2018). The report contains many spatial analyses: descriptions of the occurrence of certain activities in the field; how spatial patterns have changed over time; and what evolution can be expected. This article presents the most important results from RURA and further positions them within the international comparative literature.

RURA is inspired by indicators from the 'Compendium for the Environment' (the Netherlands) (https://www.clo.nl), by indicators collected by the European Environment Agency (https://www.eea.europa.eu/soer), by the '*Diagnostic Territorial de la Wallonie*' (CPDT Conférence Permanente du Développement Territorial Wallonie 2011), by a comparative report in France (Cget 2015), etc.

The common thread running through the report is the far-reaching fragmentation of space. Flanders is characterized by high land take, a significant rate of development, many urban and rural centers and building concentrations, large dwellings with limited building height and relatively large-scaled gardens, facilities, and businesses scattered throughout the territory, small agricultural plots, many trees but relatively few forests, lots of solar panels scattered on the roofs of many private structures, etc. This fragmentation creates many challenges for the future, such as providing sufficient drinking water, switching to renewable energy sources, reducing car mileage and promoting sustainable travel, optimizing the energy efficiency of existing buildings, etc.

2 Methodology

RURA is a bundling and compilation of research results from very diverse sources. Every year, the Department of Environment and Spatial Development launches a research agenda resulting in dozens of research reports. The studies are both qualitative and quantitative and cover various topics, ranging from policy explorations to in-depth studies in which, for example, model-based analyses are carried out. Many of these research reports have provided insights for RURA. On the other hand, we did make grateful use of many Espon studies (https://www.espon.eu), which made benchmark analyses between the various European countries that enabled comparing the results of Flanders with European averages or extremes.

The land-use map of Flanders, a grid map with 10-m resolution indicating the dominant land use for each pixel, has multiple uses. The land use refers to the effective use of land for specific activities or crops, such as farming, grass cultivation, but also housing, industry and services, recreation, etc. Of course, the land use of a location is not necessarily identical to its zoning in a legally binding zoning plan. Land can be zoned as a residential area, but effectively used as grassland or arable land. In the industrial sectors, for example, land use also includes water. In RURA, the data from the land-use database of 2013 have been used. The land-use file is drawn up on the basis of mainly vector operations, but, in the final steps, it is converted to a grid file at 10-m resolution (Poelmans et al. 2016a). European datasets on land use, such as CORINE and LUCAS, and on other themes are of course also available, but very often, due to limited geographical accuracy, they do not allow a more detailed spatial analysis to be carried out within Flanders.

The research methods used in RURA are very diverse. Broadly speaking, this can be regarded as mixed-methods research in which qualitative and quantitative research methods are combined. The exploratory method dominates. A phenomenon (such as sprawl, urbanization, underuse of houses, etc.) is investigated by means of a literature study from various sources. If data were available, this phenomenon was further explored by means of quantitative analyses and mapped, incorporating statistical and GIS methods.

The maps can be displayed at various resolutions, depending on the scale of the phenomenon and/or the geographical accuracy of the data. The RURA contains maps with indication of point locations (individual addresses), indication of spatial differences on-grid scales, on the scale of cadastral parcels, statistical sectors, and municipalities. The urbanized—urban—rural typology has as its resolution the statistical sector. This accuracy makes it possible to distinguish more or less urbanized neighborhoods (within a municipality). The center-ribbon-dispersed typology is based on differences between cadastral parcels. This approach, therefore, labels each parcel and makes clear for each parcel whether it belongs to a larger whole of parcels with similar characteristics or not. Finally, the sprawl typology uses a grid analysis with a resolution of 1 ha. These grids are sometimes larger and sometimes smaller than the cadastral parcels in the center-ribbon-dispersed typology. This alternative approach makes it possible to discover spatial differentiation within large, only partly built-up plots.

3 Diverse Spatial Typologies for Flanders

The purpose of RURA is to describe the spatial appearance and functioning of Flanders, not only on the basis of global characteristics but also on the basis of spatial differences within Flanders. Many reports describe divergences in Flanders between municipalities or provinces: examples are the municipal and urban monitor (https://gemeente-en-stadsmonitor.vlaanderen.be), analyses by VRIND (Vlaamse Overheid 2015) or the Belfius typology (https://research.belfius.be/nl/typologie-gemeenten). These administrative boundaries are not always spatially relevant. Within an urban municipality, for example, there is often both a city center and a peri-urban or rural periphery. Municipal indicators and analyses make abstractions of these various spatial environments.

For this reason, new spatial typologies were developed within RURA that make it possible to identify and describe spatial differences. The scale on which these typologies have been developed is obviously very decisive for the result. In this article, we will take a closer look at three spatial typologies, each of which has been identified on a specific, different scale.

3.1 Urban—Peri-Urban—Rural Flanders

Recent worldwide morphological development has generated new territories that are characterized by different degrees of urbanity. The traditional methods of classification based on the distinction between urban and non-urban areas are no longer functional to describe the territorial outcomes of these transformations. In recent times, scholars started questioning the urban/rural dichotomy, proposing a multi-scalar approach. Cattivelli (2019) distinguished, within Europe, more than 80 methods to describe the gradient between urban and rural areas.

In RURA, a rural–urban typology was developed specifically for Flanders (see Fig. 1). The intention is to frame the thematic analyses on housing, open space, etc. within a spatial context, making a distinction between 'urbanized Flanders', 'peri-urban Flanders', and 'rural Flanders'. Data on land take (morphology/human settlement area), population density, and employment density were combined. The threshold values were determined on the basis of European key figures and refined together with experts after an analysis of different map images and corresponding values.

The urbanized part of Flanders is characterized by:

- high land take ($\geq$32.5%, i.e., more than the average for Flanders)
- high activity rate: high population density and/or high employment density (population density $\geq$11.85 inhabitants/ha or more than average plus half the standard deviation, employment density $\geq$10.14 employees/ha or more than average plus half the standard deviation)
- contiguous, urbanized clusters with at least 15,000 inhabitants.

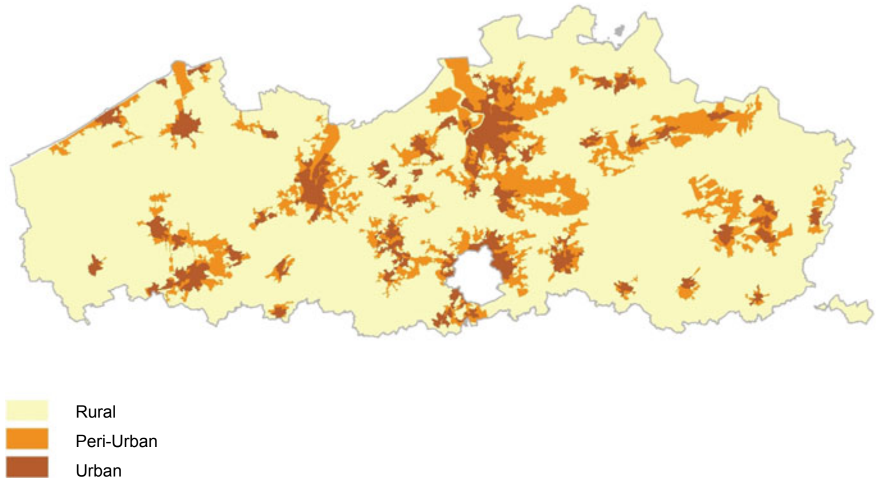

Fig. 1 Urban—peri-urban—rural Flanders (Pisman et al. 2018, Fig. 1.18: 34)

The peri-urban part of Flanders includes the area is defined by:

- high land take (≥32.5%, i.e., more than the average for Flanders)
- low activity rate, below the limits that apply to high activity rate.
- contiguous clusters adjacent to the urbanized area.

The rural part of Flanders has at least one of the following features:

- low land take, i.e., <32.5%
- high land take and a high degree of activity but not belonging to an urbanized cluster with at least 15,000 inhabitants
- high occupancy and less activity and not adjacent to an urbanized area.

The urbanized part of Flanders includes the statistical sectors which together form the city center of a large, regional, or small urban area, but also the industrial areas with a high employment density on the periphery of these city centers. The peripheral urban part of Flanders comprises sectors that are mainly characterized by human activities, but which nevertheless have a rather lower density of activity. Typical examples are the residential districts and built-up villages on the edges of the city centers. The rural part of Flanders contains sectors with scattered buildings, but also many village centers, or urban centers that do not meet the threshold of 15,000 inhabitants. The central part of Flanders is a patchwork of urbanized, peripheral, and rural areas. The periphery of Flanders has a more rural character. In Table 1, the key figures of the urban/peri-urban and rural part of Flanders are displayed.

Table 1 Key figures of the urban/peri-urban/rural typology

	Urbanized (%)	Peri-urbanized (%)	Rural (%)
Covered area	7	13	80
Inhabitants	41	20	39
Households	44	20	37
% Built-up	20	8	2
% Sealed	50	26	9
% Land take	85	61	23
% Agriculture/forestry	10	33	75

3.2 Centers, Ribbon Development and Scattered Buildings

The settlement pattern of Flanders is dominated by many scattered buildings and by ribbon development. The ribbons in Flanders were mapped in an analogue way for the first time in 1993 (Larnoe 1993; Janssens et al. 1993). At that time, the Flemish landscape was already to a large extent characterized by ribbon development, with the exception of the coastal polders and the southern part of the province of Limburg. On the maps, both ribbons radiating from human settlement areas, as well as more isolated ribbons that form the basic structure of the built-up environment, were distinguished. More recently, the Flanders Environment Agency (Gulinck et al. 2007) and the Resource Center for Spatial Development and Housing ('*Steunpunt Ruimte en Wonen*') (Tempels et al. 2011), among others, attempted to portray the settlement pattern of Flanders.

The Flanders Environment Agency detected sprawl based on maps and satellite images from different periods. Within the framework of the Resource Center, a GIS methodology was developed to distinguish between residential areas (as defined by the NIS), ribbons, and scattered buildings. De Meulder et al. (1999) point to the historical reasons for the typically Belgian form of urban expansion, encouraged and facilitated by the construction of the extensive railway network and the early introduction of cheap train tickets. De Decker (2011) stated that Belgian urban sprawl and dispersed buildings are related to an institutionalized anti-urban attitude on the part of both citizens and the government, whereby access to urban facilities is decoupled from living in the city, at least in a psychological sense. Furthermore, this is also related to the long tradition of home ownership, which has led to social norms and expectations that are strongly determined by individual ownership and to housing aspirations which are easier to realize outside the city than in the city. The regional zoning plan, in which many residential areas to be developed have been zoned all over the Flemish territory, has also played a very decisive role in the further development of housing in Flanders (Verbeek et al. 2014).

In RURA a typology has been developed in which Flanders is divided into cores or centers, ribbons and scattered buildings (see Fig. 2). This methodology is inspired by the analyses carried out within the framework of the Resource Center. For the

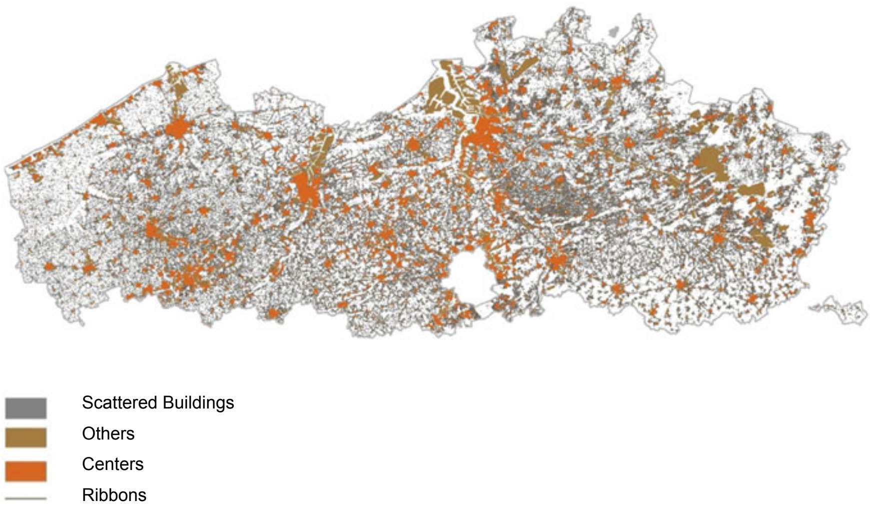

Fig. 2 Centers/ribbon development/scattered buildings in Flanders (Pisman et al., Fig. 1.26: 40)

morphological analysis, the geographical layer with the (main) buildings of the Large Scale Reference Database Flanders (state 2013) is employed. This includes housing units and apartments, but also sports halls, shops, storage space, etc. The typology is not related to legal zoning or future policy, and the analysis is not area-covering for Flanders. Military domains and the legally designated business parks of more than 3 ha, which are not completely enclosed by center-areas, are not included in the typology (about 6% of the surface area of Flanders, indicated as ‘others’ on Fig. 2). The threshold values for distinguishing the various categories were determined in consultation with experts after an analysis of various map images and corresponding limit levels. The typology has been elaborated to the scale of the individual cadastral parcel.

The centers are characterized by:

- High building density (>30 buildings within a 100-m radius)
- Substantive built-up area (>9500 m^2 within 100-m radius) or high density of households (>60 households within a 100-m radius)
- minimum total surface >5 ha
- minimum number of households >20.

The ribbons have the following characteristics:

- length >200 m
- built-up on one side of the road or on both sides of the road
- buildings situated relatively close to the road (<25 m) and close to each other (in-between distance <50 m). (This creates the impression of a built-up street wall and the view to the open area behind is limited.)

Table 2 Key figures of the centers/ribbons/scattered typology

	Centers	Ribbons	Scattered buildings
# Centers	1.485		
Length		13.000 km	
# Buildings			525.000
Inhabitants (%)	70	25	5
% Built-up	42	26	16
% Sealed	61	40	32
% Land take	95	100	100

Finally, the scattered buildings include all the main buildings that are not part of the centers or ribbons of Flanders. In practice, they are scattered in open space, or in small concentrations that do not meet the characteristics of a core or center, or they are built at a greater distance from each other and are therefore not perceived as ribbons. Table 2 shows the key figures of the centers/ribbons/scattered typology.

3.3 Urban Sprawl

In recent years, various international comparative reports on urban sprawl have been published (Bruegmann 2005; European Environment Agency 2006, 2016; OECD 2018). Although each report or analysis uses its own methodology and data, one constant remains: the sprawl in Flanders and Belgium ,in general, is high. The 2016 EEA report defines urban sprawl as the pattern in which larger areas are affected by single buildings or more extensive forms of low-density urban sprawl. The definition focuses on three issues: (1) urban sprawl refers to built-up areas, (2) which are scattered, and (3) in which the take-up of space by activities (number of inhabitants or employment) is high.

The three elements form 'sub-indicators' (PBA, DIS, and LUP) of which a product (= WUP) is finally made to yield one composite and integrated indicator of urban sprawl:

- WUP—weighted urban proliferation: weighted product of DIS, PBA, and LUP
- PBA—percentage of built-up areas
- DIS—dispersion of built-up areas: quantification of the dispersed nature of the built-up areas
- LUP—land used per inhabitant or workplace.

For years research has been conducted into the existence of urban sprawl in Flanders (De Decker 2011; De Geyter 2002; Poelmans and Van Rompaey 2009; Stec Group et al. 2018; Verbeek et al. 2014; Vermeiren et al. 2018, 2019).

Starting from the European approach (European Environment Agency 2016), but using more accurate data, WUP maps (resolution 1 ha) for Flanders were drawn up within the framework of RURA. In comparison with the European data, we can assume that a WUP value higher than 10 should be considered as urban sprawl. Approximately 44% of the Flemish land surface falls into this category and no less than 95% of the Flemish population lives in urban-sprawl areas. Only the centers of the largest cities and the larger open spaces and natural areas fall outside this category.

The WUP indicator is not so easy to interpret. An equivalent WUP value does not always refer to similar spatial patterns. Both areas with a lot of open space and locations with highly concentrated buildings have a low WUP value, and therefore have little or no urban sprawl. Very low and very high WUP values can be found correlated with different building, population, and employment densities. The WUP map was therefore crossed with data on activity levels (density of inhabitants and employment) to arrive at a more intuitive urban-sprawl typology consisting of four important categories: ‘scattered buildings’, ‘ allotments and ribbons’, ‘villages and peri-urban areas’ and ‘city centers’ (Pisman et al. 2019) (see Fig. 3).

Table 3 displays the key figures of the sprawl typology.

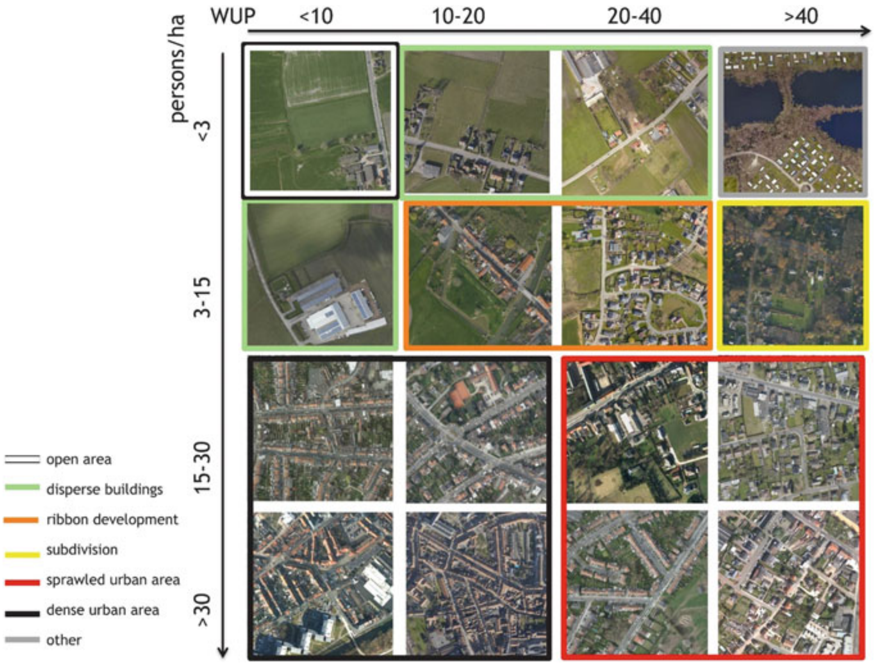

Fig. 3 Urban-sprawl types (Pisman et al. 2018, Fig. 9.10: 413)

Table 3 Key figures of the sprawl typology

	City centers	Villages and peri-urban areas	Allotments and ribbons	Scattered buildings
Covered area (%)	2	10	17	32
Inhabitants (%)	24	43	23	8
Density inhabitants (inh/ha)	59	20	6	1
% Sealed	67	47	30	9
% Land take	96	88	63	27
% Flats	20	10	0	
% Terraced houses	70	40	20	10
% Semi-detached houses	10	20	20	10
% Detached houses	10	30	60	80

4 Conclusions and Discussion

RURA collected and combined a great deal of new data related to the state of the territory in Flanders. Typologically, urbanized, peri-urban, and rural areas were distinguished; cores/ribbons and scattered buildings were mapped; and finally, areas with more or less sprawl were investigated. The three typologies were developed on different scales and resolutions, from different conceptual perspectives and using specific data. An important conclusion, however, is that within any area these three approaches should actually be combined. After all, for example, in a specific peri-urban area, both centers and ribbons may be located, and areas with a sprawl gradient may occur.

The analyses in RURA are currently frequently reproduced in other research reports. Nevertheless, there are still many challenges for the future. In our opinion, we list the three main challenges:

Challenge 1—update analyses and reflect evolutionary changes

RURA was published at the end of 2018 but mainly uses data referring to the status of 2013. In the meantime, we are already seven years further. It is therefore plausible that many things will have changed in the field. Although we know that there is some delay in making source material available, it should be possible already today to provide an update and describe evolution for a number of indicators. In any case, the intention is to launch an updated RURA 2.0 at the end of 2021, three years after the publication of the first Spatial Report.

Challenge 2—develop evidence-based policy

RURA is a status report, and, at present, the policy consequences are limited. At the same time, the Flemish authorities are actively working on a future Spatial Planning Policy Plan. In the documents of this Policy Plan (Departement Ruimte Vlaanderen 2017; Vlaamse Overheid 2012; Vlaamse Regering 2018), the policy objective to limit the land take in Flanders in the future has been made explicit. Implicitly, this also includes the objective of no longer increasing the dispersed built-up area in Flanders, and thus influencing the building typology. In the further operationalization of this policy aim, the insights from the Flanders Spatial Report can be used (more than is currently the case). In addition, the detailed information about the settlement fragmentation in Flanders can help to draw up feasible action lists to realize other objectives, such as switching to renewable energy sources and promoting sustainable commuting.

Challenge 3—revealing the underlying systems

Separate phenomena were often investigated in RURA. However, all phenomena are part of a larger whole or a system of spatial cause-and-effect relationships. A system analysis approach tries to answer the question of how the whole works by focusing on the processes that cause changes. The last chapter of RURA contains a system diagram, which is a strong simplification of reality, but illustrates how the phenomena occur together in space and how Flemish space has evolved over the last 50 years. The system diagram does not fully explain the current situation, but it does allow processes to be described and the possible consequences (desirable or undesirable) of the interaction between the various activities, the available space, policy, and external influences to be mapped out. The authors of RURA intend to focus even more on the coherence of the various phenomena in space in the future. In preparation for RURA 2.0, a scenario exercise and a system analysis of sprawl, among other things, will be elaborated.

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Thriving Governance and Citizenship in a Smart World: Environments and Approaches Fostering Engagement and Collaborative Action

The Evolution of the Planning System in Poland from Sectoral to Integrated Strategic Planning

Judyta Wesołowska, Małgorzata Mirecka, and Tomasz Majda

Abstract The paper focuses on the evolution of the planning system in Poland. Its purpose is to show the evolution from short-term planning, subordinated to the requirements of the country's economic development, to a long-term planning system, integrating various aspects of development—spatial, natural, economic, and social, taking place over the last century. The process described in the paper was largely conditioned by historical events, and the poor economic situation of the country in the post-war period and the changes taking place in the political system. The need for rapid economic development of the country dominated the planning of the interwar period (1920s and 1930s) and post-war period (1950s to 1970s), although the economic, social, and natural conditions were taken into account in 1930s spatial planning. The most complete representation of spatial integration of various planning scopes is visible in the "National Spatial Development Concept 2030," which was the main subject of the study, as the basic document concerning national spatial planning. The research demonstrates the novelty of this document in relation to previous ones. It is based on the vision of Polish space on, the development of functional areas, determined on the basis of socioeconomic and spatial features treated in a dynamic approach. The need for changes in applicable law that would allow the "National Spatial Development Concept 2030" to be implemented in planning practice is also pointed out. The material presented in the paper may form the basis for comparative studies of planning documents on a national level in various European countries.

Keywords Strategic urban-planning · Integrated-planning · Spatial-planning policy · Urban planning in Poland · Spatial planning · Green areas

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_15

1 Introduction

The greatest achievement of the UN World Commission on Environment and Development is defining and popularizing the idea of sustainable development. The document "Our Common Future" released in 1987 was followed by "Earth Summit 1992" in Rio de Janeiro with "Action Programme–Agenda 21" and finally "Habitat III, the United Nations Conference on Housing and Sustainable Urban Development," which took place in Quito, Ecuador, in 2016 and reinvigorated the global commitment to sustainable development, focusing on urbanization. These actions led to the acceptance of sustainable development over the last 20 years in Europe and culminated in the "Toledo Declaration" and the European Commission's report "Cities of Tomorrow—Challenges, Visions, Ways Forward" together with UE Urban Agenda and Amsterdam Pact in 2016, all of which stressed the need for a new approach to strategic regional planning.

A similar approach was already visible in pre-war Polish planning practice, but the specific evolution of the Polish development planning system is strongly determined by history. The main goal after regaining independence in 1918 was to ensure the cohesion of areas located for 123 years in partitions with completely different legal and economic systems. An integrated approach at the regional and national levels was the best opportunity for recovery—during World War I, the front passed through Polish land several times causing catastrophic destruction. The same need for cohesion followed World War II, but Poland did not get full independence until the 1990s; thus, the pre-war modern development planning system was influenced by the Russian economic approach. Attempts at integration continued but were doomed to failure.

The change in political situation in 1989 also affected the planning system. The change in the planning system was most strongly visible in the decision-making process for natural, green areas, especially in large urban regions, which faced planning challenges across different administrative jurisdictions, similar to the London Green Belt (Mace 2018). These areas on the edge of the city are the meeting point of urban and rural interests (Žlender and Ward Thompson 2017; Verdú-Vázquez et al. 2017), which in the Polish case caused a lack of proper protection and unplanned changes of the structure in both settings. The same problems appeared also in other post-communist countries in the last three decades (Boentje and Blinnikov 2007) and required a strong urban-planning process supported by clear policy acts to resolve the critical problems of urban development. The ideas of sustainable development and strategic, integrated planning are nowadays strongly visible by the goals set in almost all legal acts; the implementation of these ideas is continuously in transition to better meet the goals they lay out, with the same situation happening with all the Polish planning system.

2 Methodology

The subject of the study was an analysis of provisions in the field of spatial-planning policy in Poland from the 1920s to the present day, based on selected national-level planning study documents. The choice of selected studies depended on their innovation and/or the importance they had in shaping the current planning system. The analysis of these studies and regulations enabled drawing conclusions for further development of planning system towards a sustainable model and the role of studies on a national level in shaping the strategic integrated planning system in Poland understood as a continuous, long-term process that integrates various functional aspects at different spatial scales.

3 Results: Analysis of the Planning Policy System Since 1920 Until 2015 in Poland

The analysis of the Polish planning system over the last hundred years shows a strong dependence of development process on political conditions; therefore, the analysis was divided into four periods that are characterized from this point of view.

3.1 Planning Concepts on the National Level in 1920s and 1930s in Poland

The initial attempts to normalize spatial planning and management processes in Poland were made after regaining independence in 1918. The first legal act regulating land development was the "Regulation of the President of the Republic of Poland of February 16, 1928, on the Construction Law and Housing Development." It unified building regulations regarding land management and rules for urban-planning preparation. Urban-planning studies were undertaken at the national level in Poland before World War II, and the need for land-use planning processes on a larger scale resulted, among other things, in changes in the construction law. In 1937, the area of the urban plan was enlarged to a voivodship level (regional) or even several voivodships, which expanded the network of regional-planning offices. In total, ten districts were established for the development of regional plans. Planning at the national level was then the subject of interest on several levels, thus focusing on various directions: urban-regional, engineering, and economic. The group of regional planners emphasized the need to construct a regional plan based on guidelines taken from the national economic and spatial plan and to create regulations for a three-stage hierarchical planning system: local, regional, and national.

The so-called engineering trend was closer to today's strategic integrated planning and identified the need to link development to the deployment of production forces and to consider technical and economic potential of existing resources. In 1936, the national perspective plan focused on the need to industrialize the country and level out economic differences caused by the earlier division of Poland between Russia, Prussia, and Habsburg Austria. The "National Perspective Plan" was therefore treated as an economic plan with regional transformations, yet not as a spatial development plan (Czerny 1972).

3.2 Changes in the Planning System After World War II Until the Political Transformation of 1989

After World War II and until the political transformation in 1989, the hierarchy principle of planning was the most popular and led Poland's planning policy system. It was introduced by the "Decree of June 2, 1946, on the Planned Development of the Country" and then consolidated in the Spatial Planning Act of 1961 and 1984. A three-level planning system was used in which the national urban plan was at the top, and its arrangements were mandatory for regional and local plans. The Decree of 1946 did not vary significantly from other European planning standards; however, numerous loopholes allowed for decisions regarding space management to deviate from the set planning goals (Chmielewski 2006). The scope of the national plan according to the decree included the division of the country into regions; determined land-use for various needs; (1) population distribution and a network of major urban centers, (2) defining their functions, and (3) bases for development, such as transportation, power, and telecommunications network. In the first years after World War II, Poland had to deal with massive destruction and migratory movements, new borders, administrative imperfections, and a lack of basic input data for planning. Poland was largely focused on diagnosing the existing state and developing methods for elaborating the national plan. The starting point for the planning process was pre-war regional-planning concepts (especially "Warsaw Functional Concept") and theoretical systems of the Christaller's central place theory (Hsu et al. 2014). This was the basis for a prospective model of the settlement network and regionalization of the country (Toeplitz 1978) (Fig. 1). Unfortunately, due to the consolidation of the central management system and short-term planning focused on quick results in the post-war period, spatial planning implemented the state authorities' priorities, often without a connection to economic planning or the economic situation of the country (Chmielewski 2006).

From the 1950s until the1970s, the system of central governance was strongly visible in national development and departmental planning. The industry was a priority and played the main role in planning documents. The "Spatial Planning Act of 1961" maintained the hierarchy of plans and linked to economic planning even more. Regional urban planning was given a high priority, while eliminating the national urban plan—spatial planning on a national scale was carried out as part of "forward-looking plans for the development of the national economy." The purpose of spatial planning specified in the act set the stage for creating conditions to expand

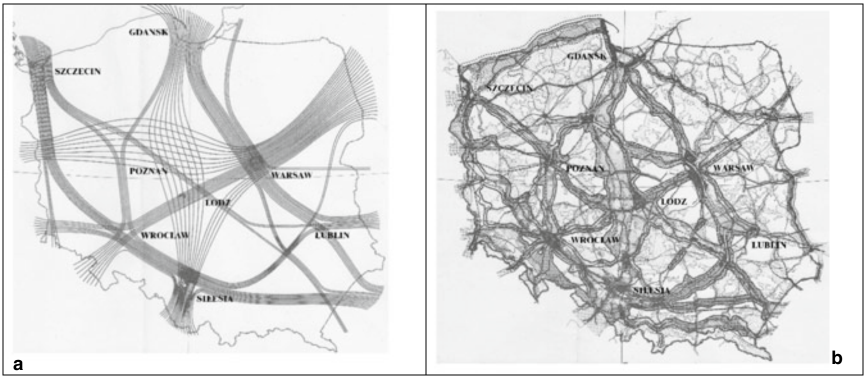

Fig. 1 The national plan of 1946 showing **a** development goals in urbanization net; **b** functional division of the country. Main development was focused in the intersection of transportation as a potential for optimal development, leaving the remaining land as rural and natural areas. *Source* Prepared by authors based on Toeplitz (1978)

the national production to meet the needs of the citizens and protect of the country's natural resources and its natural realm. However, the act lacked the tools to achieve these adopted goals, giving only written directives.

Despite the dominant position of socioeconomic planning from the 1950s to 1980s, one can also see improvements in the spatial-planning methods from this time period. The main achievements in spatial planning of these decades is the creation of new methods for analyzing development opportunities, such as Warsaw optimization and Threshold Analysis. The need for coordination of socioeconomic and spatial planning was noticed in the 1970s, which lead to the integration of the entire planning system (Secomski 1978).

The "National Spatial Development Plan until 1990" was begun in the early 1970s. At the same time, the basic assumptions for a prospective plan of the socioeconomic development of the country were made. The document was based on the interdependence of socioeconomic and spatial planning. The quantitative and qualitative assumptions were adopted from the socioeconomic development plan, mainly regarding demographics, employment, investment, and production, as well as indicators of meeting the needs of the population. The "National Spatial Development Plan" has become an extension of the socioeconomic plan by shaping settlement networks, the technical and social infrastructure grid, a basis for management of the natural environment resources and the directions of its framing, migration, urbanization processes and industrialization, and the use of agricultural/rural areas (Grabowiecki and Zawadzki 1978). Many authors referred to the importance of the plan, which focused on shaping the settlement network (Fig. 2), the goals and directions of socioeconomic policy in the regions, the development of industrial centers, the distribution of infrastructure and forming the agricultural regions (Różański 1979).

Reforms carried out in Poland in July 1975 changed the borders of its administrative regions. They introduced a new division of voivodships, decreasing their

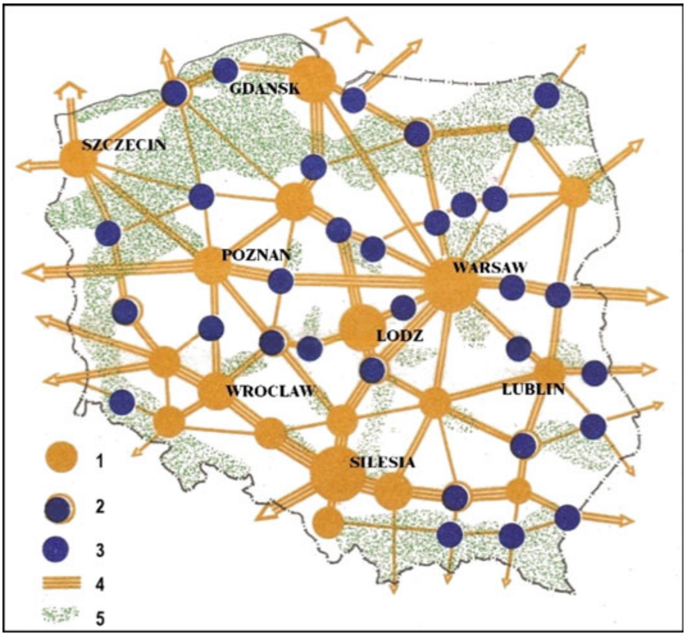

Fig. 2 Polycentric system of settlements of mitigated concentration; (**1**) agglomerations; (**2**) planned centers of development; (**3**) existing centers of development; (**4**) infrastructural connections; (**5**) recreation areas. *Source* Prepared by authors based on Grabowieck and Zawadzki (1978)

areas and dividing the country into 49 small territorial units. This helped integrate and increase the socioeconomic homogeneity of each unit. However, problems at the borders of these new units increased, and the regional plans was discontinued. Regional-tier planning departments had been closed, which caused several problems because their sphere of work also included study, diagnostic, and decision-making institutions. The scope of socioeconomic planning in the new units had been limited not only by the smaller area of planning, but also by time—only up to five years (Jędraszko 1981), thus losing the features of long-term strategic planning.

3.3 Spatial Planning of the Political Transformation Period (1980s and 1990s)

Changes in legal regulations regarding spatial planning in the following years were associated with adjustment to new political conditions (Borsa 2015). The transformations of the early 1980s gave more power to local governments and modifications in legal regulations followed. Because of the regional changes just mentioned, the planning system encountered significant changes. First, it was introduced by the "Spatial Planning Act of 1984," and then ten years later, in a completely new sociopolitical situation as the "Spatial Development Act of 1994." One of the objectives of the act from 1984 was to provide greater flexibility in spatial planning, more effectively linking prospective spatial planning with short-term socioeconomic planning. The obligatory interdependence of planning was introduced by law. The hierarchy of plans was mitigated by implementing some elements of the principle of consistency and giving lower-tier planners the right to submit applications for higher-tier plans. However, this rule did not work well in practice, and lower-tier plans continued to be adapted to those of higher-tier plans. The scope of the national plan included determining the natural, social, and economic conditions of spatial development of the country, as well as formulating the objectives and principles of spatial policy, in relation to regional diversity (Jędraszko 2005).

The "Spatial Planning Act of 1994" obliged public authorities to incorporate the economy and the significant role of local government and protection of civil and property rights in spatial planning (Fijałkowski 1994). It radically changed the comprehensive approach to planning, eliminating the regional level of planning and transferring virtually all planning power to the hands of self-governing and independent municipalities. The concept of the national spatial development policy was prepared at the national level and related to the national development strategy. On the regional tier, the regional spatial development study and government task programs were to serve the implementation of supralocal public goals. None of the mentioned studies of spatial-planning documents became applicable law, but rather played an informative and coordinating role (Kachniarz and Niewiadomski 1994). In this way, the principle of hierarchical construction of the planning system throughout the country was broken, and the only local act in the field of spatial planning became the municipal local plan. An amendment to the law on spatial development, carried out in 1999, returned the regional level of planning, which was associated with the change of regional administration borders and the new administrative division of the state. Drafted in accordance with the "Spatial Planning Act of 1994," the "Concept of the National Spatial Development Policy of 2001" was based on the so-called balanced development model, which indicated potential development areas—the nodes of efficiency, competition, innovation and entrepreneurship, and potential accelerated development directions of European, international, and national significance (Fig. 3).

Similarly to the settlement network of the polycentric mitigated concentration of the 1970s, this model referred to the band-node spatial structure of the country. The concept divided the whole country into potential development zones of ecologically driven conditions. It also defined elements considered to be stabilizing the country's development, such as metropolises, cities of European significance, and other centers for balancing development and protected areas and national and landscape parks, as well as the transport network, supralocal routes, and technical infrastructure facilities. At the same time, the NATURA 2000 network was written into the "Spatial Planning Act of 1994" with provisions on nature protection and had to be included in planning documents at all levels. The long-term view and multi-faceted connection of many areas of the country's development in one document gave the "Concept of the National Spatial Development Policy of 2001" the features of a strategic document.

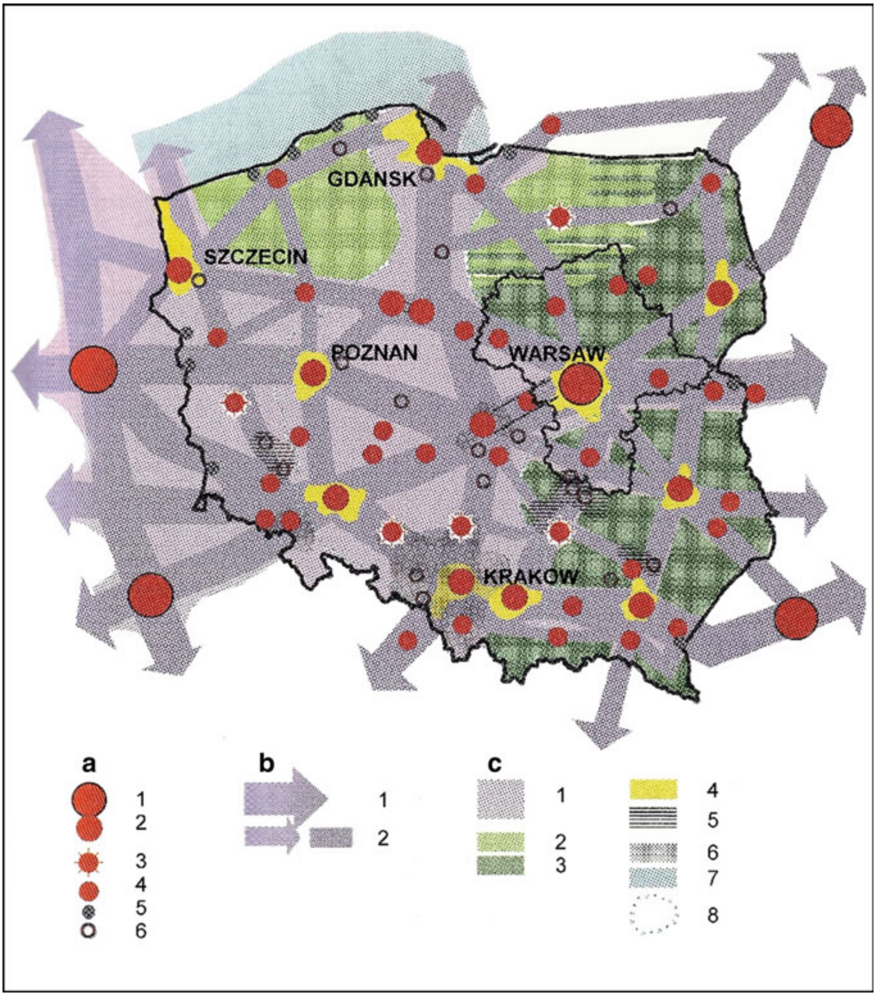

Fig. 3 Framing of the national spatial management policy—balanced development model (2001); **a** potential development areas—nodes of efficiency, competition, innovation, and entrepreneurship; **b** potential accelerated development directions shaped along with the modernization, reconstruction, and construction of the infrastructure; **c** potential zones of multifunctional, ecologically driven development. *Source* Prepared by authors based on Spatial Management Plan of the Mazovia Region, Warsaw 2004

3.4 National Spatial Management Concept 2030

The most important national strategic document on spatial planning is currently the "National Spatial Development Concept 2030" (NSDC 2030). This document introduced a new integrated approach to spatial planning, based on several development issues. It departs from the separate treatment of spatial and socioeconomic planning at the national, regional, and local level and introduces the interdependence of spatial policy objectives with the objectives of regional policy and links strategic planning with operational programming. The natural space is considered as an area where various socioeconomic, environmental, and cultural processes take place in various ways, regardless of administrative boundaries. The results of these processes vary. This approach was only possible because the authors of the NSDC 2030 departed from the previously adopted classifications, e.g., urban areas–rural areas, in favor of designating functional areas, determined by dynamically treated socioeconomic and spatial features. A vision of Polish land in 2030, based on development of functional areas, will be implemented using various instruments, one of the most important of which is spatial planning. The recommendations of those planning documents apply to national, regional, and local levels, or to spatially limited complexes, i.e., functional areas. According to this document, the national spatial development should be understood as "a way of arranging the basic elements of the spatial structure of Poland and the relations between them." The basic elements of this structure, which are the subject of analysis on the impact of public policy, include economic and social system elements, technical infrastructure, settlement network, and landscape (natural and cultural) and functional connections. The vision of NSDC 2030 strengthens five features of space: (1) competitiveness and innovation, internal cohesion consisting of integration on a local, regional, national, and international scale, (2) energy safety and natural well-being, (3) spatial order achieved through a legal system, (4) effective public institutions, and (5) biodiversity. In the last case, it was assumed that by 2030 the NATURA 2000 areas will cover over 20% of the country's area and together, with the National System of Protected Areas and ecological corridors, will form a common system of nature and landscape protection.

The integrated planning system adopted in NSDC 2030 (Fig. 4) creates good conditions for socioeconomic development, while protecting cultural and natural values, to enable coordination of development and activities at every planning level, while serving to protect the public interest. The system includes complementary elements at all planning levels. At the national level, the "National Spatial Development Concept" is maintained, alongside the "Long-Term National Development Strategy," which includes spatial elements in relation to socioeconomic elements. The "Long-Term Strategy" will be implemented through nine integrated strategies defining the basic conditions, objectives, and development directions in the areas indicated in the "Mid-Term National Development Strategy," in relation to the functional areas of the national and macro-regional level.

The typology of functional areas specified in the NSDC 2030 will primarily serve the implementation of the national and regional development objectives to minimize potential conflicts, create conditions for development, and create territorial potential. In addition to the classification of functional areas, NSDC 2030 provides features of individual types of areas and criteria for their designation, providing that their delimitation will take place at regional or local level.

An integral element of the regional development planning system, together with the strategy, will be the regional spatial development plan, which determines the coordinating role for all undertaken projects. Both documents will include plans and

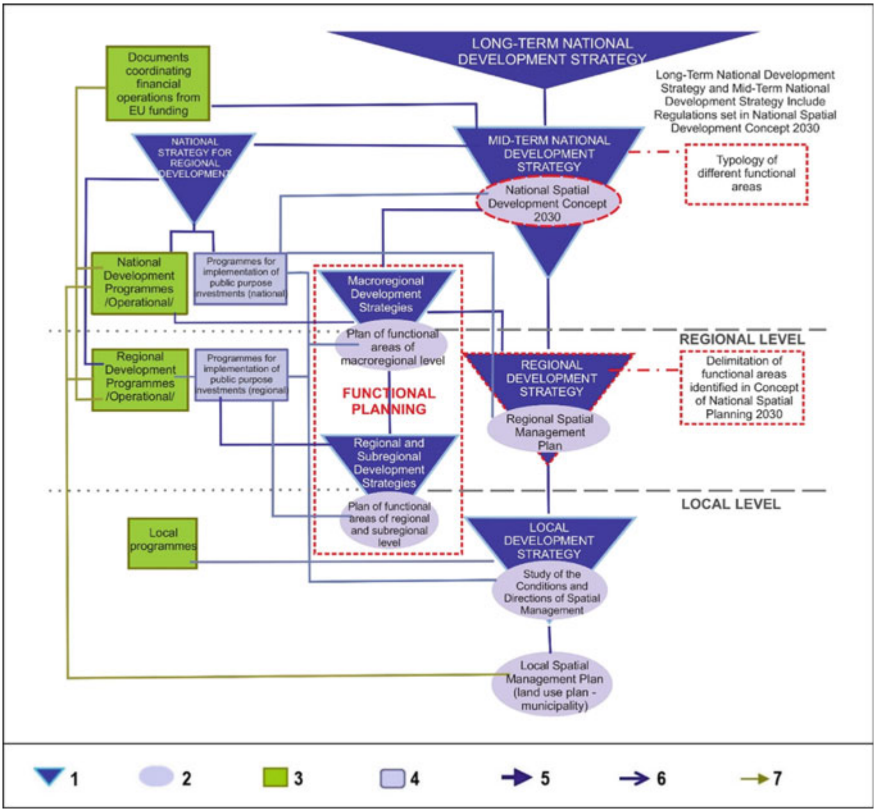

Fig. 4 Target hierarchical spatial-planning system in Poland: (**1**) strategic plans; (**2**) urban plans; (**3–4**) investments on national and regional level; (**5**) main planning direction; (**6**) functional planning; (**7**) operational planning. *Source* National Spatial Development Concept 2030

strategies for functional areas at the national, macro-regional, and regional levels. The coherence of socioeconomic planning with spatial planning at the regional level should ensure the requirement to harmonize both their content and the preparation method.

At the local level, the main document remains the local spatial development plan, consistent with the study of conditions, and directions of spatial development of the municipality. The study, as a document expressing the spatial policy of the commune, should also bring together all other documents and all decisions issued in the commune in relation to space management and land-use changes. It should also include tasks arising from strategic documents that pursue long-term local development goals, as long as they do not conflict with the documents of socioeconomic and spatial development at the national and regional level, the findings of which must also be included in the study documents and plans for development and implementation.

4 Discussion and Conclusion

The review of post-war planning studies and documents on a national scale indicates an evolution of the approach to spatial planning, focused on integration with other planning sectors, i.e., economic, social, environmental, and cultural planning. This manner of performing the planning procedures was used in the currently binding document—"National Spatial Development Concept 2030." This document derives directly from legal acts, where the scope of the document is defined as: (1) the distribution of basic elements of the national settlement network, with the separation of metropolitan areas and problematic zones; (2) the distribution of social amenities, technical infrastructure and transport facilities and water management facilities; (3) other elements of the spatial structure; and (4) environmental protection elements with their regulations, including protected areas. This approach is an expression of the pursuit of broadly understood strategic integrated planning—a long-term process in which it is necessary to integrate various fields and levels of planning, which will give a better chance to achieve sustainable goals of development.

Further development of urban-planning documents must include the demands of the ongoing global debate on changes in regional and national spatial policy. The currently binding documents have many features that make it possible to consider them as modern and corresponding to contemporary challenges emphasized by the OECD and EU institutions. These features include linking the regional development strategies with spatial policy issues and considering it as an immanent part of the country's long-term development strategy; strengthening connections between major cities, which favors the emergence of synergy effects, also in terms of the best chance to create a knowledge-based economic structures, and obtaining a competitive position among the regional networks of metropolitan centers in Europe; and approaching environmental issues with greater emphasis on the need to include sustainable development principles in spatial development strategies, which is particularly important in the context of climate change. These demands are implemented in a new document in the perspective of 2030.

Its introduction to practice will require: changing provisions in the law; strengthening the authority of national and regional planning, so far weakly associated with local planning and implementing functional areas in planning practice that have a chance to develop more evenly throughout the country (metropolitan areas): making better use of existing potential (protection areas); protecting resources from misuse (water deficit areas); providing a basis for building future capacity (coastal zone); and adapting activities in accordance with the analysis of the state of development and functional connections (areas with poor time accessibility, rural areas).

As the analysis has shown, the assumptions of the "National Spatial Development Concept 2030" regarding the need to preserve the principle of joint control and subsidiarity with respect to determining responsibility for drawing up spatial development plans for functional areas are represented in correct a manner regarding the existing conditions. Their delimitation and the setting of planning standards and planning procedures as guidelines should be carried out with the participation of national, regional, and local entities, to find optimal and universal solutions.

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SUMPs Implementation: Designation of Capacity Gaps of Local Authorities in the Delivery of Sustainable Mobility Projects

Sofia Kalakou, Sebastian Spundflasch, Sofia Martins, and Ana Diaz

Abstract There are numerous initiatives at the European level that are aimed at increasing the capacity of cities with regard to sustainable mobility planning by developing guidelines and various forms of training materials. An important prerequisite for systematic capacity building is to understand what capacity actually means in the context of mobility planning and which concrete factors influence the ability to shape and deliver sustainable mobility solutions. In the SUITS EU project, a tool for capacity assessment was developed and tested with six participant cities. Through interviews and workshops with mobility stakeholders in the participating cities, 15 challenges that the cities face while planning and implementing mobility plans were identified and led to the design of a set of 54 indicators that assess the capacity of an authority to develop and implement a mobility plan. The presented methodology enables authorities to self-assess their performance and capacity and identify the sources of the problems they face and that are impeding their effectiveness in developing and implementing mobility plans. The application in the six participating cities demonstrated that the evaluation tool here introduced is comprehensive, encompasses all the aspects of the environment in which a local authority (LA) operates and effectively highlights the areas where interventions are required so that the LAs can systematically increase their capacity.

Keywords Monitoring mobility plans · Sustainability management · Capacity evaluation · Sustainable urban mobility plans (SUMPs) · Local authorities

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_16

1 Introduction

In a technological, fast-developing world, the quality of life has still not achieved universally satisfactory levels. Lower-income populations tend to experience restricted accessibility to transport services and consequently fewer professional opportunities (OECD 2017) while vehicle-related pollution and transport safety are still challenging issues for transport planners and regulators (World Bank 2017).

During recent years, there has been a great effort to move toward more sustainable cities following the UN Agenda. Goals, planning tools, and practices are being diffused worldwide. In this effort, Sustainable Urban Mobility Plans (SUMPs) have arisen as a policy tool to enhance sustainable mobility. Several initiatives for the strategic planning of sustainable urban development exist (Sustainable NI 2016; Plevnik et al. 2019), and useful tools, criteria, and relevant indicators have been proposed for different geographies to assist the application of sustainability plans (Zheng et al. 2013; DSDG–UNHQ 2016; Perra et al. 2017; Alonso et al. 2016; EUROSTAT 2019; Mozos-Blanco et al. 2018; Ali-Toudert et al. 2019). To enhance the implementation of these applications, regulators are also contextualizing the monitoring process (RFSC 2013). Cities, as well, have launched initiatives for sustainability monitoring, such as the initiative of Local Governments for Sustainability (ICLEI). However, the path from theory to practice is not seamless. The motivation for sustainable plans stems from national or international policies, however the implementation fully relies on local governments and stakeholders (Zoeteman 2013). The provision of technical support, stakeholder engagement, alignment of investments and facilitation of collaborations have been reported as priorities for SUMP implementation (Skoudopoulos et al. 2016). The success of SUMPs is also dependent on the evaluation process employed after the implementation, but loose or lack monitoring is a common practice in many cities (Mozos-Blanco et al. 2018).

The smart city concept is often encountered in SUMPs, and many sustainable mobility measures are often described as smart mobility measures as well. A study in Belgium suggests that, depending on the characteristics of the cities, it is likely that the understanding of “smart” differs among Las, and city clusters may emerge according to the city’s size (population), the degree of urbanization (urban, rural) and the region it belongs to (part of the country) (Desdemoustier et al. 2019). Four clusters on “smart” understanding have been suggested: technological (implementation of a technology); societal (a human, sustainable and institutional positioning); comprehensive (an integration of technology, human-centricity, sustainability and institutional factors); and non-existent (absence of understanding). The relevant application in 113 municipalities in Belgium indicated that the cluster of municipalities without any understanding (non-existent) or with a technical understanding are mostly located in small and rural areas where there is resistance to the application of smart mobility because such projects are considered too complicated for their regions and with low expectations of benefit. The view of project complexity is shared by medium- and large-sized municipalities, but these clusters mostly develop a societal or comprehensive understanding. This study implies that the city size affects internally the capacity of LAs to correspond to novel concepts without analyzing the views of several stakeholders in each city.

While many studies have focused on the assessment of sustainable urban development and the assessment of SUMPs, evidence of the capacity of the relevant stakeholders to successfully implement those plans is scarce. As there are differences between traditional transport plans and SUMPs (ELTISplus 2012), there is the need to analyze the conditions that can lead to the delivery of SUMPs. Early work in the field, focused on the barriers faced by LAs while implementing SUMPs, has indicated that financing is the greatest impediment, followed by modeling techniques, monitoring of the process and the evaluation, while the aspects of strategy option generation and strategy appraisal were reported to be less impact (May 2005). The legal aspects, the existence of national guidance, the number of plans in place, the set of sustainability objectives, the level of public involvement, the finance state, and the political support can serve as indicators for the status of SUMPs at a European level, as well (ELTISplus 2012). A case study for Mexico City revealed that from the perspective of mobility stakeholders, the negotiation success with and among internal transport stakeholders and the cooperation among the political entities in the region are driving forces for the development of sustainable transport systems (Steurer and Bonilla 2016). Public participation through information sharing and activity communication has also proven to be a contributor to collaborative mobility initiatives and a determinant factor for the successful implementation of plans, especially when there is a stakeholder annual agenda (Gil et al. 2011). The importance of collaborations on data sharing and exploitation was highlighted by Tafidis et al. (2017), who, through the assessment of data availability, frequency, and reliability over 80 data types in the city of Thessaloniki, underlined the need for the operation of a unique urban observatory.

Local authorities (LAs) are still dependent on external aspects so that they implement plans toward sustainable mobility. A survey to 328 European cities demonstrated that there is an expressed need for support in the following areas: financing the measures and their development, providing support with guidance and training, defining a legal framework that enhances the integration of land and mobility planning, defining the institutional framework, and organizing the monitoring of the process (Plevnik et al. 2019). Another study with a narrower context (24 closed responses) designated the lack of a governance framework, the lack of consistency in the legal framework, the understanding of the SUMP concept, the lack of awareness at national level, the compatibility of SUMPs with existing plans, and the need for good practice diffusion as major gaps hindering SUMP development at the national level (Durlin et al. 2018).

Environmental regulations and the provision of public funding are both motivating and forcing LAs to develop and deliver SUMPs. However, they are not always capable of successfully planning and implementing them. To assist cities with the implementation of their mobility plans, it is essential to analyze which factors influence their capacity to plan, develop, and implement sustainable mobility measures. The current work is studying more meticulously the issue of the capacity of LAs to implement SUMP and the barriers and the challenges met while applying mobility measures as part of SUMPs. An evaluation process for the capacity of LAs to implement SUMPs is developed in the framework of the SUITS-CIVITAS H2020 project. The aim is to understand the gaps and challenges for cities during the planning or implementation of mobility measures, as well as the requirements of cities and mobility planners in terms of support. It presents an evaluation framework and the results of its application to six European cities. The next section of the paper presents the methodology that was followed based on the knowledge acquired from previous work conducted on the field, workshops, and interviews with mobility stakeholders of the cities. The results are then presented, and they are discussed in the fourth section. The paper terminates with some conclusions concerning the results of the assessment.

2 Method

Understanding the way in which a LA works requires thorough understanding of its structure, planning, operations, and relationships to other stakeholders. The nature of capacity assessment, in the context of transport planning, concerns organizational and behavioral aspects of the stakeholders involved. The prerequisite for supporting the capacity of cities to implement sustainable mobility measures is a clear understanding of what capacity actually is and how it is reflected in the planning and development of mobility measures. The multifaceted nature of sustainability and the numerous stakeholders involved in this process increase the complexity of capacity assessment. According to OECD, capacity is the ability of people, organizations, and society to manage their affairs successfully. The European Commission (2014) defines capacity building as a process that comprises the ability of LAs to perform their functions and which can be improved by focusing on both the individuals and the entities. At the level of individuals, skills and competences need to be developed inside the public authorities, and at the level of entities, processes, structures, and resources are the focal points to assess. In this study, capacity is defined as a process through which a transport organization or institution responsible for transport planning and management at the urban level is able to develop and implement various transport projects with short- or long-term objectives, with the final aim to enhance integrated transport systems in a sustainable way (Martins et al. 2017). To assess the activities of a LA to build its capacity, the views of organizational, political, legal, and societal players are considered. Transport and mobility departments of LAs, transport authorities and operators, mobility agencies, infrastructure providers and transport users, citizens representatives and funding agencies give feedback on the LAs' capacity to implement mobility plans. The following methods can be employed for the collection of the data and information that will be analyzed in order to complete the assessment: workshops, focus groups, interviews, and self-assessments. In this study, workshops and interviews with the mobility planning departments or the departments that are involved in mobility planning of nine LAs were conducted, and a self-assessment capacity tool is presented.

2.1 Arising Challenges for SUMP Implementation

An important focus of the work with cities was to better understand the challenges cities face when planning and implementing mobility measures. This understanding provided an important basis for the development of support materials, such as guidelines and webinars in the project, and secondly, it formed a basis for the organizational-change process that was carried out with the participating cities as an example. The challenges were derived from the work with nine European cities in various workshops and through interviews with mobility planners of the local authorities. The main goal was to understand their general knowledge interest when planning and implementing mobility solutions, their experiences with a focus on occurring problems, barriers and enablers, as well as their requirements for support and training materials. Table 1 presents 15 challenges derived from the workshops that every city copes with when shaping sustainable urban mobility. Depending on the kind of the mobility measure, the capacity of the mobility department and the local context, individual challenges can have a higher or lower importance. Overall, larger cities are usually better situated than smaller ones. The large size of staff makes it possible to build up a wide range of knowledge and expertise.

2.2 Capacity Assessment Framework

The capacity assessment aims to evaluate the performance and identify the potential for capacity building. Based on the retrieved information of the interviews and the workshops, a set of indicators is composed to assess and reveal possible inefficiencies in all the elements that form the capacity. They describe the range of activities that will lead to efficient and successful development and implementation of sustainable plans. The proposed set of indicators assesses the current operations of the institution in four main areas (organizational, political, legal, and societal) and four subareas (communicational, financial, managerial, and technical) related to the environment in which the authority exists and operates. They measure the inputs, the processes, the outputs, and the outcomes of an organization. The key composites of each of these categories are presented in Table 2.

Each indicator can be assessed for both the LA's performance level on it and its attributed importance to the LA's capacity. To assess the performance, the respondents indicate the frequency with which actions are taken in what concerns the indicator's content. Appendix 1 illustrates an example of how the assessment of an indicator is presented to the stakeholders during the assessment process. The design is intended to be user-friendly to enhance the response rate. This proposed process makes possible the designation of four clusters of indicators: those that have high performance level and high importance (HH); those with high performance and low importance (HL); those with low performance and high importance (LH); and those with low performance and low importance (LL). The indicators that fall into the HH

Table 1 Description of cities' challenges in SUMP implementation process

Challenge area		Challenge description
1	Sustainability thinking	Shaping sustainable mobility requires sustainability thinking among the staff and those who are involved in the process. Anchoring a sustainable mindset is one of the biggest challenges for local authorities, as this cannot be dictated by leadership, rather it is a way of looking at things that needs to develop gradually. The LA must always provide impulses and constantly raise awareness of the issue
2	Institutional cooperation	The challenge illustrates the need to improve the cooperation between local and regional authorities and decision-makers who are directly and indirectly involved in the development of sustainable mobility measures. The aim is to motivate the various municipal departments to develop a common vision, to participate and to commit to projects
3	Systematic staff deployment and development	In recent years, the field of mobility has become increasingly broad, complex, and difficult to penetrate. Although an incredibly large pool of knowledge and experience is available in general, mobility departments often lack the capacity to develop their own technical know-how in all mobility areas. A major challenge is to develop the needed competencies within the staff systematically, with a view to the long-term, ideally in such a way that synergy effects between the projects can be exploited
4	Project management and monitoring	Effective and efficient project management forms the basis for successful projects. This aspect is still a big barrier and often leads to serious delays or even the failure of mobility projects. The challenge is to critically support and optimize project management and monitoring processes

(continued)

Table 1 (continued)

Challenge area		Challenge description
5	Knowledge management and transfer	Shaping mobility depends to a large extent on experience. The challenge is to enhance and establish a sustainable process for knowledge management/knowledge transfer among mobility departments and stakeholders. The aim is to apply and try out established methods in order to learn from experience and from that of others. It is about applying these findings to new projects and transmitting them to new employees
6	Understanding and applying innovative financing	The challenge is to increase the ability to identify funding sources and to use innovative financing methods. This requires capacity to identify, evaluate, adapt, and apply financing methods to projects for which there is no funding available or urban funds are insufficient
7	Innovative procurement	The challenge is to integrate sustainability criteria and requirements to procurement processes and sensitize procurement agents to sustainability aspects and opportunities arising from the procurement reform
8	Understanding political interests and decision making	No matter how well planned a measure may be, without political backing, it will not be implemented. The challenge is to increase the capacity to assess political moods and to affect political bodies through evidence and argument
9	Understanding legal and regulatory framework	As many policy areas are directly or indirectly affected by the development of mobility measures, various legal and regulatory frameworks need to be considered. Some of these regulations also may change over time. The challenge is to further develop strategies and skills, to access the legal framework conditions and to take them into account for planning and implementation of mobility measures

(continued)

Table 1 (continued)

Challenge area		Challenge description
10	Citizen participation	The challenge is to increase the capacity to identify and actively involve citizens in the development process of measures and strategies. This requires a precise understanding of benefits and concrete methods of citizen participation. Citizens need to be informed about measures, goals, and backgrounds in order to engage with the measures
11	Estimating the feasibility and acceptance of measures	It is particularly difficult to obtain the necessary political support for innovative measures when there is a lack of experience and a high degree of uncertainty in terms of feasibility and acceptance. The challenge is to use methods to try out innovative measures in a scaled version, in a closed system beforehand, to gain a better understanding for upcoming problems and to be able to make predictions for workability and acceptance
12	Interaction and cooperation with business partners	The interaction and cooperation with business partners has become increasingly important in order to implement new mobility services (e.g., sharing services). The challenge is to combine new offers with existing services, adapt them to the local characteristics, and make them attractive to citizens. The conditions must be attractive for providers to offer such services in the city. Close cooperation with business partners is a key factor
13	Identification and utilization of synergy effects	The challenge is to identify early connections and dependencies between mobility strategies and measures or between different mobility services

(continued)

Table 1 (continued)

Challenge area		Challenge description
14	Use of innovative technologies and data-collection methods	The challenge for the cities and the mobility departments is to raise awareness of technologies, tools, and methods for the effective and efficient collection and evaluation of data and its use for the planning, implementation, and evaluation of mobility measures. It is also a matter of looking across other departments to see who is already collecting certain data, or who might still be interested in certain data. Multiple use of the data and the exploitation of synergy effects is particularly important
15	Application of research knowledge and adaption of good-practice examples	The challenge is about a greater application of research findings and knowledge. It is also about a better understanding of the transferability of good-practice examples. The identification and understanding of contextual factors that are relevant to the success or failure of measures are challenging and that must be taken into account when trying to adapt measures to the specific conditions of a city

Table 2 Description of self-assessment indicators

Organizational	
Indicator's name	Indicator's description
Subcategory: Coordination/cooperation	
Cooperation	Level of collaboration among the LA and the organizations that participate in all stages of planning and implementation of a plan (financing, procurement of products and services, public–private partnerships)
Decision-makers	Number of policy-makers involved in planning and implementation
Operational autonomy	Organization's autonomy to implement plans independently of other stakeholders' approval
Financial autonomy	Financial independence from central government and other financial agents
Interdepartmental cooperation	Level and frequency of cooperation and networking between the involved departments inside the same organization
Subcategory: Process	
Implementation rate	Number of implemented or planned measures
Monitoring	Project management activities to control technical and processual issues
Punctuality	Rate of compliance with deadlines with clear milestones' identification
Budget management	Ability to realistically includes plans/measures in the organization's budget
Progress control	Regular process evaluations to determine gaps and flaws in the plan's workflow execution, avoiding delays and redundant work
Risk awareness	Frequency of identification and assessment of possible risks that may appear during all the project's lifetime
Adaptability/contingency plans	Capacity to adjust plans/measures in reaction to an extraordinary event. Existence of risk-control measures defined to control the impact of the risks that affect the project
Process learning	Organization's acknowledgement of internalizing past experiences, both positive and negative, to solve present/future issues that may arise
Subcategory: Financial sources	
Financial sources	Efficient use of national–international, public–private investment sources

(continued)

Table 2 (continued)

Organizational	
Indicator's name	Indicator's description
Understanding (IF) innovative financing	An understanding of the benefits that innovative financing methods have on the financial capacity of the organization
Identification of IF	Ability to identify innovative financing opportunities
Training of IF	Number of people in the organization who are trained in innovative financing
Use of IF	Organization's employment of innovative financing resources
IF and local economy	Economic status of city increased through projects funded by innovative finance
Innovative business model	Organization's development of innovative business models in the projects developed/implemented
Subcategory: Technical/data resource	
Logistical resources	Available resources' quantity/quality needed to properly complete the tasks required for planning and implementation. Easy access to logistical tools
Communication resources	Available resources' quantity/quality needed to properly complete the tasks required for planning and implementation. Easy access to communication tools
Technological resources	Available resources' quantity/quality needed to properly complete the tasks required for planning and implementation. Easy access to technological tools
Use of new technologies	Willingness to use new technologies and familiarity with their application for data collection
Data availability	Availability of the necessary data required to complete all project's tasks
Data collection	Availability of necessary tools, networks, and resources to efficiently collect data from diverse sources and in different formats
Data analysis	Availability of the necessary tools, networks, and capabilities needed to efficiently analyze data collected of diverse sources and formats
Data sharing	Being able to retrieve valuable information as an output from the data analysis. Quantity and quality of data shared among departments (paper-form, electronic, etc.)
Subcategory: Human resources	

(continued)

Table 2 (continued)

Organizational	
Indicator's name	Indicator's description
Staff's commitment	Staff´s alignment, in attitude and performance, with the goals of the organization
Realistic goals and priorities	Link between managers' notion of the team's capacity and the real team's capacity to deliver the expected outputs
Participatory management	Level of bidirectional communication between various management levels of the organization. Global knowledge increment
Effective delegation	Each member of the organization has a clear vision of her participation and responsibilities for the successful completion of the plans. Clear understanding of one's role and participatory timeline
Team's trust in processes/tools	All staffers involved in the plans' planning and implementation phases feel completely comfortable with the tools and methodologies needed to successfully carry out all projects' tasks
Early engagement	Everyone participating in the project is involved from the beginning enabling all stakeholders to have a full view of the entire process
Team's dimension	Human resources available to complete all the project's tasks
Team's skills	Knowledge, competences, and abilities of the team to meet project's needs
Supporting resources	Responsiveness to operational/process inefficiencies
Subcategory: Working environment	
Regular assessment/self-assessment	Identification of strengths and weaknesses of each member of the team
Staff's needs	Team members' needs are encouraged to be transparent inside the organization
Continuous learning	Permanent effort in keeping the staff updated regarding tools and techniques that would enable the project and include the level of evolvement in workshops, seminars, conferences, etc.
Turnover rate	Reflects the stability in the composition of the team
Political	
Political commitment	Defines how the project will be led and if it is a priority in the political agenda

(continued)

Table 2 (continued)

Organizational	
Indicator's name	Indicator's description
Coordinated institutional agendas	Consistency in national/regional/local priorities. Correspondence between the plan and the national political agenda
Coordination/cooperation	Effective networking between the national departments of transport, land use, mobility, energy, etc.
Continuity	Commitment to the continuation of the project independently of the authorities elected; the plan's progress is maintained unimpeded when moving from one political framework to the next one elected
Financing	Existence of financial programs within the national general budget to undertake the implementation of the Plan
Legal	
Legal and regulatory framework	Contribution of legal and regulatory frameworks to efficient decision-making processes
Legal power delegation	Organization's autonomy to solve its own legal issues regarding the planning and implementation of the projects
Understanding of applied legal framework	All applicable legal framework should be clearly understood by all the involved stakeholders
Procurement decision criterions	Way of using decision criteria in the public procurement procedure (price, fuel, etc.)
Societal	
Public awareness	Use of communication channels related to the project, its design, implementation, and impact included
Public participation	Actions taken to engage citizens in the development of the project
Public acceptance	Level of willingness to support and engage with the implementation
Media reaction	Responsiveness of social media

and HL areas comprise the set of strengths of the city, while the LH and LL areas encompass the weaknesses of the city. More specifically, the indicators of the HH area can be considered as the opportunities of the city, i.e., the capacity enablers, and the indicators of the LH area entail the barriers of the city that do not favor the implementation of the plans. One can deduce that this is an area in which attention should be paid so that capacity improvements are achieved.

3 Results

Six European medium-sized cities were analyzed in their capacity to implement sustainable mobility plans. In total, twelve local organizations (operators, regulators and all the city LAs) were interviewed. At a city level, all the indicators were assessed individually and per category, thus enabling an easy assessment of the performance on each indicator. When several institutions assess a city's capacity, comparisons can be made on the perceptions of the stakeholders (example in Appendix 2). All the clusters of indicators can be aggregated in one graph (example in Appendix 3) to illustrate the results of the analysis for a specific city. The highlighted LH cluster area encompasses the indicators that are considered important but were attributed low scores and represent the city's capacity barriers.

Observation of the city results indicate that there are some indicators that demonstrate a common need for strengthening among the cities. These aspects represent internal processes (monitoring), the working environment (staff needs and self-assessment), cooperation with other organizations and alignment with external aspects, specifically the legal framework (legal and regulatory framework, legal power delegation, and understanding of applied framework). The aggregated results (Appendix 4) demonstrate that there are indicators to improve that are dependent on the LA's operation which are more controllable than others. These include regular self-assessment, staff's needs, participatory management, support tools/techniques and personnel, team's dimension and continuous learning, coordination and cooperation among sectors, staff's commitment, data analysis, data collection, and early engagement. Others, such as financial autonomy, political commitment, continuity, data availability, and public acceptance, are more difficult to manage and thus achieve a satisfactory level of performance. This is mainly observed due to the impact of the external factors that are linked to the operation of a LA and the interdependencies among all the entities. For example, it is easier to control, during a certain period of time, the internal human resources, their expertise, and the organization of the work to be delivered than to guarantee political continuity and financial inputs, which mainly depend on the priorities each political entity sets during its governance period.

4 Discussion

The results of the individual cities are used to assess Las' capacity, designate capacity enablers and barriers, and derive recommendations for action for the capacity-building activities. Overall, the awareness of the legal framework was very high, especially in the municipality respondents, because it forms the basis of the work on the mobility measures. However, slightly more than 20% of the respondents were not fully aware, which can be explained by the fact that mobility stakeholders also took part in the survey, often not knowing the legal framework in much detail. Results regarding financial autonomy vary: larger cities in economically strong regions are much more independent of federal funding than smaller cities in structurally weak regions. The two indicators, continuity and staff needs, also reveal very different assessments. Looking at the point continuity, in the workshops it became clear that some cities are struggling very much with political instabilities, which makes it hard to develop and follow long-term strategies in the mobility sector. Staff needs also shows that, when it comes to the needs of employees, very different situations exist in municipal administrations, like those in private sector companies.

The study indicates that there is room for improvement in the operations of the LAs through the early alignment with the legal framework, the focus on staff operations, and the increase of cooperation with other organizations. Improvements could be achieved through early participation of LAs in the legal framework formulation and the increase of project management skills of LA's staff. The results are aligned with previous research conclusions on the areas of interventions (Skoudopoulos et al. 2016; Mozos-Blanco et al. 2018). Overall, the results reflect good performance, which is a sign that the topic of mobility is being taken very seriously, at least in the participating cities. However, as the results are based on a relatively small sample, this cannot be generalized.

5 Conclusion

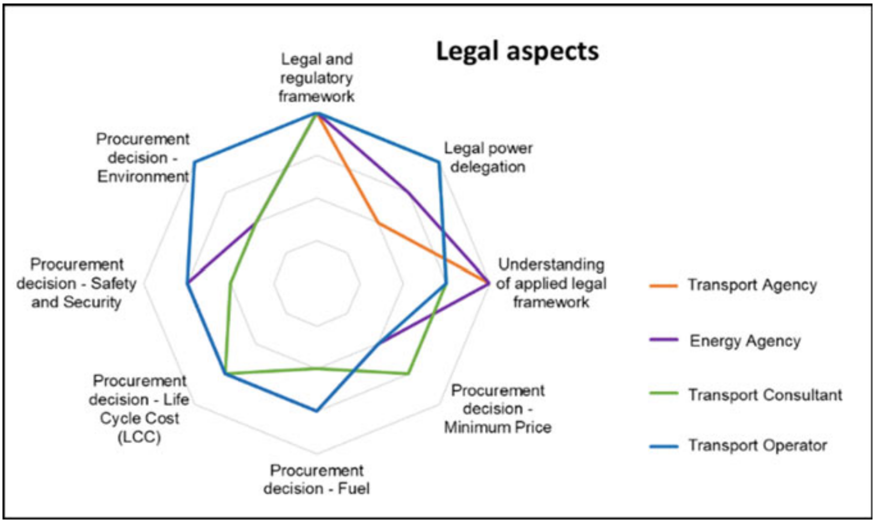
This paper deals with the capacity of LAs to develop and implement sustainable mobility plans. A capacity assessment method consisting of a set of indicators is presented and applied to a small sample of European cities in the framework of SUITS project. The presented methodology allows authorities to self-assess their performance and capacity and to identify the sources of the problems they face and that impede their effectiveness in developing and implementing mobility plans. The application of the assessment tool designates the areas in which interventions are needed to enhance the achievement of more successful development and efficient implementation of transportation plans. The application to six cities demonstrates that the priority areas that need interventions so that capacity is enhanced are project management and staff-related and legal aspects. Because LAs are multifaceted entities, further interviews with several departments (e.g., finance, political) can be taken to identify the differences in their perceptions of capacity. Future work can also apply the framework to the systematic development of training tools and the comparison of ex-post assessment of LA capacity.

Acknowledgements This research received funding from the European Union's Horizon 2020 research and innovation program under grant agreement no 690650 for SUITS Project.

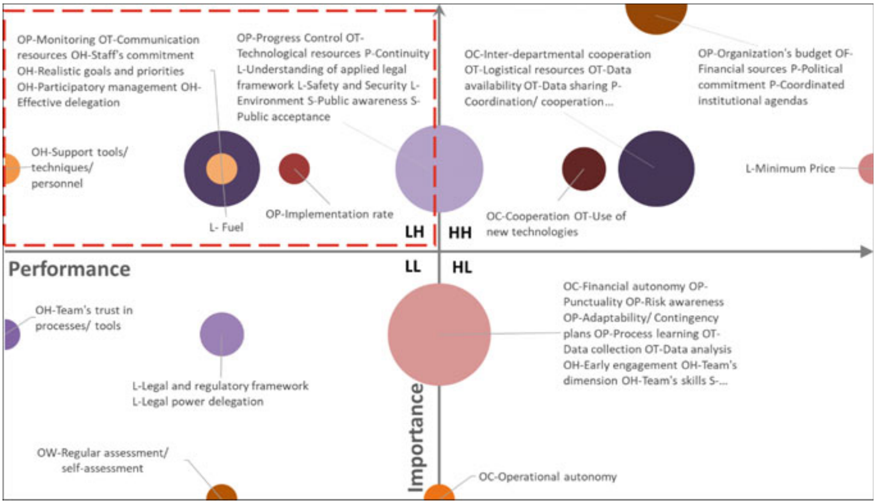
Appendix 1 Sample from the Capacity Indicators Assessment Survey

Indicator O1	**Cooperation**
Category	Organizational
Sub-categories	Financing/management
Definition	Level of collaboration among the LA and the organizations that participate in all stages of planning and implementation of a plan (financing, procurement of products and services, public—private partnerships)
Context and relevance	Assesses the model and level of cooperation between LA and the other participant organizations.
Assessment	High, Medium, Low, Insignificant
Importance	(0—100)

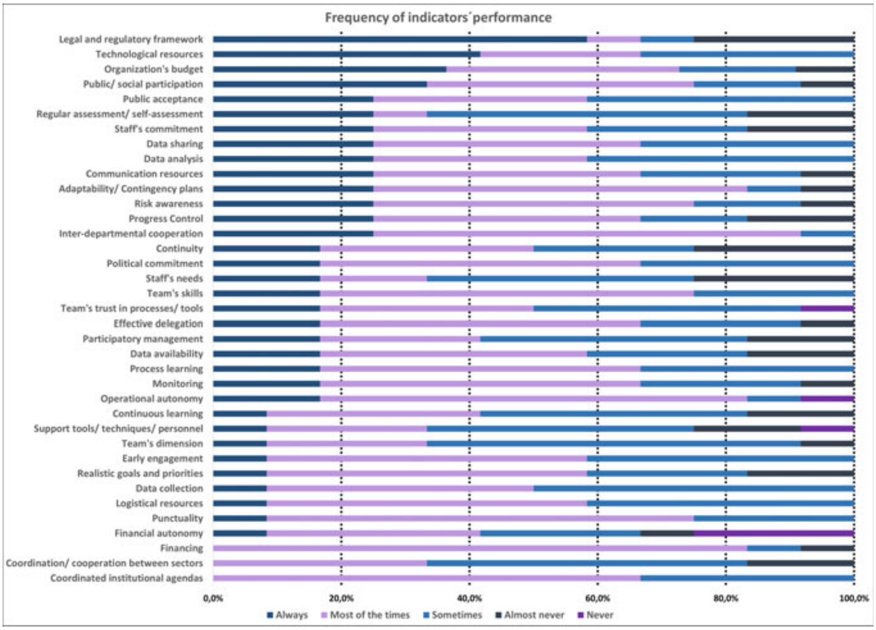
Appendix 2 Example of Capacity Indicator Assessment on Legal Aspects



Appendix 3 Example of the Cluster Indicators of a City



Appendix 4 Aggregated Results on the Frequency of Performance Indicators



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Co-creation Pathway for Urban Nature-Based Solutions: Testing a Shared-Governance Approach in Three Cities and Nine Action Labs

Israa Mahmoud and Eugenio Morello

Abstract Nature-based solutions (NBS) implementation in urban contexts has proven outcoming multiple benefits to reverse the current trend of natural resources' degradation adversely affecting biodiversity, human health, and wellbeing. Yet, the current urban-planning policy frameworks present a rigid structure to integrate NBS definitions, and their co-benefits to get mainstreamed and up scaled on a wider urban spatial dimension. In this research, we test a complete co-creation pathway that encourages decision-makers to embed citizen engagement methodologies as an approach to co-design and co-implement NBS in shared-governance processes aiming to increment the greening of urban spaces, towards more inclusive and climate resilient cities. On one hand, we assess a tendency to involve a multiplicity of stakeholders that collaborate to the establishment of an Urban Innovation Partnership (UIP) aiming at increasing the social awareness around NBS themes, and at the same time tackling both financial and governance aspects. On the other hand, the innovation embedded in NBS paves the way to combine a multi-scalar flexibility in implementation tools and place-based urban actions, hence resulting in widespread economic, environmental, and social impacts in place. The novelty in embedding the co-creation process in urban-planning practice lies in catalyzing resources towards the transposition of research into practice through policy and planning tools for local authorities and decision-makers. Three front-runner cities (Hamburg, London, and Milan) are under investigation as part of Clever Cities—a Horizon 2020 project—aiming at implementing NBS in diverse urban-regeneration processes, through nine up-running Urban Living Labs (ULLs). Grounded on a comparative analysis of these three cities, key characterization for NBS implementation framework could be categorized into: (1) current urban-planning greening strategies in each context, (2) specific environmental and societal challenges addressed, (3) different typologies and scales of NBS integration within urban morphologies, (4) specific governance

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_17

process as response to co-design and co-implementation processes, and (5) availability of financial investment and main stakeholders. As research results, we emphasize using co-creation approach in urban planning to embed and upscale NBS in an inclusive shared-governance process, hence contributing to social awareness and acceptance. Meanwhile, spatial, and financial challenges could be majorly resolved using a multi-scalar approach to manage newly embedded urban-greening policies at the urban level. Lastly, the implementation scale of NBS with local communities requires a radical paradigmatic shift in societal, individual and administrative urban-planning practices.

Keywords Nature-based solutions · Co-creation · Shared governance · Urban regeneration · Urban living labs

1 Introduction

While the environmental policy and governance research around nature-based solutions (NBS) are currently under discussion, the implementation of green measures has taken a leap forward, proliferating in a diversity of urban contexts. That is mainly due to European Commission accelerated funds in Horizon 2020 program (European Commission 2015). Nonetheless, the academic domain has raced to catch-up with advanced major endeavors to utilize the NBS umbrella concept of ecosystem-based approaches to address sustainability challenges, such as resources shortages and flood and heat risks, as well as climate-change adaptation and mitigation aspects (Albert et al. 2019; Cohen-Shacham et al. 2019; Lafortezza and Sanesi 2019). The focus on NBS as a potential topic for research and innovation in urban-regeneration processes was identified by the European Commission (2015: 4) to address four fundamental goals: (1) enhancing sustainable urbanization; (2) restoring degraded ecosystems; (3) developing climate-change adaptation and mitigation; and (4) improving risk management and resilience in urban settings (Bourguignon 2017; Raymond et al. 2017).

This research originates as part of the Clever Cities[1] project, which investigates and implements NBS to address urban challenges and promote social inclusion in nine cities across Europe, South America, and China. Three cities are the frontrunners in the experimental processes: Hamburg, London, and Milan and other six cities are to follow with NBS implementation. Starting from this wide research scope, the present research work aims at testing the methodological scientific effectiveness of co-creation and shared-governance approaches specifically developed for Clever Cities and nine Urban Living Labs (ULLs), called Clever Action Labs (CALs). In particular, this study is divided in three main parts: (a) the co-creation concept explanation and principles of implementation; (b) the methodology to adopt NBS in CALs; and (c) a comparative analysis of co-creation process results as initiated by

[1] A European Commission funded project from the Horizon 2020 Innovation Action Programme under Grant Agreement No. 776604. See https://clevercities.eu/.

Clever Cities. The first part analyzes in depth the ongoing co-creation processes, its theoretical inception and possible correlation with urban regeneration to implement the NBS concept within the wider scope of the project. The second part compares the nine CALs co-creation pathways of NBS within urban-regeneration processes, while testing citizen engagement toolkits and an inclusive shared-governance approach. The last part reflects on the lessons learned from the co-creation process and urban-regeneration challenges addressed by NBS in place.

While the relevance is evident for using NBS in solving sustainable urbanization issues and climate- change pressures, there is no denying that there is an emerging need to embed a more citizen-oriented engagement approach within its' implementation (Gudowsky and Peissl 2016; Sanders and Stappers 2008). The literature emphasizes the radical role of a shared process with a multi-scalar stakeholder partnerships to increment the greening potential of urban spaces towards more inclusive and climate resilient cities (Bason 2010; Bisschops and Beunen 2019; Jansen and Pieters 2017; Leith et al. 2014; Puerari et al. 2018). Hence, we opted for testing a complete co-creation pathway that supports decision- and policy-makers towards embedding co-design, co-implementation, co-monitoring and co-development of NBS during the whole process (see Clever Cities Guidance in (Morello et al. (2018)).

Co-creation is not a novel concept; however, incorporating co-creation in CALs to implement NBS required a solid initiative from the three city authorities for getting accustomed to a shared-governance approach based on open participation and citizen empowerment. Accordingly, the novelty in applying co-creation in urban-greening projects has a threefold aim: firstly, to enhance the awareness and knowledge of citizens and stakeholders around NBS and their co-benefits; secondly, to enhance inclusivity in decision-making for urban transformation, hence, accelerating the need for capacity building in public administration towards an effective shared governance; and thirdly, to achieve a better quality of the regeneration interventions, emerging as the results of site-specific processes that build on the continuous improvement cycles and design-thinking stages during the various co-creation phases (DeLosRíos-White et al. 2020).

In the first 20 months from June 2018 until January 2020, nine ULLs were setup, and numerous stakeholders and partners were actively involved. Here, we depict the current status of the co-creation experiences and bottlenecks faced by the cities during the establishment of the UIP and partially during the initiation of the co-design phases in the CALs. Hence, we propose the use of the co-creation methodology as a catalyst and a driver to respond to the urgent climate-change adaptation and mitigation challenges, pressuring health and well-being, social and economic aspects. We mainly argue about the motivation of stakeholders' *multiplicity* for adopting a co-creation approach towards NBS implementation in cities, as well as the *multiscalar* spatial impacts observed added values into urban-regeneration processes.

2 Framework of Co-creation: Characteristics and Implementation in Urban-Regeneration Contexts

2.1 Co-creation in Theory: Definition and Added Values

Co-creation arose from the business world as "the practice of collaborative product or service development: where developers and stakeholders are working together" (Pater 2009; Prahalad and Ramaswamy 2004; Ramaswamy and Ozcan 2018). Bason (2010: 6) referred to co-creation as the "systematic process of creating new solutions with people-not for them; involving citizens and communities in policy and service development." Until recently, these two definitions remain grounded in the academic literature as a common framework to integrate co-production of knowledge intertwined with the co-design of solutions based on implementation cases: definitions, outcomes, and joint framing of social problems with stakeholders (Agrawal et al. 2015; Burkett 2016; Mauser et al. 2013).

Bason (2013: 26) alerted European Commission expert group on public sector innovation to the need to embed co-design and co-creation of innovative solutions. This could be worked out within governments, non-governmental sector, businesses, third sector and citizens as the main experts to orchestrate the design-driven processes of organizational learning and institutional innovations. A new EC project on fostering territorial innovation for climate action (TeRRIFICA 2019)3F calls for adopting co-creation as a form of collaborative social innovation wherein ideas are shared and improved together rather than kept to oneself. As a matter of fact, co-creation could also be seen as a *living concept* for an active involvement of actors during the processes of knowledge production and the design of engaged solutions. In addition, stakeholders and academic institutional involvement along the process are regarded through the lens of sectoral integration, with the ambition of transforming decision-making processes into flexible learning processes that bring together multiple actors and knowledge practitioners to jointly produce a mutually valued outcome (Galafassi et al. 2018; Parsons et al. 2016).

Throughout the pathway, partners explore the benefits of cooperating and highlighting mutual strengths, making the whole process more efficient and leading to better outcomes. The collaborative dialogue is not designed to force compromises, but rather to facilitate learning and build on harmonizing strengths and assets. Nonetheless, the need for multiple stakeholders to join forces and craft effective responses highlights the unusually important role of social science in the analysis of urban resilience. As an example, each partner brings different expertise: some know more about the area, others about the people and their daily experiences, and others about the local challenges for technical NBS implementation aspects. In other words, successful solutions to environmental problems in urban areas using a complete co-creation process require the combined efforts of different scientific disciplines and active dialogues between stakeholders from policy and practice actors (Frantzeskaki and Kabisch 2016). Hence, we conclude that instead of the traditional hierarchical organization structure, co-creation goes beyond common participatory methods to develop innovative solutions for complex (environmental/social/economic) problems in cities.

In fact, when it comes to urban regeneration, co-creation shifts the focus from centralized governance towards a more shared decision-making approach by empowering local civic actors and encouraging strong partnerships (McCormick and Kiss 2019; Rock et al. 2018). However, the concept remains fuzzy since it was not "put-into-practice" enough times to triangulate and evaluate if co-creation really leverages the possible outcomes on the long-run and has a transformative added values effects, especially on the urban-planning policies scale (Bisschops and Beunen 2019; Gudowsky and Peissl 2016). Academic research pinpoints some fundamental principles of implementation that amplify the circle of co-creation such as (1) adequate tools for citizen engagement (Engage 2020, 2015; Serrano Sanz et al. 2014); and (2) stakeholder collaboration in a flexibly structured process5 (Wippoo and van Dijk 2019).

Another important aspect in co-creation implementation principles is that it needs to *harness a spatial context*; co-creation does not occur if there is no "real problem" to solve; in urban regeneration, this is called *place-based approach.* Yet, scientific experiences are rushing to set out guidelines and principles to make co-creation principles more feasible to local governments, policy-makers, and practitioners, to be embedded in urban-regeneration processes (Jansen and Pieters 2017). Hence, the research question lingers on how to embed co-creation principles in cities' complex and sophisticated urban reality, whereas stakeholders run their agendas separately, resources are scarce, and land availability is limited. What's more, if we have specific guidelines to get co-creation done right, what are the main principles and rules to get co-creation done inclusively?

Lastly, the co-creation process does not have a *one-size fits-all* approach (Wippoo and van Dijk 2019: 8). Understanding pathway structure and sleeve tools are important to undertake the practical aspects of co-creation facilitation towards implementation, especially that each co-creation process is unique; and theoretical frameworks do not necessarily mirror co-creation in reality. Co-creation, therefore, needs a *medium* to get implemented and a flexible *operational structure* to be optimally concluded. Nonetheless, the co-creation effectiveness and efficiency of results relies on the implementation of each pathway based on attained outcomes and intermediate milestones. As a consequence, the paradigm shift accompanying co-creation somehow "unavoidably" occurs and shifts the organizational hierarchy of local governments and institutional structures towards integrated management and shared responsibility (Leroy and Arts 2006).

2.2 Co-creation in Practice and Urban Living Labs Experiences

From the recent literature on how co-creation supports inclusive design of long-term solutions, it is evident that co-creation is a way to cope with the complexity and uncertainty that NBS have added for delivering results on sustainability measures and resilience programs (Frantzeskaki 2019; Lawrence et al. 2013). This embeddedness of co-creation in urban-planning policies to embrace a user-centered approach and to co-designing approach often happens in a spatial *medium*, the so-called Urban Living Labs (ULLs). Those ULLs are the "enabling environment" whereas the participation—conceptualized as co-design instead—focuses on including diverse forms of knowledge generation in urban- governance processes to create inclusive solutions (da Cruz et al. 2019; Lund 2018). Nesti (2018) iterates on the co-production of services' peculiarities occurring differently based on the service itself. For instance, in some ULL contexts the innovation originates mainly during the co-design stage. While in others, innovation embraces different co-delivery stages as well (e.g., co-building or co-maintenance); that stem mainly from the nature of the ULL itself and the approach to public-service innovation.

From a practical perspective, these values of co-creating better and more innovative solutions have a wider impact on problem-solving in a spatial ULL context, by taking a progressive approach towards co-identifying a problem or need and co-ideating, co-designing and co-implementing a solution to it, in addition to co-maintenance aspects. ULLs are not a new phenomenon anyway. They have been defined by many scholars as the real-world laboratories for experimental research with edges between research institutions, society, and public authorities. Hence, Living Labs encompass societal and technological dimensions simultaneously in a business–citizen–government–academia partnership (Bulkeley et al. 2018; Menny et al. 2018). Some scholars particularly grasp ULLs as "spatially embedded sites for co-creation of knowledge and solutions by conducting local experiments" (Puerari et al. 2018: 2).

This type of spatial configuration enables experimentation for engagement instruments leading to social urban innovation; the idea of complete co-creation is to offer space for adaptive multi-actor learning and collaborative environment and to enable progressive urban transition (Bulkeley et al. 2016; Evans 2019; Evans and Karvonen 2011; Voytenko et al. 2016). Moreover, the academic literature reports the lessons learned from co-creation experiences in various ULLs applied over a wide spectrum of sectors: mobility, sustainability, food security, natural risks, and others....[2]

[2]Among others, these projects: Looper Project, Sunrise, MUV, and Cities4people.

3 Methodology: Sewing the Co-creation Pathway and Urban Living Labs Establishment for NBS Implementation

Setting out the framework of what is meant by co-creation of NBS is challenging. Sewing the bits and pieces of an environmental concept such as NBS with a fluid concept such as co-creation requires: (1) an extensive (and exhaustive) literature review; (2) cross-cutting case-study analysis; and (3) a close monitoring to the current European projects and advancements of urban-planning policies. This paper triangulates data from literature analysis, project materials, and lastly a cross-case study comparison. However, few scientific references bring together both concepts of NBS and co-creation, mainly because the topic is fairly new to the research world, and few implementation experiences have accrued so far.

In Fig. 1, we represent the conceptualization of the complete co-creation environment resulting from the Clever Cities experience. In this figure, we sum up the main concepts originating from the theoretical framework with the methodological corresponding aspects as practiced in Clever Cities co-creation pathway and operational structure through the CALs. The co-creation environment enforces two mains concepts: a *medium* and a flexible *operational structure*. In urban contexts, the enabling medium for co-creation would be the ULLs, while the operational structure corresponds to the co-creation pathway that infuses reflection, production, evaluation, and re-adaptation into the process. Accordingly, Clever Cities translates these two concepts introducing: on one hand, the UIP and the CALs as the *medium* to operate in the spatial context, and the Clever Co-creation pathway (Mahmoud and Morello 2019) as the *flexible operational structure*, on the other hand.

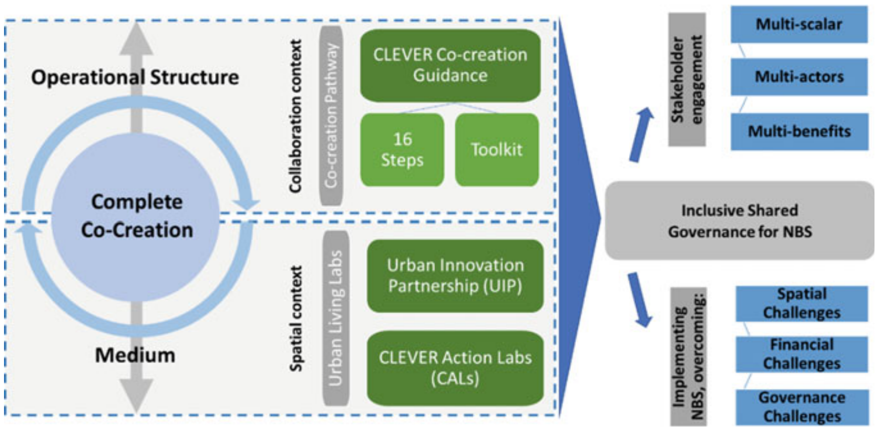

Fig. 1 Concept of the complete co-creation for NBS implementation that integrates the co-creation pathway (the operational structure) and the Urban Living Lab (the spatial medium)

The Urban Innovation Partnership and the Clever Action Labs, as two main examples of the mechanisms to implement NBS in urban processes, work at different scales, respectively, the urban level and the project-site level. The UIP activates stakeholders at the urban scale, involving them in high-level governance and lobbying for promoting city-wide greening policies and practices. On the other side, CALs operate at the local level in the spatial domain for the tangible co-creation of NBS.

In fact, NBS implementation requires a strong shared-governance approach. Involving a multiplicity of stakeholders aims at attracting a multitude of resources and assets (e.g., financial, human skills, equipment, time, and space availability), achieving a true sense of belonging and adoption of NBS in the urban context. This is not a *one-day* or *tactical urbanism* expected result process; on the contrary, to put NBS into place, a sense of co-maintenance and co-management by all stakeholders is recommended (Calliari et al. 2019). In this study, we argue that the spatial, financial and social inclusiveness challenges around NBS could eventually be overcome through the effective involvement of stakeholders and gradual positive impacts generated from the co-benefits resulting from NBS in loco over the long term.

As *operational structure*, a complete co-creation approach is encouraged to activate the long-term maintenance of NBS after these have been implemented later. Many academics and urban practitioners reveal the lack of guidelines and toolkits to meld both concepts together in a feasible implementation and evaluation frameworks for cities authorities to grasp. The theoretical frameworks of analysis were not holistically approached to embed the stakeholders' collaboration and engagement as an iterative, inclusive, and shared-governance process. The need for integration between NBS challenges and putting co-creation methodologies into practice seemed legitimate. We touch base on the implementation of co-creation in urban-planning practices; as well as, introducing the experience of how the application of co-creation in Clever Cities projects using a pathway for NBS implementation in nine ULLs.

To sum up, the co-creation pathway as a reflection to the operational structure of NBS implementation has been established as a methodological framework (refer to the *Clever Cities Co-Creation Guidance*[3] by (Morello et al. 2018)) encompassing six phases as follows: UIP establishment, co-creation planning, co-design, co-implementation, co-monitoring, and co-development.

Specifically, the phases are composed of 16 steps, not necessarily consecutive nor synchronous. The structure is intended to be flexibly handled within different urban contexts. These steps are furnished with a variety of recommended, optional, and fundamental tools that help cities establish a complete co-creation process taking in consideration the different spatial place-based contexts, the type of NBS interventions and the governance model selected by the responsible authority. Sleeve toolkits for the co-design, co-implementation, and co-maintenance of NBS are developed with cities to be used as a reference in their progressive co-creation process. The provided guidance documents aim to better articulate the co-creation processes that shape the implementation of NBS in its most effective way. The guidance efficiency

[3] see https://guidance.clevercities.eu/ and https://clevercitiesguidance.wordpress.com/co-creationpathway/.

for the cities is currently being monitored through online surveys and face-to-face workshops with local cities teams. The co-creation pathway and guidance in Clever Cities projects are intended as a support methodological tool for *open innovation*, in which ideas are shared, closely connected to user-generated content and actively communicated to the wider public in order to embed originality and achieve effective governance.

4 Discussion: A Comparative Study of Nine Action Labs in Three Cities

Since June 2018, three cities (Hamburg, London and Milan) have been on the forefront of implementing NBS by applying the co-creation pathway, through up-running nine urban living labs as part of diverse urban-regeneration processes. The main involvement of stakeholders in the co-creation process occurs through the phases of co-design and co-implementation. From July 2019 until June 2020, the cities are conducting local workshops with citizens where they work hand-in-hand with local administrations and facilitators to raise awareness of NBS, co-produce interventions and identify the expected co-benefits in a specific CAL context. During the co-implementation phase, they work more on synthetizing and merging stakeholder capacities, funds and overcoming limitations in the CAL-specific status quo and check with specialists the feasibility of the NBS in place.

In this section, an overview analysis of the CALs’ experience has been elaborated based our analysis on a comparative study mainly from the official deliverables of the project, such as D2.1: Urban Innovation Partnership establishment (December 2018); D2.2: co-creation planning, and co-design of solutions (June 2019); and D2.3: co-implementation planning (November 2019). To complement the data acquisition, we conducted multiple site visits, regular monthly teleconference calls with cities leaders, bimonthly steering group meetings and interviews with the main local cluster partners.

Grounded in a comparative analysis of these three cities and nine living labs, the key characterization of the NBS implementation framework could be categorized into several key topics as follows:

Firstly, all the three greening strategies target social challenges in neighborhoods contexts with social cohesion problems and undergoing urban regeneration. Hence, NBS are intended as a medium to catalyze attention and interest by citizens, to test collaboration and to build local identity. According to project partners’ co-creation workshops, the envisioned measures have been selected to have an impact mainly on human-centered aspects, such as social inclusion, safety and security and well-being and only to a lesser extent on environmental quality, biodiversity and climate-change mitigation since they are considered as NBS spillovers in place. In particular, to respond to the situated challenges, each city applies an NBS of different types and at different scales. For instance, Hamburg opted for a green corridor with spots-scaled interventions on a cross-neighborhoods ULL; London is working on a water-body intervention in Thamesmead Lake on a whole neighborhood ULL; and Milan promotes punctual interventions along a railway infrastructure and a green roofs and walls in the southern transect of the city. Secondly, most of the selected NBS are small- to medium-scale applications, cheap or of medium cost and potentially easy to implement and be managed by local people within existing community initiatives. Among the most diffused NBS to be co-developed with citizens, we can list raised-bed gardens, nano-gardens to be installed in private balconies and small-scale aquaponics solutions in school yards. More technically demanding NBS from a financial and construction point of view, like green walls and noise barriers, green roofs and phytoremediation, are instead implemented by public or private actors, in the quality of the owners of the NBS measures while co-management is given to citizens. Henceforth, opening the co-creation of these cost-intensive solutions to the wide public is a way to increase their social local acceptance, sense of belonging to the measures in place, and shared outcomes achievement.

Thirdly, it was important to recognize the specific room for maneuver in promoting co-creation as part of the collaborative pathway within each CAL and for each proposed NBS: for instance, some measures cover the complete co-creation pathway, including citizens from ideation to construction and co-management; other NBS, on the contrary, can only allow consulting citizens in the early stage of ideation and engage them in the maintenance at the end. Based on the NBS types and the corresponding co-creation potential, different custom-made governance models have to be established. In fact, in Hamburg, the large-scale green corridor foreseeing multiple NBS in schools and public-owned spaces, requires a strong public authority-driven coordination; in London, the role of Peabody, the social housing property manager is crucial to engage residents, facilitate the collaboration, and provide the right instruments to achieve implementations; in Milan, the variety of the three CALs' objectives require very different governance models, some led at the city level for promoting the engagement of private property owners to install green roofs and walls, some others led by co-creation facilitators at the community level to cope with the complexity and priorities of local people, also in relation to the specific financing mechanisms and co-management options of the proposed NBS.

Grounded in this overview of the local contexts, the following analysis summarized in Table 1, specifically addresses spatial, governance, and financial challenges occurring in the various contexts.

The most connoted differences between the three cities are the urban spatial domains embedding the NBS interventions and the CALs. In fact, some CALs refer to local areal interventions (a new park, a public square, a schoolyard), while some are small-scale measures and diffused over the district (nano-gardens on balconies) or even the whole city (green roofs and walls). Moreover, within the same CAL, several NBS can be co-created and put in place, for instance, within the same public garden.

Therefore, depending on the scale of the NBS, the involvement of the citizens in ideation, construction and maintenance can vary significantly, thus impacting the shared-governance potential. Moreover, the target users and stakeholders involved

Table 1 Summary of the spatial, governance, and financial challenges addressed by the CLEVER Action Labs

Topics	Strong influences	Weak/negative influences
Spatial challenges		
Urban scale of intervention	*Hamburg*: opted for a single district green corridor, unifying efforts on stakeholder's engagement and collaboration *London*: used a "hybrid solutions" model for a classic district urban-regeneration process for testing the co-creation of NBS methodology feasibility and economic viability	*Milan* has fragmented ULLs of interventions which require more "diversity" of stakeholders and further collaboration beyond one CAL-specific scale *All*: large-scale interventions require long-term maintenance; the co-implementation plans of the nine CALs are developed to include sections on long-term maintenance
Type of interventions	*Hamburg*: a diversity of solutions in school yards and green roofs enable a variety of co-benefits spreading *Milan*: a new train stop embedding green walls and noise barriers and a green public living space as an open-air waiting room for commuters	*Milan*: a variety of types of interventions, which makes the prioritization of specific NBS in place a hard process in co-design *All*: Integration of CALs in existing urban contexts is noticeably slow because citizen engagement is happening in a gradual involvement process
Maintenance and upscaling	*All*: Possible success stories in EU contexts due to citizens' stewardships (e.g., in London) *Hamburg:* educational aspects and awareness raised for school students and possible future interventions	*All*: Lack of financial resources due to long-term feasibility models that require return of investment in sustainable planning *All:* Citizen stewardship tested against the co-creation process and requires long-term involvement of stakeholders
Environmental benefits	*London*: The lake to be regenerated and reclaimed, hence enhancing biodiversity *Hamburg*: Social cohesion with schoolyards project and raised-bed gardens *Milan*: less noise pollution and a new community garden in Giambellino area	*Milan*: possible green gentrification from green roofs and walls lab *Hamburg*: low impact from green roofs labs due to small-scale intervention *London*: possible green gentrification from lake cleaning and NBS social segregation

(continued)

Table 1 (continued)

Topics	Strong influences	Weak/negative influences
Governance challenges		
Urban policies and regulations	*Hamburg* opted for digital participation for citizen engagement in the process *London*: overcome the low participation from local citizens with school students *Milan*: CAL 1 embedding co-creation procedure involving stakeholders (municipality, professionals and citizens) as part of the public bid for green roofs and facades as a prerequisite to access funding	*All*: many assessment frameworks and procedural inequalities that a specific pathway for implementation does not necessarily work equally - No specific guidelines on how NBS should be co-created and up-scaled in urban contexts; the co-creation guidance was the first experience to guide the process development
Urban Innovation Partnership	*London*: inclusive process by bringing on board citizens, residents, environmental agencies, and local government authorities. *Milan*: innovation to embed co-creation in a municipal governance process	*Milan*: fragmentation of resources between public and private authorities which requires longer times to overcome the breaking-siloes process, defined as path-dependency processes
Management and monitoring	*London*: potential usage of smart applications already in the market to measure the success of social cohesion in the area, safety and security	*Hamburg*: Lack of adequate framework for assessment of NBS impacts of social cohesion (in general) and specific measures to inclusion
Communication and transparency	*Milan*: periodic newsletter sent to a network of stakeholders for events and participation *All*: cross-cutting collaboration and information circulation between PM and all involved partners due to shared digital platforms	Different Language in *Hamburg* and *Milan* made the communication with the public harder due to translation of NBS materials *All*: benchmarking CLEVER CALs is challenging to communicate in the same way to local agencies and citizens
Financial challenges		
Installation, maintenance, and type of intervention	*All*: the difference in spatial scales of NBS interventions make the financial investment vary by consequences. In other words, the commitment to co-maintain the solution varies by the type of social responsibility, as well	*All*: risk of lack of wider citizen engagement in ULLs and co-design processes. Engagement through volunteering or in-kind compensations in general

(continued)

Table 1 (continued)

Topics	Strong influences	Weak/negative influences
Securing long-term funds	*Milan*: public and private funding opportunities on a public bid for promoting green roofs and walls, with extra 10% on-top increment in case of implementing innovative solutions	*Milan*: difficulties to implement a financing scheme in public tenders that enables embedding co-designed interventions

the co-creation (e.g., citizens in general, school pupils, social housing residents) affect the medium of the CALs, ranging from a variety of in-presence activities (focus groups, public events, contests) to online participatory tools (surveys, social media groups, and debates). In addition to the modalities to engage stakeholders, collaborative decision-making requires public authorities to incorporate the shared-governance attitude into routine planning procedures, breaking the silos of traditional decision making. Moreover, co-creation of NBS requires robust maintenance and a monitoring cultural approach, particularly essential when dealing with evolving living green features.

Finally, financial challenges also depend on the scale of intervention, the type of stakeholders involved and the owners of NBS, either public or private. For instance, a hard infrastructure like a green noise barrier or a lake-wide phytoremediation requires concentrated investment, often based on consolidated procedures, like public tenders. In fact, embedding co-design interventions in public procurement procedures has turned out to be one of the most crucial challenges that requires the implementation of innovative financing schemes. On the other hand, diffusing small-scale NBS among citizens can be based on public incentives (e.g., a public tender for funding green roofs) or happen at no cost, when exclusively relying on people voluntary contribution (i.e., nano-gardens on balconies).

5 Conclusions and Bottlenecks: Lesson Learned from Experiences of Implementing Co-created NBS in Cities

Relying on real on field experience carried out in the aforementioned European cities, this paper investigates the major challenges encountered during the implementation of a co-creation pathway for embedding NBS in urban-regeneration processes in the three front-runner cities. Beyond these three cities, the project has six fellow cities that follow the co-creation pathway and are setting up their ULLs at a later stage. The evidence about experimental indicators for success of the co-creation process is the knowledge transfer between cities and lessons learned during the process. However, the project is still in its first two years, which gives space to iterate on the process and periodically inform the lessons learnt. The ultimate goal of this study is to understand if it is possible to move from siloes thinking and decision-making routines to experimental co-creation experiences, adopting more consolidated and shared-governance routines and participatory practices in urban policies at city level.

Since the integration of NBS in the urban context comprises a variety of typologies, scales of applications and sizes, ULL types and actors involved, the question is if it is possible providing a universal, comprehensive and at the same time flexible co-creation approach to meet all these conditions under the bigger umbrella of a holistic urban-greening strategy. Elaborating on these questions, the study investigates the current ongoing co-creation experiences of nine living labs, resulting on the major issues and challenges, as summarized below.

(1) *Localizing NBS into urban-regeneration context of ongoing processes*: exploring how NBS interventions enter the narrative of urban-planning strategies at city and local level; how cities are providing a solid vision and mission for mainstreaming urban-greening projects. Most of the times, NBS projects overlap with ongoing urban dynamics. In some cases, NBS are assumed to be an occasion to accelerate urban transition; in other cases, NBS do not meet societal priorities in specific contexts, whereby urban greening is not always recognized as a key topic when it comes to allocating limited economic resources.
The lesson learned is to introduce NBS as a key city-wide urban-regeneration priority action from the very beginning, hence ensuring that the co-benefits are highlighted to stakeholders and end-users during the whole decision-making process and not just as the result of a greening intervention. This will ensure a wider sense of belonging and ownership.

(2) *Communicating NBS to wider society public*: by definition, NBS should aim to address specific environmental and social challenges that are place-based. We examined if this is always the case, and if people perceive the role of NBS effect in providing those expected co-benefits. For instance, it is not easy to communicate and acquire evidence of the wider role NBS can play. The translation of the technical term of NBS into practice, i.e., its common use as a concept in participatory activities, is questionable. In fact, the term, originated in academic and research domains, is hardly transferable to the wider public during engagement processes.
The lessons learned is hence to build a strong network that can diffuse NBS culture to a wider audience through a consolidated partnership, whereas the supply and demand for greening services are dialoging, communicating and constantly collaborating and simplifying its dissemination.

(3) *Homogenizing approaches for different NBS interventions*: NBS have revealed to be extremely varied terms of typologies and operation at different scales. This variety makes a universal approach to co-creation rather uncertain. For instance, stressing participatory approaches and the involvement of a multitude of actors, in the implementation of very small-scale interventions, might waste resources, especially in fragile urban contexts. On the contrary, high-impact large-scale NBS infrastructure can only hardy be shared with the wider public.

The lesson learned is to use innovative tools of co-creation (like co-design by immersion, personas simulation and digital participation tools) to facilitate and speed-up the implementation of complex large-scale NBS with limited timespan and flexibility.

(4) *Attracting investments*: The attraction of financial investment around NBS follows very complex patterns. Interpreting actors' constraints in the absence of a direct and tangible return of investment and investigating how cities try to provide effective stimuli are crucial aspects of successful NBS implementation. Financial issues refer in particular to both the implementation and the long-term co-management of NBS and the need for new business models in urban nature stewardship.
The lessons learned is that incurring multiple stakeholders' involvement through an urban partnership and the establishment of a strong city-wide vision and narrative of NBS role in the overall greening strategy is crucial, in order to support the consolidation of a strong economic long-term investment.

(5) *Enabling shared governance in public authorities' routines*: Finally, the overall capacity of a city administration to provide a reliable and consolidated framework for enabling a shared governance and an effective and continuous participation process consistent with the NBS co-creation pathway remains the main challenge in the background of this study. This work examined: if cities are able to translate experimental processes into policies; if cities are gearing up to make co-creation practices a routine into all urban-greening interventions; and if cities are embedding co-creation sleeve tools and updating urban-planning policies and bureaucratic procedures to make co-creation easier.

The lessons learned is that embedding co-creation into decision-making routines is still a challenge and requires to overcome practical obstacles, among others: breaking siloes in decision-making procedures, managing the costs of continuous day-to-day activity of back-and-forth dialogue between owners, authorities, and stakeholders, which is demanding in terms of effort, time and money. People responsible for NBS implementation tend to avoid sharing decisions with the public to reduce conflicts and delays. If applied from the very beginning and with all the stakeholders, co-creation can give a boost to regeneration processes, but it requires skills in facilitation public participation and co-creation.

To sum up, although NBS are lately gaining a widespread consensus among researchers and are supported by the European Commission funding schemes with a remarkable outreach, there is a further need to formalize their impacts and potentials with a multitude of actors and implementation mechanisms, taking into account the variety of NBS types, scales and applications situations. Bringing the process inside local authorities' headquarters, municipality seats and public or private organizations was shown to be rather challenging. Nonetheless, it is doubtless that citizen engagement in urban-planning processes has become more diffused, structured, and institutionalized, especially through these pilot projects. However, co-creation of NBS is still perceived—and often applied—as a fuzzy concept and time-consuming task. More research is needed to enable co-creation to be embedded deeper into ordinary planning processes.

Acknowledgements This document has been prepared in the framework of the European project CLEVER Cities. This project has received funding from the European Union's Horizon 2020 innovation action program under grant agreement no. 776604. The sole responsibility for the content of this publication lies with the authors. The authors would like to thank Dr. Carolina Cantergiani De Carvalho from Tecnalia team; the project coordinator, Dr. Martin Krekeler, from HWWI; Emilia Barone, Nicola-Murphy Evans and Jan Pastoors, city project managers of Milan, London, and Hamburg, respectively, for their work on the coordination of the co-creation process in cities and the provision of documents and project deliverables.

The authors would like to thank the two anonymous reviewers for their valuable comments and contribution to improve the quality of the manuscript in its final form.

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Innovative Approaches to Energy Governance: Preliminary Quantitative Insights from the Literature

Silvia Tomasi and Sonja Gantioler

Abstract With a significantly changing global climate and related impacts on our societies becoming increasingly visible, the call for a significant change of the energy production and consumption system gets increasing attention. Defined as energy transition, such change involves at least two dimensions: one technological and one social. Especially the latter is gaining importance because it is argued that the impact of technological innovation could be limited, if not harmful, if the technological would not be matched with social innovation. This refers to the emergence of decentralized energy systems at the local scale, and the increased involvement of non-state actors in shaping the transition, like civil society, business, and local public authorities. It includes new forms of governance, ranging from energy communities to the design of urban living labs. This work aims to provide the first insights for the further development of a theoretical framework in relation to governance and social innovation in the context of energy transition. It builds on a bibliometric quantitative analysis to explore the extent to which changes in energy governance are reflected in the scientific literature. Results indicate that energy governance issues have quite settled in the scientific literature across the world, but that social innovation is only a recently emerging topic. A snapshot interpretive analysis is then performed to get a better understanding of what types of energy governance and social innovations are addressed. These mostly refer to energy communities and organization types related to the use of renewable energies (e.g., cooperatives and public–private partnerships), as well as obstacles and opportunities that drive their implementation. A keyword analysis is used to get the first indications on the direction of the discussion. Generally, this seems rather heterogeneous, though most often it is related to urban development and cities, as well as in relation to the planning practice. Future research should extend and carry out further in-depth analysis of the preliminary insights outlined in this work.

Keywords Energy transition · Energy governance · Social innovation · Bibliometric analysis

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_18

1 Introduction

As recently reported by the United Nations, which is responsible for assessing science related to climate change, the climate is dramatically changing, and its impacts are already affecting our societies (Intergovernmental Panel on Climate Change 2018). Thus, a disruptive revision of the energy production and consumption system is urgently needed. The energy transition can be characterized as a complex change process concerning the way energy is produced and consumed (Cherp et al. 2018). In fact, the energy transition involves at least two dimensions: the technological one requiring the introduction of technological innovations and the societal one whose impact would be limited or even potentially harmful if such a change would not be matched by social innovation (Domanski et al. 2019; Hoppe and de Vries 2018). At the same time, it has been widely recognized that such a process involves a change also in the governance of the energy system: decentralized energy systems need a multi-level and polycentric governance approach that embraces strategies at different scales, including, even if not limited to, the local one. In addition, non-state actors are gaining a central role in energy decision-making, like civil society, business, and local public authorities (Sovacool 2011, 2014). In this context, new approaches to energy governance are emerging, which can be described as forms of social innovation, ranging from energy communities to the design of urban living labs (Hoppe and de Vries 2018). However, a theoretical framework linking together and exploring the connections among the concepts of governance and social innovation in the energy transition is still lacking. By providing the first insights into the quantitative interplay of the concepts of governance and social innovation in the context of energy transition in the scientific literature, as a result of an extensive bibliometric analysis, this work aims to shed some preliminary light on the knowledge gap on the topic and to further inform the author's development of such a framework, related to new approaches to energy governance in the energy transition. In this regard, it is expected to contribute to expanding the knowledge about new approaches to governance of the energy transition and aims to support the local energy planners in including the social innovation dimension in their local energy strategies.

This paper is structured as follows: Sect. 2 introduces the key research questions and describes the method selected and used to perform the extensive literature review, including the quantitative bibliometric analysis and the qualitative content analysis of the identified literature bodies. Section 3 provides the results of such analyses, which are further discussed in Sect. 4, where also conclusions are drawn.

2 Method

This study analyzes the linkages between the concepts of governance and social innovation in a context of energy transition in the scientific literature. Hence, the central research question addressed by this work is:

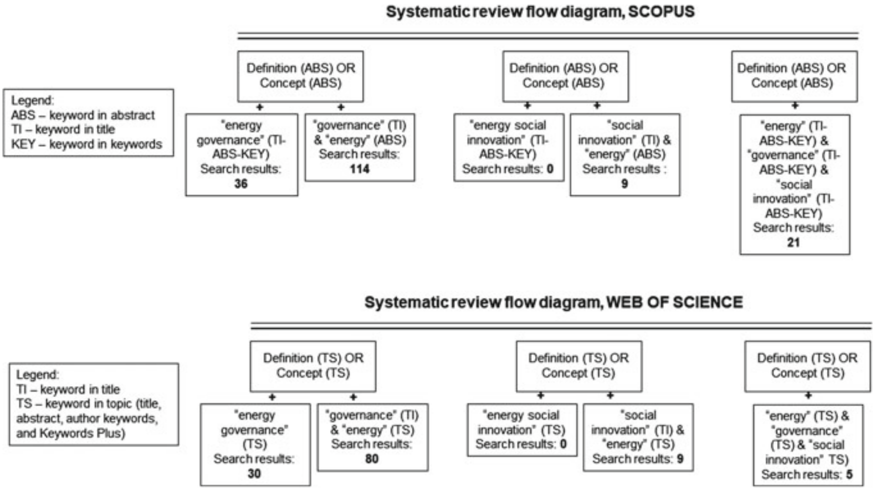

Fig. 1 Overview of the systematic literature search via Scopus and Web. *Source* Own elaboration

To what extent are innovations in energy governance referenced in the scientific literature?

It can be further broken down in two sub-questions:

1. *What types of energy governance are addressed?*
2. *Is the social innovation dimension considered in energy planning?*

The first main question is answered by an extensive bibliometric analysis, while the following two sub-questions are addressed by an initial, mainly quantitative content analysis: the first one by digging deeper in the scientific publications looking for case studies; the second one by performing a keyword frequency analysis.

2.1 Bibliometric Analysis

Bibliometric analysis applies quantitative and statistical methods to study scientific publications (Wu et al. 2020). The authors performed an extensive and systematic literature review of the concepts "energy transition," "governance," and "social innovation," using the two most common scientific search engines, i.e., Scopus and the Web of Science (core collection) (Andrés 2009). More specifically, since the objective of the research and analysis is to investigate the concepts of "governance" and "social innovation" in the energy field, in each search the keyword "energy" appears. Figure 1 shows the eight datasets obtained and the parameters used for each search.[1] Since the aim of this work is to explore the first quantifiable linkages among different

[1]Last update: 29/11/2019.

Table 1 Summary of the bibliometric analysis results and type of analysis performed

Dataset number	Search keywords	Dataset size	Search engine	Type of analysis
1	Energy/governance	150	SCOPUS and WEB OF SCIENCE	Temporal and geographical analysis; Citations count; Publication platforms; Salient keywords
2	Energy/social innovation	13	SCOPUS and WEB OF SCIENCE	Temporal and geographical analysis; Citations count; Publication platforms; Salient keywords
3	Energy/governance/social Innovation	23	SCOPUS and WEB OF SCIENCE	Temporal and geographical analysis; Citations count; Publication platforms; Salient keywords

Source Own elaboration

concepts, for each search we added the condition that either the word "definition" or "concept" should also appear. In addition, the search is limited to keywords in abstracts, title and keywords.

Table 1 shows the final datasets containing the literature bodies obtained once the preliminary ones were merged, harmonized, and cleaned, and synthesizes the types of analysis performed on each dataset. These analyses provide descriptive statistics such as:

- Number of publications per year for each dataset, to understand the evolution of publication trends. All publication platforms, such as journals, books, and conference proceedings have been considered;
- Geographical distribution of publications by country. The analysis takes into account the countries affiliated with all authors, i.e., not just the affiliation of each publication's first author. The geographical analysis of publications contributes to understanding if the scientific discussion in the field is spread all around the world or rather occurs in selected regions;
- Likely impact of research on the scientific community, measured by citation frequency, both of publications and journals;
- Most salient keyword terms associated with each subset of datasets. When merging the preliminary datasets obtained from the two different search engines, if different, the list of keywords for each publication were integrated.[2]

[2]This refers to the list of keywords not given by the author, i.e. Index Keywords for Scopus and Keywords Plus® for Web of Science.

2.2 *Content Analysis*

Content analysis makes possible performing a more in-depth analysis of the selected publications, although the key focus of this study was a quantitative approach by looking into the frequency of some selected terms. The authors selected a range of publications based on their content, looking for the following keywords either in the title or among the article keywords listed: case study; approach; top-down; bottom-up; energy community; energy cooperative; and living lab. We obtained a list of 64 publications which were further screened in order to realize a final selection down to eight relevant articles and to carry out a snapshot interpretive analysis.

3 Results

In general, the energy/governance literature body is the largest with 150 publications, while the other two literature datasets are smaller. The temporal analysis of the publication trends however shows (see Fig. 2) that the literature bodies "energy/social innovation" and "energy/governance/social innovation" are more recent. While the concept of energy/governance appeared already in the literature in the early 1990s and has gained momentum since 2007, the concept of social innovation in energy research emerged just ten years ago and is still rather underrepresented in the scientific literature body.

The geographical distribution of the three literature bodies widely varies, as Table 2 shows. The concept of energy/governance is researched all over the world, particularly in Europe and North America, except in South America. However, also Chinese

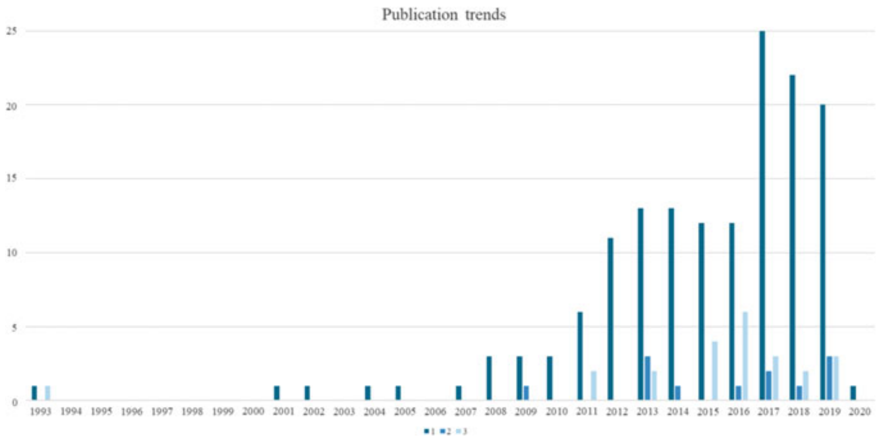

Fig. 2 Temporal analysis of the publication trends: number of publications, for each dataset, per year (1993–2020). *Source* Own elaboration of data of the three datasets

Table 2 Geographical distribution of the three literature bodies. For dataset 1, only countries with up to six affiliations are shown

Dataset 1. Keywords: Energy/governance		Dataset 2. Keywords: Energy/Social Innovation		Dataset 3. Keywords: Energy/social innovation/governance	
Germany	41	Germany	9	Netherlands	8
Netherlands	30	United Kingdom	7	United States	7
United Kingdom	29	Japan	4	France	6
United States	29	Italy	3	Germany	5
Finland	16	Netherlands	2	Canada	2
Australia	15	France	1	Australia	1
China	14	Austria	1	Sweden	1
Sweden	13	Spain	1	Belgium	1
Malaysia	12	Poland	1	India	1
Canada	9	Brazil	1	Italy	1
Belgium	7			Austria	1
Mexico	7			Japan	1
Norway	7			Brazil	1
India	6			United Kingdom	1
Ireland	6				
Singapore	6				

Source Own elaboration of data about authors' affiliations of the three datasets

and Australian academics significantly contribute to the scientific literature body about energy/governance. Such a worldwide diffusion reflects the long-lasting article production as illustrated before.

The scientific literature about social innovation in energy research originates mainly in Europe, where Germany is the country producing the largest number of articles, similar to the first dataset. However, energy/social innovation is also discussed in Asia (i.e., Japan) and South America (i.e., Brazil), as Table 2 illustrates.

Finally, even if the scientific discussion about social innovation and governance related to energy issues in literature takes place mainly in Europe and North America, contributions to it come from every continent, Africa excluded (see Table 2).

The citation analysis is assumed to identify the scientific literature that likely has had the most significant impact on knowledge. The ten most cited publications of the overall dataset obtained with the three strings are reported in Table 3. Overall, it includes eleven publications, due to the last two articles having an equal amount of citations. None of the papers belonging to the second sub-dataset are part of the list, reflecting also the limited size of the extent of the scientific literature's discussion concerning social innovation. Interestingly, two authors appear more than once in the list of the most cited publications. Both publications do not address energy issues specifically. They focus on governance in relation to the urban environment and the

Table 3 Overview of the ten most cited publications

Authors	Title	Year	Cited by	Dataset
Haase, D., Frantzeskaki, N., Elmqvist, T	Ecosystem services in urban landscapes: practical applications and governance implications	2014	261	1
Florini, A., Sovacool, B.K	Who governs energy? The challenges facing global energy governance	2009	143	1
Bhattacharyya, S.C	Energy economics: Concepts, issues, markets and governance	2011	142	1
Turnheim, B., Berkhout, F., Geels, FW., Hof, A., McMeekin, A., Nykvist, B., van Vuuren, D.P	Evaluating sustainability transitions pathways: bridging analytical approaches to address governance challenges	2015	115	1
Orsini A., Morin, J.-F., Young, O	Regime complexes: a buzz, a boom or a boost for global governance?	2013	114	1
Benson, D., Gain, A.K., Rouillard, J.J	Water governance in a comparative perspective: from IWRM to a “nexus" approach?	2015	100	1
Späth, P., Rohracher, H	Local demonstrations for global Transitions-dynamics across governance levels fostering socio-technical regime change towards sustainability	2012	85	1
Walker, G	The role for “community” in carbon governance	2011	85	3
McPhearson, T., Andersson, E., Elmqvist, T., Frantzeskaki, N	Resilience of and through urban ecosystem services	2015	82	3
Zelli, F., van Asselt, H	The institutional fragmentation of global environmental governance: causes, consequences and responses introduction	2013	82	1

Source Own elaboration

concept of ecosystem services, in particular. Other papers rather more widely discuss low-carbon governance or integrate different topics (e.g., integrated water resource management, sustainability, and environmental governance).

Table 4 shows the assumed impact on knowledge not only of single publications but of journals, particularly those that published more than two papers of our datasets. They account for almost one-third of the entire set of investigated publications included in the three datasets. Energy policy is overall the most predominant journal in our dataset and is also listed among the most relevant international peer-reviewed journal in energy research. It investigates the policy implications of energy

Table 4 Overview of the most productive journals of our dataset. Source: Own elaboration

Journal	TA[a]	IF 2018[b]	Categories[c]
Energy Policy	9	4.880	Economics; Energy and Fuels; Environmental Engineering and Energy; Environmental Sciences; Environmental Studies; Social Sciences, General
Energy Research and Social Science	7	5.525	Environmental Studies; Environmental Studies, Geography and Development; Social Sciences, General
Sustainability (Switzerland)	6	2.592	Environment/Ecology; Environmental Sciences; Environmental Studies; Environmental Studies, Geography and Development; Green and Sustainable Science and Technology
Energy, Sustainability and Society	4	1.901	Energy and Fuels; Engineering; Green and Sustainable Science and Technology
Journal of Cleaner Production	4	6.395	Engineering; Engineering, Environmental; Environment/Ecology; Environmental Engineering and Energy; Environmental Sciences; Green and Sustainable Science and Technology
Environmental Science and Policy	3	4.816	Environment/Ecology; Environmental Sciences
45th International Conference on Large High Voltage Electric Systems 2014	2	–	
Climate Change Management	2	–	
Current Opinion in Environmental Sustainability	2	4.258	Environment/Ecology; Environmental Sciences; Green and Sustainable Science and Technology
Ecological Economics	2	4.281	Ecology; Economics; Economics and Business; Environment/Ecology; Environmental Sciences; Environmental Studies
Environmental Politics	2	3.827	Environmental Studies; Environmental Studies, Geography and Development; Political Science; Social Sciences, General
Global Environmental Change	2	10.427	Environment/Ecology; Environmental Sciences; Environmental Studies; Environmental Studies, Geography and Development; Geography; Social Sciences, General

(continued)

Table 4 (continued)

Journal	TA[a]	IF 2018[b]	Categories[c]
Journal of Environmental Policy and Planning	2	4.195	Development Studies; Environmental Studies, Geography and Development; Regional and Urban Planning; Social Sciences, General
Journal of Environmental Studies	2	–	
Review of European, Comparative and International Environmental Law	2	2.125	Environmental Studies; Law; Social Sciences, General
Social Innovation: Solutions for a Sustainable Future	2	–	

[a]Total of Articles in the three datasets
[b]*Source* 2018 Journal Impact Factors, Master Journal List, Web of Science
[c]*Source* Master Journal List, Web of Science

issues by economic, social, planning, and environmental perspective. According to the investigation, it comprises articles belonging to all three sub-datasets and therefore covers all the concepts studied in this work. Other predominant journals are Energy Research and Social Science, which focuses on the relationship between energy systems and society, and Sustainability (Switzerland), which has a broader scope, not focusing exclusively on energy.

In order to enable an inter-journal comparison, the study relies on the Impact Factor (IF), which is commonly used to measure the importance of a journal, in its field, meant as the assumed impact on knowledge that it has had during a fixed period of time and included as a reference each journal's influence on the scientific discussion. The higher the IF is, the better the journal ranking, compared to others of its own discipline. In order to enable such a comparison, the study looked at the discipline categorization of journals provided by Web of Science. For the most common categories in our list, Environmental Sciences and Environmental Studies, the most prominent journal is Global Environmental Change (IF of 10.427), which includes a few of the listed articles. Excluding this broadly labeled journal, the most influencing journal in Environmental Sciences is the Journal of Cleaner Production (IF of 6.395), comprising four articles of our dataset. Energy Research and Social Science (IF of 5.525), comprising seven publications, seems to be the predominant journal in Environmental Studies.

The previous analysis of the scientific literature's discussion of the topics of governance and social innovation in the energy transition is thought of foremost importance to understand its state of the art and its evolution. Focusing on the content of the papers is necessary to understand the potential empirical implications of the changing and developing discussion on energy governance. Table 5 lists the eight publications that have been identified by the literature datasets to be the basis of the initial investigation, based on specific keywords as described in Sect. 2.2. They were selected because of the empirical information they provide, in particular the case studies they describe and the examples of social innovation initiatives they present. They not only

Table 5 Selected publications for snapshot interpretive analysis

References	Research subject	Form of social innovation	Country
Fuchs and Hinderer (2014)	New governance structures for decentralized electricity generation—four local initiatives	100% bio-regions: energy independent, generation of electricity only from RES, resulting from citizen action groups or hosted by public and private actors	Germany
Chatfield and Reddick (2016)	Smart community projects which use informal social governance mechanisms for effective smart city implementation	Smart community and testing of citizen-centric e-governance in Kitakyushu City, Fukuoka Prefecture, Kyushu	Japan
da Silva et al. (2018)	Energy Living Lab implemented at the University of Campinas, model for sustainable campuses in Latin America	Living Lab installed for University Campus Campina, as an open innovation ecosystem through the integration of users, academia and the market	Brazil
Hewitt et al. (2019)	Role of Citizen-driven Renewable Energy (RE) projects, community energy, in the worldwide transition to cleaner energy systems	Historic development of community energy initiatives in eight selected countries, by energy type (e.g.. wind power, biomass) and organization type (e.g.. most often renewable energy cooperatives, local government + citizen participation, public–private partnerships)	Belgium, France, Germany, Italy, Poland, Spain, Sweden, and United Kingdom
(Van Veelen 2018)	Assessment of the complex and varied ways in which communities in Scotland practice energy governance	15 energy community groups across Scotland, sorted into five broad categories: “Small Is Beautiful,” “Community Developers,” “Innovators,” “Energy cooperatives,” “Transition Towns”	United Kingdom

(continued)

Table 5 (continued)

References	Research subject	Form of social innovation	Country
Reinsberger et al. (2015)	Identification of critical factors, which foster or hinder the development of bottom-up initiatives—social innovation—in the diffusion of photovoltaics	PV bottom-up initiatives, including voluntary associations, social enterprises, co-operatives, informal community groups, farmer societies, or municipal public buildings for PV plants	Austria
Nolden (2013)	Analysis of the development of community energy in the UK by comparing it to Germany in relation to decentralization, scales and ownership structures particularly of wind energy	Wind energy communities, either actively engaged in technological diffusion through community-led projects, or through the (part-)ownership of municipal utilities, or benefitting through co-ownership, business taxes, community funds and/or share offers from commercial developments	United Kingdom
Heldeweg et al. (2015)	Collaboration of government with private sector organizations toward a proper "energy transition" through regional and local projects	"Biogas grid Noordoost Fryslân," public–private partnership (PPP)	The Netherlands

Source Own elaboration

describe European initiatives, but also experiences from Latin America and Japan, reflecting the results of the geographical distribution of the scientific discussion in energy research. Most of the energy/governance/social innovation initiatives refer to energy communities that produce electricity from renewable energy sources (RES), although they vary in size, territorial level and kind of stakeholders involved. They also mostly focus on describing contextual barriers and opportunities that drive the development of such initiatives. Two publications go beyond the concept of energy community and refer to more integrated experiences, such as living labs and smart city projects. However, it remains surprising the limited extent to which the living lab concept seems to have entered the scientific discussion in relation to energy governance and social innovation. This might be linked to one of the main challenges regarding the implementation of the concept: a stable and effective participation of various stakeholders throughout energy governance and ICT processes and the creation of a community beyond the framework of timely limited smart city projects (Nesti 2018). The application of the concept is currently further explored by the authors in the framework of the EU Horizon 2020 project STARDUST (Tomasi et al. 2019).

Finally, an analysis of the keywords frequency has been performed. Keywords analysis can highlight the research focus and direction of an article (Wu et al. 2020) and therefore sheds further light on its content. The keywords frequency analysis has been performed with the software NVivo, treating similar words, i.e., stemmed words (e.g., policy, policies), as one keyword. Datasets 2 and 3 appear to be more heterogeneous than dataset 1, since in both cases around 60% of the keywords only appear once. Interesting, in all three sub-datasets, the keyword *city/urban* appears within the 20 most recurring, and in datasets 2 and 3 within the first four, meaning that the research about social innovation in energy research occurs for the moment mainly at the urban level. Moreover, the keyword *planning* is also one of the most frequently occurring ones in all three datasets, suggesting that (urban, spatial) planning is closely interlinked with energy governance and social innovation.

4 Discussion and Conclusions

This study combines bibliometrics with content analysis to mainly quantitatively but also qualitatively analyze the interplay of the concepts of governance and social innovation in the context of energy transition, by exploring the relevant discussion in the existing scientific literature to the present and the extent and impact of such discussion. The size of the three obtained literature datasets was constrained by the choice of resorting to the two main scientific search engines. Thus, future research should consider including Google Scholar as a publication source: A recent article highlighted that, on the one hand, Scopus and Web of Science are quite reliable, but only partially cover the relevant literature. On the other hand, Google Scholar is more comprehensive but its automatized approach to select documents may lead to duplicates, errors and a high amount of gray literature (Martin et al. 2018). Moreover, the criteria used for publication source could bias the datasets obtained. Relaxing the search parameters could lead to a more comprehensive review of the status quo of knowledge about social innovation and governance in the energy transition. In addition, the selection of the search keywords could be further refined (e.g., by including selected social innovation or energy governance types) to gain more specific insights into the concepts and reduce inaccuracies linked to the screening of mainly abstracts and keywords.

All things considered, this study makes a first attempt to investigate the role of new approaches of energy governance in the current energy transition, as perceived by the scientific community and reflected in the current scientific knowledge about the topic. With the rapid changes that the current energy transition requires, the scientific discussion in energy research literature is increasingly focusing on the governance aspects of new energy systems, and innovative social innovation initiatives are receiving growing attention. As the analysis of the various dimensions of the three literature datasets has shown, social innovation individually is yet less often discussed. However, the research about new energy governance has been increasing over the last two decades, and it now covers each continent, with Europe being the frontrunner. And, as the content analysis revealed, practitioners increasingly take into consideration energy governance in local and regional energy planning. At the same time, it needs to be highlighted that most of the papers discussing concrete examples or case studies focus on identifying barriers and opportunities that might further drive the development of new forms of energy governance or social innovation. They highlight that still a major gap exists between existing policy targets, e.g., in further fostering energy communities, and the actual implementation (e.g., big utilities as major national and regional players). In addition, the scientific literature discussion on governance seems strongest where wider environmental aspects or the development of integrated solutions is studied, likely hinting that governance and social innovation play a particular important role with regard to the solving of complex problems. However, this needs to be subject to further scrutiny in upcoming research.

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City Engagement in the Joint Programming Initiative Urban Europe and the Role of Intermediary Organizations in R&I Policies for Urban Transition

Susanne Meyer and Robert Hawlik

Abstract This research investigates the case of the Joint Programming Initiative (JPI) Urban Europe and its role as an intermediary organization, developing research, and innovation programs for urban transition. In the literature, the role of an intermediary organization has recently been discussed as an effective promoter and developer of connecting visions, strategies, activities, and stakeholders. A conceptual approach to intermediary organizations for urban transition is operationalized, and its functions are discussed in this paper. As an example, the Joint Programming Initiative Urban Europe reveals how a transnational R&I initiative, represented by 20 national R&I programs in Europe, can provide scientific evidence for sustainable urbanization with a cross-sectoral, integrated, inter- and transdisciplinary approach implemented through activities beyond joint calls. The findings show that JPI Urban Europe acts as broker and facilitator of joint visions and starts to build communities for innovation, which is one of the important functions of intermediaries. The development of its Strategic Research and Innovation Agenda clearly followed a co-creation process, putting the dilemmas of city practitioners in the center. JPI Urban Europe managed to attract high levels of commitment from a diversity of stakeholders to its strategic priorities and mobilized respective budgets for its implementation. The analysis of JPI Urban Europe participation in funded projects shows that challenge-driven calls (putting the problem owners in the center) seems to successfully develop a common language for all stakeholders and has a higher likelihood to generate more transformative outcomes. The number of funded urban living labs in projects shows that room for experimentation in niches and their extension is provided. The number of city representatives as funded project partners could be increased to further stimulate active involvement. The JPI Urban Europe also acts as a translator and enabler for learning in the urban—as well as in the policy sphere—the third function. This can be confirmed by the number and type of organizations reached with its specific formats. JPI Urban Europe coordinates joint activities of mainly national R&I programs but has only

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A. Bisello et al. (eds.), *Smart and Sustainable Planning for Cities and Regions*, Green Energy and Technology, https://doi.org/10.1007/978-3-030-57764-3_19

indirect influence on change in these organizations and limited influence on changes within research organizations, businesses, or cities that are even less connected. Overall, it can be concluded that the strategic ambition of JPI Urban Europe towards transformative change is obvious, but some instruments and formats to translate the ambition into action need further refinement, and it needs further in-depth research to better understand the outcomes and impacts of its diverse activities.

Keywords City engagement · Transition pathways · R&I policy making · Challenge-driven

1 Introduction

The transition of urban systems is central to a sustainable and resilient future as urbanization megatrends continue to persist, and principal global problems can only be addressed by system change in the urban area (Wolfram et al. 2019). An indication of the urgency of urban transition is the high-level policies that recently address this topic, e.g., the United Nation SDG (No 11 is dedicated to cities, UN 2019), the Paris Agreement with cities addresses as central players to fulfil the national climate goals or the EU Urban Agenda). But urban transition calls for an open, complex, self-organizing, adaptive and evolving systems, such as cities that need boundary-spanning collaboration, trust building, goal coordination and knowledge co-production (World Climate Research Programme 2019). Cities as problem owners should play a key role as they are both transition agents and subjects of transformation.

Wolfram et al. (2019) argue that deficits of effective intermediation are widespread, and the intermediation gap needs a dedicated response for urban transition. In the literature, the role of intermediary organization has recently been discussed as an effective promoter and developer of connecting visions, strategies, activities, and stakeholders. This research investigates empirically whether the Joint Programming Initiative (JPI) Urban Europe takes the role of an intermediary in sustainable transition, especially highlighting its role for R&I policies, governance, engagement, and collective action towards urban transition. The JPI Urban Europe is a transnational R&I programing initiative of 20 active European countries aiming to drive research and innovation for urban transitions and provide scientific evidence for sustainable urbanization with a cross-sectoral, integrated, inter- and transdisciplinary approach implemented through activities beyond joint calls (JPI Urban Europe 2015). The study addresses the following research questions: (1) What is the role of intermediary organizations for sustainable transition; (2) is JPI Urban Europe as a transnational R&I program of 20 countries an intermediate organization for urban transition; and (3) are cities successfully engaged in this program as problem owners and change agents? To answer these questions, the paper is structured as follows. Section 2 introduces a conceptual approach on intermediary organizations for urban transition. Section 3 operationalizes the concept and outlines the functions of intermediaries like the JPI Urban Europe. Section 4 presents the methods used to investigate the intermediating role of JPI Urban Europe. Section 5 reports the respective results, and in Sect. 6 a discussion and concluding remarks take place.

2 Intermediaries for Urban Transition—A Conceptual Basis

The transition of urban systems is central to a sustainable and resilient future (Wolfram et al. 2019). The sustainability challenge for cities is time sensitive regarding the need to address it (UN 2019). Clear commitment and targeted efforts are needed to achieve the system transition on a grand scale and immediate action by various actors in society. Innovation is pivotal to transform the socio-technical system in urban areas; however, delivering urban change that is transformative is still a challenge. The role of intermediary organizations to contribute to the delivery of urban transition seems to be key (Wolfram et al. 2019; Kivimaa et al. 2019b) because they can spread niche innovation to a broader scale. In this conceptual part, firstly the multi-level-perspective on transition of socio-technical systems will be discussed, revealing how system change takes place and, secondly, the role and function of intermediary organizations for systems will be introduced. This forms the basis to discuss the role of JPI Urban Europe as a transnational intermediary organization and its ability to mobilize cities for change in the empirical part.

2.1 Socio-technical Transition—A Multi-level-Perspective

The urban system is a socio-technical system. Socio-technical systems are systems in which technological elements (e.g., physical infrastructure) and social elements (e.g., governance arrangements) are deeply intertwined. The socio-technical systems perspective highlights that both dimensions evolve together to address specific societal needs, such as mobility, sanitation, and energy (De Haan et al. 2014). A transition of socio-technical systems in cities is needed to address the sustainability challenge for cities.

Social technical landscapes embed both niches and regimes. Regimes represent highly stable and entrenched configurations of the underlying rules and routines that determine how things are being done in socio-technical systems (Fuenfschilling and Truffer 2016). Niches refer to spaces in which radical innovations emerge that fundamentally challenge the status quo. They are conceptualized as a protective space offering ‘seeding’ conditions for innovative practices (Kemp et al. 1998). The multi-level perspective argues that transitions come about through interactions between three levels: landscapes, regimes, and niches. Changes in the socio-technical landscape can be achieved through the processes of learning by experimentation new socio-technical solutions/configurations occurring in niches. Innovation occurring within niches needs to be extended to change the regime. Changes on the landscape level create pressure on the regime and opens windows of opportunity for niche innovation (Geels and Schot 2007; Schot and Geels 2008).

Change is transformative, when dominant rule sets, visions, norms, routines, and capacities that underpin dominant practices in socio-technical systems are changed (Ghosh and Schot 2019; Schot and Kanger 2018). Such changes in fundamental rules will involve multiple stakeholders.

2.2 Role of Intermediary Organizations for Systemic Change Processes

Various scholars have shown that changes for socio-technical transitions can be triggered and accelerated through intermediary organizations as part of the sustainability transition policies orchestrating a network of diverse actors, activities and resources and create momentum for change (Kivimaa et al. 2019b). Intermediary organizations can intermediate between innovative practices in niches and dominant practices in socio-technical regimes (Kivimaa et al. 2019b). Such organizations are particularly important in transformative change processes because system change is a multi-actor and multi-scale process that requires strong intermediary action (Fischer and Newig 2016). As such, intermediary actors are consistently described in the transformative change literature as important and active agents of change (Fischer and Newig 2016; Hodson and Marvin 2010; Kivimaa et al. 2019b). For urban transition, Wolfram et al. (2019) explicitly call for a stronger role of intermediaries to close the intermediation gap.

Kivimaa et al. (2019b) developed a typology of intermediary organizations including five types:

- A *system intermediary* promotes an explicit transition agenda and taking the lead in aiming for change on the whole system level.
- A *regime-based transition intermediary* is tied through institutional arrangements to the prevailing the socio-technical regime.
- A *niche intermediary* works to experiment and advance activities in niches.
- The *process intermediary* facilitates a change process often without a specific agenda but in context of priorities set by actors.
- A *user intermediary* translating new niche technologies to users and user preferences to developers and regime actors.

Many intermediaries are likely to tap into more than one type. Moreover, intermediaries act on different phases of levels of transition (Kivimaa et al. 2019a).

3 Functions of System Intermediaries for Urban Transition

JPI Urban Europe promotes urban transition through R&I, and it can, therefore, be assumed that it mainly acts as system intermediary according to the typology of Kivimaa et al. (2019b). Recently, the intermediation gap in urban transition, as well as the main function of system intermediaries, has been outlined by multiple scholars (Kivimaa et al. 2019b; Klerkx and Leeuwis 2009; Geels and Deuten 2006; Wolfram et al. 2019; Hargreaves et al. 2013; Smith et al. 2016; Hodson and Marvin 2012). The three main functions of system intermediaries can be summarized as follows to answer research question 1:

1. *Broker and facilitator of joint visions and communities for innovation*
   - Connecting and coordinating between multiple stakeholders and their priorities, strategic interests and knowledge pools, as well as creating and aligning those to facilitate transitions,
   - Opening up space in the urban context for new and diverse kinds of activities,
   - Connecting and integrating European, national and regional strategies and priorities, and
   - Creating and exploring alternative governance structures.
2. *Translator and enabler for learning*
   - Translating scientific knowledge for urban stakeholders,
   - Articulating opinions and demand of cities and other urban stakeholders to the R&I community, and
   - Supporting learning processes of new urban stakeholder communities.
3. *Provider for room for experimentation in niches and extend niches*
   - Mobilizing political and financial programs for urban innovation,
   - Setting up experiments in niches, and
   - Connecting local experimentations and global niches for transition by aggregating learnings and translating good practice and standards to influence new projects.

JPI Urban Europe could well function as a system intermediary organization for urban transition. One of the key challenges for an intermediary like the JPI Urban Europe is the mobilization of cities with a set of activities. The next empirical chapter will focus on the research questions 2 and 3 investigating whether JPI Urban Europe has attributes of an intermediary organization for urban transition and if it successfully mobilizes cities as problem owner to the program.

4 Method

The research is based on primary and secondary data collection performed 2018–2019 in the course of program monitoring related tasks and a self-evaluation of the engagement of cities in the JPI Urban Europe (Meyer et al. 2018, 2019). The primary and secondary analysis methods will be described in the following while further details on the data can be found in the Appendix.

Secondary Data Analysis: The JPI Urban Europe has developed a project database which includes information on JPI Urban Europe funded projects from the first six calls (2012–2017). The list includes a total of 73 projects and 493 project partners based in 29 countries. Detailed information on the countries involved, as well as a map displaying the geolocation of the European project partners, is shown in the Appendix. An analysis of the cities involved in the projects has be conducted using this project database. Furthermore, a social network analysis was performed on the connections between project partners in funded projects.

Based on the list of participants in events of the JPI Urban Europe in the period 2017–2018, a database of JPI Urban Europe event participants (individual level) has been developed. The list includes events that have been open for cities and aid the analysis of stakeholder involvement in the JPI. In addition, a comparison of cities engaged in JPI Urban Europe projects and city participation in the EU Framework Programme based on the AIT-EUPRO database has been conducted to compare city participation in the two programs.

Primary Data Analysis: Semi-structured interviews with five (Limassol (CY), Ludwigsburg (DE), Almada (PT), Stockholm (SE), Southend-on-Sea (UK)) out of twelve pre-selected cities which were formal JPI Urban Europe project partners and three interviews with city experts have been conducted in winter 2018/2019 to learn from the cities perspectives what are the success factors for beneficial participation and what formats they recommend for engagement in JPI Urban Europe. The JPI UE project database (see Appendix) was used to identify cities from various countries.

Moreover, an online survey to the JPI Urban Europe Funding Agency Working Group was conducted to construct an overview of current funding and potential other support conditions for cities in the future. Responses from 20 agencies elicited across Europe were received. The survey targeted the types of entities that can be funded given the current involvement of the funding agency in JPI Urban Europe, the eligibility of city authorities/municipalities for funding and other opportunities to supporting city authorities.

5 Results and Discussion

This section answers research question 2—whether the JPI Urban Europe fulfills the function of an intermediary organization and research question 3—whether the JPI Urban Europe managed to engage cities as problem owners in the program.

The following sections illustrates the findings from the primary and secondary data analysis in relation to research questions 2 and 3.

5.1 Joint Vision and Research Agenda

As a transnational R&I programing initiative of 20 European countries (AT, BE, CH, CY, DE, DK, ES, FI, FR, IT, LV, NL, NO, PL, PT, RO, SL, SE, TR, UK), JPI Urban Europe follows a vision formulated as Strategic Research and Innovation Agenda (SRIA) in a co-creative process involving policy makers, researchers, city administration, city networks, societal actors, and research funders (JPI Urban Europe 2019a). The SRIA was developed over the course of an approximately one-year-long process including an open consultation, stakeholder dialogue, and national consultations in member states, as well as input from researchers, other networks, and European policy actors.

The SRIA focusses on urban transition on a systemic level by aiming at impact on cities, national urban policies and R&I policies. In its vision, JPI Urban Europe defined its ambition to support cities in their transition efforts and create robust evidence according to their needs. The SRIA follows a dilemma approach putting the conflict of interests and trade-offs between urban developments in the center because the hardest challenges for cities are reflected in trans-silo complex nexus issues. The JPI aims to explicitly address competing goals of multiple stakeholders, as well as urban governance as a cross-cutting concern. The dilemmas in the SRIA identify the need for integrating European, national and regional strategies and policies that the JPI aims to broker by creating knowledge and exchange interfaces. By targeting the stabilizing and destabilizing forces in regimes of socio-technical urban systems, the JPI Urban Europe assumes the role of a system intermediary.

Multiple instruments for implementing the SRIA focus on the connection and coordination between stakeholder types to match the priorities of urban practitioners. The Funding Agencies Working Group implements an annual Joint Call program focusing on a challenge-driven approach towards funding R&I projects in the area of urban transition illustrated in Sect. 5.2. Furthermore, the stakeholder platform, AGORA, is designed as instrument to bring together, problem owners, industry, and research in a series of target-group specific events. Findings in relation to the platform are described in Sect. 5.3.

To conclude, with its co-creative and participatory process to develop a joint vision and a research strategy between all countries, cities and other stakeholders, the JPI Urban Europe could prove to fulfil the first function of an intermediary organizations as ‘broker and facilitator of joint visions and communities for innovation.’ The JPI Urban Europe managed to coordinate the interests and priorities of all participating countries and gained approval of a research agenda and a commitment for implementation. Meanwhile, €50 M were invested in the implementation of the research agenda and over 70 projects funded. JPI Urban Europe does not only manage to coordinate national strategy and interests on a high level, but also on an operational level when it comes to the management and monitoring of joint calls and projects of the countries. Additionally, JPI Urban Europe managed to open up space for new R&I actors—namely cities. Cities have not only been engaged in the development of the research agenda, but have been empowered by their needs being put at the center.

5.2 City Engagement in Projects and Local Experimentation

The series of annual R&I calls is one of the most important instruments addressing and engaging cities as problem owners in the urban transition. However, only 22 cities out of 445 funded project partners have been involved in JPI Urban Europe projects in the first six calls. The engagement of city representatives as project partners varies by call format as shown in Table 1. While less than one in ten project partners were city representatives in the first five R&I calls, the sixth call was specifically designed to engage a high share of cities by funding challenge-driven innovation projects and requiring consortia to include at least one business and one city partner. Thus, it aimed to support new structures in the funded projects putting the problem owners in the center and fostering bidirectional learning between the cities and other R&I partners. The total number of cities with granted funding was, nevertheless, low as the call included a small number of participating funding agencies and allocated national budgets.

A collaboration analysis of funded projects highlights the role of JPI Urban Europe in connecting multiple stakeholder types. Figure 1 displays the collaborations between city representatives and other actor type groups in a collaboration network of funded projects. Nodes represent actor types in a given country collaborating with other actors via joint projects. While universities take up central roles in the network—three out of four projects are led by universities—cities are less frequently represented in the network. Interviews revealed that cities take roles as data and feedback providers, providers of specific non-research expertise, and test beds for

Table 1 Cities with granted funding in the first six JPI Urban Europe Joint Calls

	Project running time	Project partners	Cities (funded)	% of total
Call VI	2019–2022	42	6	14
Call V	2018–2021	135	4	3
Call IV	2017–2020	84	2	2
Call III	2016–2019	100	6	6
Call II	2014–2017	47	1	2
Call I	2013–2016	37	3	8
Total		445	22	5

Source Own calculations based on the JPI Urban Europe Project Database

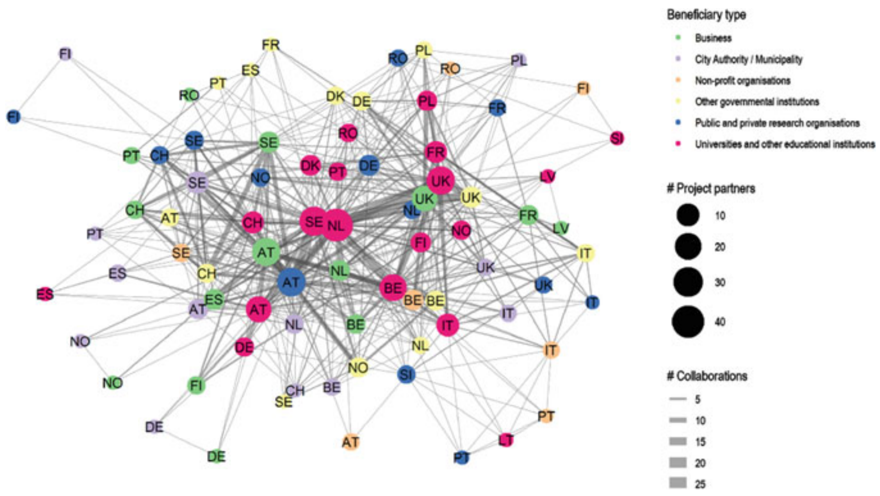

Fig. 1 Collaboration network based on JPI Urban Europe project partners by country and actor type. The network position is based on the frequency of cooperation between project partners in various countries (country code labels, ISO 3166-2) and the project partner type (color). Node size shows the number of project partners of the type in the country, while the edge width depicts the number of joint projects. *Source* Own calculations based on the JPI Urban Europe Project Database

piloting project outputs. University–business cooperation is the most frequent type of transdisciplinary collaboration.

A geographic distribution of cities in projects shows that one out of four cities that are project partners in Joint Calls is located in Sweden as shown in Table 3. The survey to all JPI Urban Europe funding agencies revealed that cities are eligible only for funding in 45% of the funding agencies; however, the interviews with cities clearly indicated how important funding for cities is to engage in R&I projects. This enhances cities internal justification for participation and made engagement more effective by increasing the city's feeling as 'problem owners.'

Out of the 20 JPI Urban Europe cities involved in projects, five cities are also active in H2020 projects, whereas 15 (75%) cities are not active in any H2020 projects dedicated to sustainable urbanization. JPI Urban Europe attracts new cities for projects at the European/transnational level and therefore works complementarily to H2020. Moreover, JPI Urban Europe calls tend to mobilize smaller cities than H2020 calls, hinting at its role as a provider of room for experimentation in niches and extending niches (Table 2).

Formats that allow less experienced and often smaller cities to connect to successful networks and consortia can be seen as a strength of JPI Urban Europe. City interviews reveal that the classical call structure of JPI Urban Europe represents a high barrier to entry for both experienced and inexperienced cities. In this regard, the city interviews found that additional formats, such as structured exchange and mutual learning processes between cities and/or between cities and academia/business, could lower the entry barriers.

Table 2 City characteristics in H2020 and JPI Urban Europe projects

	H2020			JPI Urban Europe		
Pop-class	Total ($n =$ 128)	Share (%)	Cum. share (%)	Total ($n =$ 20)	Share (%)	Cum. share (%)
<50,000	12	9	9	3	15	15
50,000–100,000	20	16	25	2	10	25
100,001–250,000	28	22	47	7	35	60
250.001–500,000	25	20	66	3	15	75
500.001–1 M	24	1	85	4	20	95
>1 M	19	15	100	1	5	100
Total	128	100		20	100	

Source Own calculations based on the JPI Urban Europe Project Database and AIT-EUPRO

Urban living labs represent an important means by which JPI Urban Europe provides room for experimentation in niches and extending niches. Nearly half of the 73 funded projects engage with urban living labs, i.e., arenas for experimentation, innovation and transformation, while providing test grounds in a real-world environment for urban transition (JPI Urban Europe 2018, 2019b). JPI Urban Europe follows recommendations highlighting the importance of experimentation and science-policy cooperation as one central requirement for addressing transition processes (Weber et al. 2018). Living labs not only serve the purpose of gaining experience and capacity building in cities, but also as a first step towards scaling-up responses in systems of provision (Marvin et al 2018). 'Learning journeys' including stories of success and failure are shared between and within various contexts to stimulate urban transitions. The survey to R&I funding agencies, furthermore, revealed that funding living labs is an alternative way to support cities in cases where cities are not eligible for funding as project partners; three quarters of all surveyed funding agencies may support cities indirectly via urban living labs.

The empirical results on the funded joint projects prove that JPI Urban also fulfills the third function of an intermediary 'provider of room for experimentation in niches and extend niches.' The joint calls mobilizing the cooperation of national R&I programs for urban transition and can address challenges that cannot be addressed by one country alone. The funded projects according to cities' needs, but especially the living labs provide concrete opportunities to experiment with products, services, tools, methods and processes to support the urban transition. Since the very beginning, JPI Urban Europe synthesized results from the projects and labs towards policy recommendation and policy action. It has established channels for dissemination across all participating countries. By this activity, JPI Urban Europe could prove that it not only provides innovation in niches, but also try to extent niches towards changes in the regime level.

The analysis of city engagement in the projects provides answers to research question 2. Although JPI Urban Europe manage to engage cities in the process of visioning and research agenda development, the actual number of cities that engaged as formal partner in projects is low. Many more cities have been engaged in the projects in other ways (via letter of intent, subcontract, expert). However, cities reported that that higher justification and the change effect are realized if they participate as formal partners. The main reason for the low number of partner cities in projects is that they are not eligible for funding in some R&I program. In the future, JPI Urban Europe must ensure that the framework conditions to participate in the actions are available and attractive to various stakeholder types. This relates especially to cities as the core spaces of transition. Providing funding opportunities for cities is a key success factor for the JPI Urban Europe in fostering challenge-driven R&I projects that meet cities' problems and increase the likelihood to produce transformative outcomes. However, JPI Urban Europe's activities also trigger changes of funding rules on national level, e.g., two funding agencies have made cities eligible for funding since the inception of the program. As JPI Urban Europe has its roots in national and regional R&I funding agencies, the entry barrier for less experienced cities to take part in the action is lower than in European Framework Programme projects, which shows that the JPI Urban Europe functions as broker and translator also for smaller cities and reaches them.

5.3 Knowledge Community on Urban Transition in Europe

JPI Urban Europe aims to translate knowledge between various stakeholder communities and bring them together for mutual learning. On the one hand, the stakeholder communities represent urban communities of practice (e.g., urban research, citizen organizations, city authorities, business, public utility providers) and, on the other hand, they are policy communities of practice.

JPI Urban Europe has developed a Stakeholder Involvement Platform, namely AGORA, as an instrument to translate scientific knowledge for urban stakeholders, articulate opinions and demands of cities and other urban stakeholders to the R&I community and support learning processes of new urban stakeholder communities. AGORA has been established to create a space to meet in interactive formats and exchange for all stakeholders, in particular, urban actors with a diversity of backgrounds (researchers, practitioners, public administrators, entrepreneurs, social innovators, etc.), discussing current themes and priorities and identifying the most pressing urban challenges of today and the future. Additionally, JPI Urban Europe has developed high-level policy conferences organized in Brussels where the policy community meets and engages.

An analysis of the participation of stakeholders, especially cities, in the respective events for the urban and policy communities reveals whether JPI Urban Europe has reached out to a wider community.

One hundred thirty three cities have participated in events organized by the JPI Urban Europe between 2014 and June 2018. Only events that were targeted and/or open to cities have been analyzed. The JPI Urban Europe Policy Conferences have mobilized the highest share of cities (15%), followed by AGORA events (8%). Of the 1281 participants, 10% of the total number of events have involved cities (city authorities, city agencies, regions, networks of cities within a region). Two AGORA events took place from 2017 to June 2018 having cities as target group.

The empirical results on community building revealed that JPI Urban Europe also fulfilled the second function of an intermediary 'translator and enabler for learning.' It brings together a diversity of stakeholders in interactive formats and enables learning, connecting and synthesizing of results. Within this stakeholder platform, a science-policy community on urban transition was built putting the cities as problem owners in the center. One main element was the establishment of a dialogue between researchers, urban stakeholders and policy makers in cities to generate a joint understanding of problems and common language.

The analysis of the strategic approach and activities of JPI Urban Europe could prove that it fulfills to a considerable extent all three functions of an intermediary organization outlined in Sect. 3. This answers research question 3.

6 Conclusion

The transition of urban systems is central to attaining a sustainable and resilient future. Cities as problem owners should play a key role as they are both transition agents and subjects of transformation. Deficits of effective intermediation of priorities, stakeholders, and activities at the European, national and local levels are widespread, and the intermediation gap needs a dedicated response for urban transition. The results of the empirical analysis have shown that transition-oriented R&I programs of many countries, such as the JPI Urban Europe, can take this intermediating role and act as intermediary organizations. The case of the JPI Urban Europe could prove that it acts as effective promoter and developer of connecting visions, strategies, activities and stakeholders. JPI Urban Europe also has managed to attract high levels of commitment from a diversity of stakeholders to its vision and strategic priorities and mobilized respective budgets for its implementation. JPI Urban Europe opened spaces for cities as a central R&I player to ensure that their needs become strategic priorities for the research agenda. Challenge-driven calls with room for experimentation (putting the problem owners at the center) seem to successfully develop a common language of all stakeholders and has a higher likelihood to generate more transformative outcomes. The involvement and empowerment of cities as problem owners is relevant for system transition. The number of city representatives as funded project partners could be increased to further stimulate active involvement because the eligibility of cities as project partners has been identified as a supporting factor. As an intermediary organization, JPI Urban Europe needs to work on this framework condition. This also calls for experimentation on the policy and program level as this is key to move urban transition forward. However, JPI Urban Europe can only stimulate these changes on the regime level, and it remains unknown what changes of behavior and organizations occur because of the engagement in the JPI Urban Europe. JPI Urban Europe coordinates joint activities of mainly national R&I programs but has only indirect influence on change in these organizations and limited influence on changes within research organizations, businesses, or cities which are even less connected.

Overall, it can be concluded that: (1) The strategic ambition of JPI Urban Europe indicates a strong role of JPI Urban Europe as intermediary organization for urban transition, but some instruments and formats to bring the ambition into action need further refinement and experimentation, whereas other already work well; and (2) it needs further in-depth research to better understand the outcomes and impacts of its diverse activities.

Appendix

JPI Urban Europe has developed a project database which includes information on 73 funded projects from the first six calls (2012–2017) including a total of 493 project partners among which 445 received funding. The database includes the following information:

- Project name and respective call, call topic and Strategic Research and Innovation Agenda topic to which it is dedicated
- Project duration and research type
- Beneficiary names, country, types, and funding.

The structure of the project database allows for a social network analysis in which project partners are connected via projects.

Figure 2 shows the geographic location of 374 geocoded project partners colored by partner type. A country is colored light red if a funding agency based in the country participated in at least one R&I call.

Table 3 provides further details on the countries involved in the JPI Urban Europe, the number of project partners and city representatives interviewed in the primary data analysis. In addition to 20 official member countries, five countries participate as observers without voting rights in the Governing Board. Further ten countries have funding agencies participating in Joint Calls without membership in the JPI Urban Europe. Out of the 445 funded project participants shown in the table, 22 were city authorities or municipalities. City representatives from five of the participating cities were interviewed in the course of a self-evaluation on the engagement of cities in the JPI Urban Europe (Meyer et al. 2018, 2019).

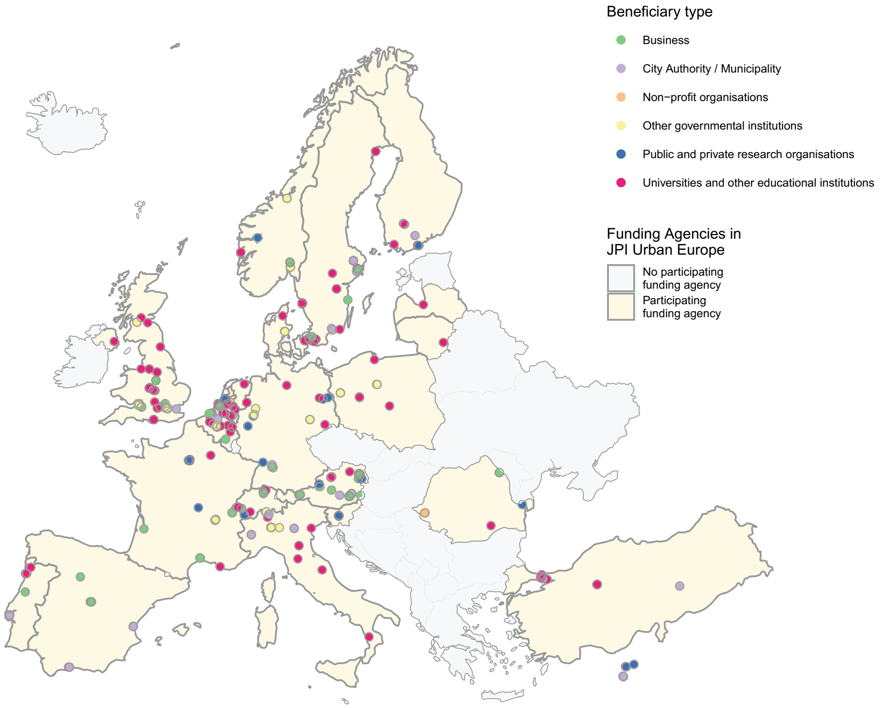

Fig. 2 Geocoded location of JPI Urban Europe project partners. *Source* Own calculations based on the JPI Urban Europe Project Database. Geolocation received via the Google Geocoding API

Table 3 Countries involved in the JPI Urban Europe (Status 2019), the type of involvement (member, observer, participant in joint calls), the number of project partners based in the country, the number of city authorities/municipalities as official project partners and the interviews conducted)

Country	Level of involvement	Number of project participants	Thereof City Authority/Municipality	Interviews
Argentina	Joint Call	1		
Australia	Joint Call	1		
Austria	Member	78	5	
Belgium	Member	33	1	
Brazil[a]	Joint Call	6		
Chinese Taipei	Joint Call	5		
Cyprus	Member	6	1	Limassol
Denmark	Member	9		
Finland	Member	10	1	
France	Member	14		
Germany	Member	16	1	Ludwigsburg
Italy	Member	13	2	
Japan	Joint Call	4		
Latvia	Member	2		
Netherlands	Member	45		
Norway	Member	14	1	
Poland	Observer	8	1	
Portugal	Observer	9	1	Almada
Qatar	Joint Call	4		
Romania	Observer	7		
Slovenia	Member	4		
South Africa	Joint Call	6		
Spain	Observer	7		
Sweden	Member	47	6	Stockholm
Switzerland	Joint Call	12		
Turkey	Observer	10		
United Kingdom	Member	53	1	Southend-on-Sea
USA	Joint Call	21	1	
Total		445	22	5

[a]São Paulo

Source Own calculations based on the JPI Urban Europe Project Database and primary data analysis

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