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The role of spatial circular planning in urban governance. A set of indicators to evaluate performance in urban regeneration.

Ginevra Balletto[1], Mara Ladu[1],

[1] DICAAR - Department of Civil and Environmental Engineering and Architecture, University of Cagliari, 09100 Cagliari, Italy
balletto@unica.it; mara.ladu@unica.it

Abstract. Cities are strategic places for development, but also places where many environmental, social, and economic problems arise. The scenario that by 2050 two thirds of the world's population will live in cities confirms that cities will still be responsible for growing consumption and, consequently, for a significant production of waste. Within this worrying situation, the principles of the Circular Economy (recovery, recycling and sharing) offers the opportunity to rethink the way goods and services are produced and used, exploring new approaches to ensure long-term prosperity. These principles find direct application in energy planning and urban governance at different scales.
In this framework, the manuscript proposes a methodology for the evaluation of a set of indicators capable of measuring the degree of circularity in the various urban scales (from small to extra large), with particular attention to energy performance.

Keywords: Energy Transition, Energy planning, Circular City.

1 Introduction

The Circular City is based on the dynamic principles of the circular economy, a concept that is still complex and controversial today. Although it is not possible to declare a universal definition of Circular Economy, precisely due to its dynamic and constantly evolving nature, the scientific debate agrees on how the circular city aims to eliminate waste and emissions, as well as to provide services through the combined digital-ecological transition to ensure prosperity, improve the livability and resilience of communities [1]. An effective use of resources, as much as possible on local production, using renewable natural resources, is at the core of the circular city, which evolves between the concepts of sharing, efficiency and protection [2]. It is not a new urban model: the origins date back to the first phases of the industrial revolution, then re-emerge in the contemporary industrial phase 4.0.

Linear, circular and mixed economic models have developed, spread and alternated throughout history (Fig. 1).

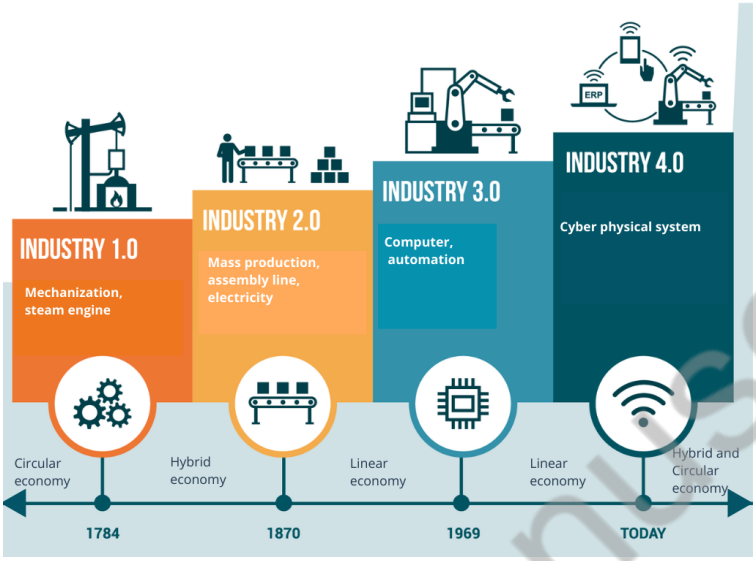

Fig. 1. Industrial phases and models based on circular, linear and hybrid economy. Author: G. Balletto.

The proto-industrial phase was characterized by a Circular Economy (proximity materials, spoliation of monuments). In the various industrial phases, from 1.0 to 3.0, a linear economy prevailed, which neglects the environmental and social impacts of the process: production based on the use of natural resources regardless of their effective long-term availability; growing energy production capacities; significant production of waste and waste. Finally, the 4.0 phase is characterized by a hybrid economy in which the paradigm of the linear economy coexists with that of the circular economy characterized by Recovery, Recycling, Reuse and Sharing. This last phase introduced renewable energy, secondary raw materials, sharing mobility, hybridizing the linear economy with the circular one.

The circular city model offers the opportunity to rethink the way we produce and use goods and services by exploring new ways to ensure long-term prosperity [3]. In the city, it may be applied through the reduction of urban enclaves [4], the reuse and regeneration of the built environment [5], in particular the unused public real estate asset [6], where the opportunities of the Circular City are concentrated [7]: from the sequestration of CO_2 to the use of recycled materials; from the implementation of proximity networks to the production of renewable energy, seizing the opportunities of the Renewable Energy Communities (REC) [8].

The manuscript proposes a set of indicators to represent the circular city, in quantitative-qualitative terms, at different urban scales, within a broader research on the circular city which investigates the role of the regeneration of the built environment, in particular of the public city [9], in sustainable urban planning. In this sense, the manuscript investigates the relationship between city and energy, health and mobility

[10], with the aim of proposing advances in the research field of the circular city according to the European policies framework.

After introducing the research topic, the contribution develops as follows:

- Section 1.1 analyzes the relationship between energy consumption and resources, with particular reference to the Italian context;
- Section 2 focuses on the ecological and energy transition in European and national policies;
- Section 3 proposes a methodology to define a set of KPI to assess the circularity of urban governance at different urban scales;
- Section 4 is dedicated to the conclusions and future development of the study.

1.1 Energy consumption and resources

Energy production from renewable sources plays a strategic role in the implementation of the circular economy model, in contrast to the energy production model established from 1800 to 2021 [11] (Fig. 2).

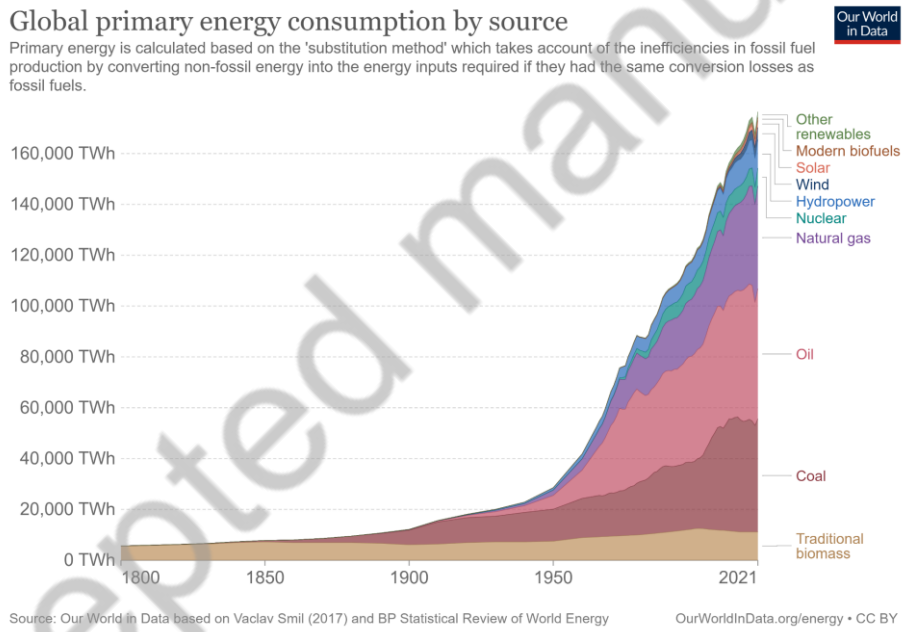

Fig. 2. Global primary energy consumption source. Sources: [11].

The issue of energy production, like that of the Circular City, requires a global scale of analysis and intervention. Studies show that in 1980 and 2021, in various parts of the world, energy consumption derives from the use of non-renewable sources. The situation is different in European Union as a part of consumption, albeit small, is attributable to the production of energy from renewable sources [11] (Fig. 3a, b).

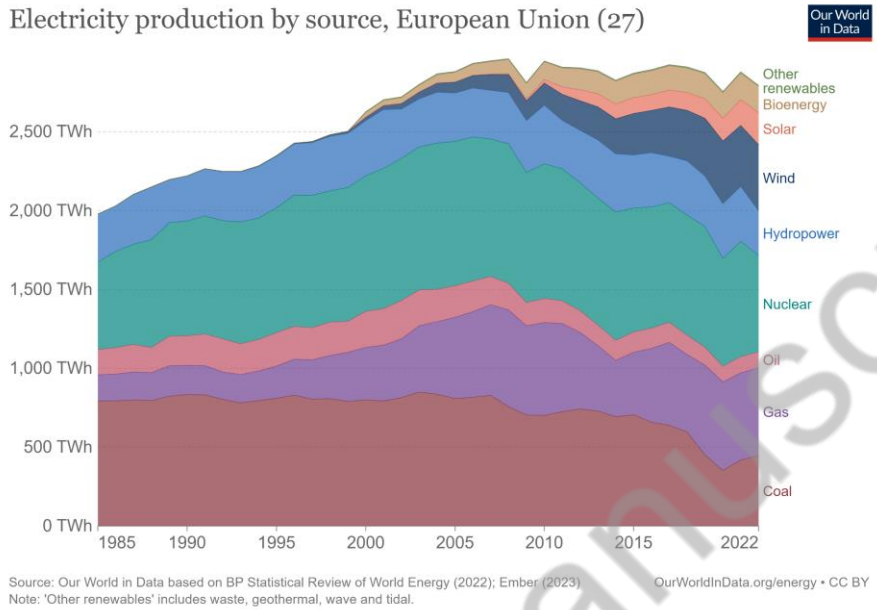

Fig. 3a. Electricity production by source and shar electricity production from renewable (EU27). Sources: [11].

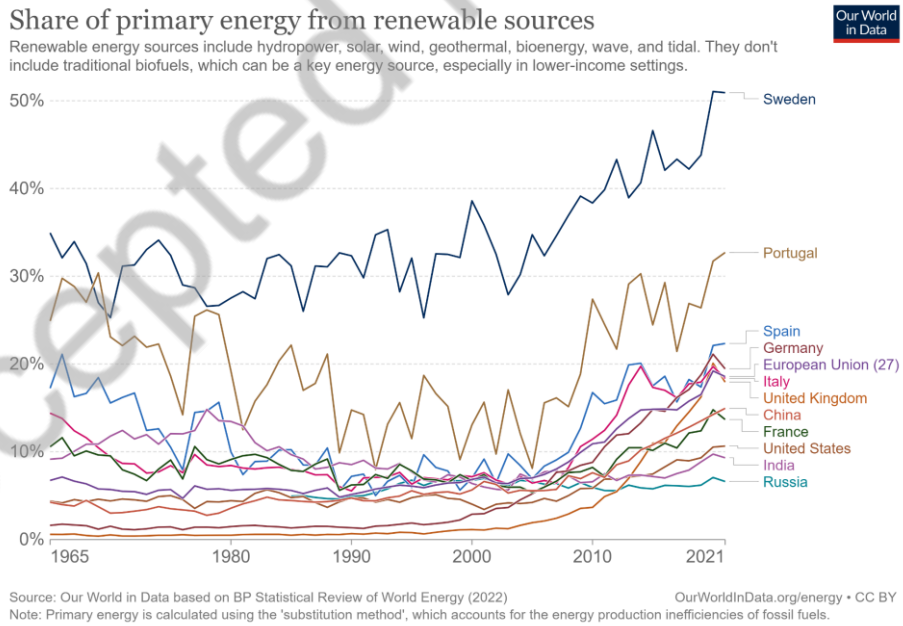

Fig. 3b. Share of primary energy from renewable sources. Sources: [11].

Italy has recorded a very modest energy renewal and a slow transition in the last twenty years. On the contrary, in other countries, an impetus has been given to a real transition by favoring electrification based on renewable sources and, consequently, eliminating the consumption of primary resources.

Another aspect to consider is that the energy vector is part of an international grid that connects all states. Italy, for example, exchanges with France, with Switzerland and vice versa. There are no governmental problems, they are just international agreements that arise with the European Union, with the need to create the possibilities to move services and goods, including energy (Fig. 4).

Fig. 4. CLIMATE, INFRASTRUCTURE AND ENVIRONMENT EXECUTIVE AGENCY / ENERGY - PCI Transparency platform - Projects of common interest – Interactive map. Source: [12].

Among the indexes for evaluating the environmental efficiency of an energy system or more generally, of the overall energy system for the production of goods and services, there is also the carbon intensity [13]. A low carbon intensity corresponds to a high efficiency of the energy transformation system. The Italian Electricity map platform (Fig 5a, b) represents production and distribution.

The particular coal, gas and oil are energy-dense sources. In Europe, the transition from coal to gas (both energy-dense). It developed because gas is compressible, thus responding to the growing demand for energy. Analyzing the condition of the Italian regions, it can be seen that Sardinia still depends on coal, therefore the carbon intensity is high with a high production and distribution inefficiency.

In this framework, the circular economy makes it possible to balance the demand for energy and to introduce the principle of circularity in the production of energy and its distribution to meet the needs of communities by reducing impacts. Energy production from renewable sources represents the first objective to be pursued, which requires a progressive convergence between urban planning and energy planning.

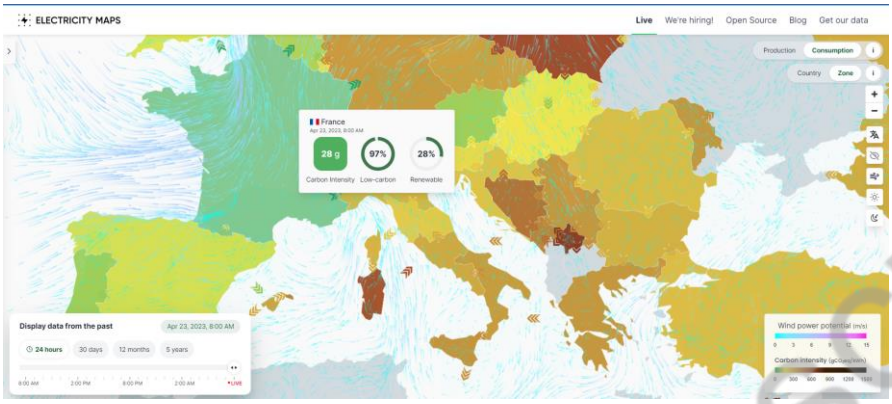

Fig. 5a. Electricity Maps, production and distribution. Source: [13].

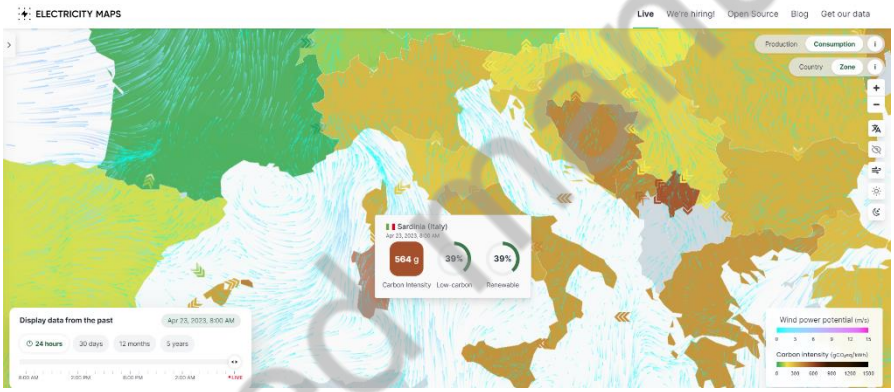

Fig. 5b. Electricity Maps, production and distribution. Sardinia case. Source: [13].

2 The ecological and energy transition in European and national policies

The European Green Deal launched by the European Commission in December 2019, is a set of policy initiatives with the overarching aim of making the European Union (EU) climate neutral in 2050 and the first continent to have a zero-climate impact.

The primary objective of the European sustainable development strategy is to drive the green transition of the member countries, thus achieving the international commitments established by the Paris Agreement and the 2030 Agenda for Sustainable Development (UN – HABITAT). According to the legally binding targets established by the European Climate Law, the Member States are bound to raise the EU's ambition on reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030.

In this sense, the integrated National Energy and Climate Plans (NECPs) for the period from 2021 to 2030, represents a set of policy initiatives adopted by each country in the following sectors: energy efficiency, renewable energies, reduction of greenhouse gas emissions, interconnections, research and innovation. Among these, the clean energy transition, i.e. the decarbonization of the EU energy system, represents one of the main challenges, considering that energy production and use account for more than 75% of greenhouse gas emissions of the EU [14].

The transition takes place through a series of actions responding to three principles of a social, economic and environmental nature, which may be summarized as follows:

- ensuring secure and affordable EU energy supplies;
- developing an energy sector based largely on renewable sources to improve energy efficiency, especially of existing buildings;
- developing a fully integrated, interconnected and digitized energy market.

This is the framework that will drive an integral transformation of Europe towards a circular economy.

According to this approach, the National Recovery and Resilience Plan (NRRP) presented by Italy as part of the Next Generation EU (NGEU) programme, is developed around three strategic axes shared at a European level: digitalization and innovation, ecological transition, and social inclusion [15]. This is a unique opportunity to address and resolve the social and economic damage caused by the pandemic, as well as to overcome structural gaps in the Italian economy, reducing territorial, generational and gender inequalities.

The Plan aims to lead a long-term ecological transition of Italy through 6 missions:

1. Digitization, innovation, competitiveness, culture and tourism.
2. Green revolution and ecological transition.
3. Infrastructures for sustainable mobility.
4. Education and research.
5. Cohesion and inclusion.
6. Health.

With a total of € 68.6 billion allocated, the mission 2 is the one funded with the most resources with the main goals of improving the sustainability and resilience of the economic system and ensuring a fair and inclusive environmental transition through specific actions: waste recycling enhancement; reduction in drinking water leakage on water networks; increase in the number of more efficient private and public buildings; support for research on the use of hydrogen in industry and transport.

Most of these goals testify the role of the circular economy paradigm and of spatial energy planning in urban governance. Recent studies show that European cities are characterized by specific trends to steer the circular transition, as well as important challenges still outstanding [16]. Cities differ in the initiatives adopted in the various sectors. A significant set of policies refers to: circular infrastructure and construction to close material loops; public procurement to reduce their environmental footprint; local food systems more regenerative; raising awareness of citizens. At the same time, cities still face several issues like overcoming capacity and resource limitations, securing political support, measuring circularity, shifting the paradigm from linear to circular systems.

According to the system of indicators carried out by the EU to monitor member states in 4 areas (Production and consumption; Waste management; Secondary raw materials; Competitiveness and innovation) [17], several studies focused on the definition of indexes and related key performance indicators to assess the circularity of urban policies and projects, at the urban [18] and regional scale [19].

Within this research field, the paper proposes a set of key performance indicators (KPIs) to assess the level of circularity of regeneration projects at different urban scales, in order to fill the gap in data collection and monitoring frameworks, thus supporting urban governance in the energy and ecological transition.

3 Method

The methodology develops a set of key performance indicators (KPIs) to assess the level of circularity of interventions in the different urban scales (USs), according to the interpretative review of the literature [16, 18]. Starting from the results of a previous research [7], which identified the 7 pillars of the Circular Economy - Adaptive and resilient; Culture & society; Health and wellness; Renewable energy; Recycled materials; Protects biodiversity; Innovation & Value -, declined by 4 focuses - Green and recycled materials; CO_2 uptake; Renewable energy & REC; Proximity -, the study proposes a set of KPIs and related units of measurement (um) for the following USs (Fig. 6, Fig. 7): Small scale - Building area; Medium scale - Cluster or District; Large scale - Metropolitan City; X Large scale - Regions.

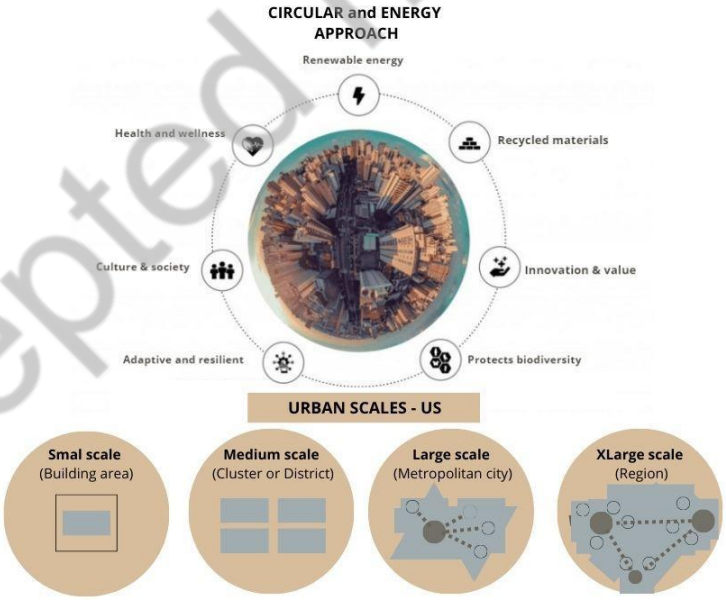

Fig. 6. Pillars of the circular and energy approach (Author: Balletto G., 2023).

Pillar of circular economy	Focus	KPI Small and Medium scale (Building area, Cluster or District)	um	KPI Large and XLarge scale (Metropolitan city, Region)	um
Recycled materials Innovation & Value	1) Green and recycled materials	1.1) All recycled material	US/US	Waste Recovery Plants: 1.1) Municipal 1.2) Special	N. of waste recovery plants per 100.000 inhabitant
Protects biodiversity Innovation & Value	2) CO_2 uptake	2.1) Green area; 2.2) Recycled materials (cement -lime)	US/US	Coverage of Protected Natural Areas: 2.1 - 2.6) Six Categories of protected areas (IUCN)	Protected natural areas (km2)/ total US area (km2)
Sustainable energy Innovation & Value	3) Renewable energy & REC	REC: 3.1) SCP 3.2) STC 3.3) EFET 3.4) SCSTC	US/city district of REC	Renewable Energy: 3.1 - 3.5) Five renewable energy sources (Wind, Photovoltaic, Geothermal, Hydro, Thermoelectric)	Renewable energy produced (MW)/total energy consumption per US
Culture & society Health and wellness Adaptive and resilient Innovation & Value	4) Proximity	15 Minute City: 4.1) Places of movement 4.2) Central places of health and welfare 4.3) Central places of commerce	15 min of US/city district	Health: 4.1) Healthy life expectancy MaaS: 4.2) Road transport 4.3) Rail transport 4.4) Flight transport	N. of years (average) per US % of population per US

Fig. 7. Matrix of pillars of circular economy, focuses, literature, and key performance indicators (KPIs) of Circular city. Authors: G Balletto and M. Ladu (2023).

The proposed KPIs for the different USs are as follows:

1) KPIs Focus (1) - Green and recycled materials.

Small and medium scale: All recycled material (as concrete, plaster, steel).

The KPI refers to the percentage of recycled material of the total, with reference to each building material used (concrete, cement, plaster, steel, aluminium, etc ..) [20, 21]. The KPI is closely related to the concepts of Minimum Environmental Criteria [22], which in Italy should be respected in all interventions which involve public real estate assets. The Minimum Environmental Criteria are green criteria introduced to support public administrations in implementing the ecological transition phase, which requires applying the life-cycle approach in public governance.

Large and XLarge scale: Waste Recovery Plants.

The KPI related to the number of Waste Recovery Plants (Municipal and Special) [23, 24] per 100.000 inhabitant, in each US, is a direct consequence of the basic concepts related to waste, recycling and recovery, as well as of the progress in the waste management field for several waste streams, including municipal waste, construction and demolition waste. The separate collection of specific waste materials and sets ambitious targets for municipal waste recycling in an effort to boost the transition towards the circular economy, according to the European targets established by the Waste Framework Directive [25, 26]. Within this framework, EU countries shall take

the necessary measures to guarantee that, by 2025, the preparation for re-use and the recycling of municipal waste shall be increased to a minimum of 55 %, 60% and 65% by weight by 2025, 2030 and 2035 respectively.

2) KPIs Focus (2) - CO_2 uptake.

Small and medium scale: Green areas and Recycled materials (cement-lime) [27].

The KPIs are important parameters to be considered in the renovation projects of the existing building stock and in the urban regeneration projects of public and private real estate complexes.

Large and XLarge scale: Coverage of Protected Natural Areas.

Protected Natural Areas include both Natura 2000 sites (Special Protection Areas-SPAs; Sites of Community Importance-SCIs; Special Areas of Conservation-SACs) and those areas established at national and regional level, according to the related law [28, 29]. Although the classification of protected natural areas differs in different countries, the International Union for Conservation of Nature (IUCN) identified six different protected area categories based on management objectives. This is a fundamental attempt to describe and categorize the different management approaches in individual sites [30].

The Common Database on Designated Areas (CDDA) [31] collects the main data referring to the protected area in European countries. It is the official source from Europe to the World Database of Protected Areas (WDPA). The share of terrestrial protected areas in 2021 amounted to 26.4%, of which 18.5% falling within Natura 2000 sites, while 7.9% in areas established at national or regional level [31].

In this sense, the coverage of protected natural areas in relation to the total US area represents an important parameter to be considered to ensure high levels of CO2 uptake and environmental protection in metropolitan cities and regions.

3) KPIs Focus (3) - Renewable Energy & REC.

Small and medium scale: Renewable Energy Communities-REC [32, 33].

As discussed in previous research [7], the set of indicators which support the project of Renewable Energy Communities-REC can be summarized as follows:

- Self-consumed over the total energy produced over a set period in the city district - SCP
- Shared energy over total energy consumption of the community over a set period in the city district - STC
- Ratio between energy fed to the grid and energy withdrawn from the grid over a set period - EFET
- Ratio between the sum of self-consumed and shared energy over the total energy consumption of the community over a set period – SCSTC

Large and XLarge scale: Renewable Energy.

The set of indicators refers to the amount of renewable energy produced from renewable sources (wind, photovoltaic, geothermal, hydro, thermoelectric) in relation to the total energy consumed in each US. The indicator monitors the results of energy transition policies in different contexts and at different scales [34], according to the objectives of the European Green Deal and the Recovery and Resilience Plans.

4) KPIs Focus (4) - Proximity.

Small and medium scale: 15 Minute City.

The 15 minutes city indicators refer to an urban planning model aimed at guaranteeing citizens high levels of accessibility to the main urban facilities, which can be reached on foot or by bike within 15 minutes [35, 36]. The promotion of a slow and sustainable mobility stimulates virtuous and healthy lifestyles, as well as reducing polluting emissions from transport systems. In this sense, the 15 Minute City arises from awareness of the value of good behavioral practices and motor activity for the so-called culture of healthy living.

Large and XLarge scale: Health and Mobility as a Service (MaaS).

In particular, Health has declined according to the concept of Healthy life expectancy [37], while Mobility according to the framework that may be adopted in a Mobility as a Service (MaaS) [38, 39]. KPIs are the direct consequence of a new awareness that considers health, well-being and sustainable mobility as a conceptual unicum.

According to recent studies, the transport system is one of the most polluting factors worldwide. Therefore, favoring the transition towards sustainable transport systems is a precondition to protect the environment and people's health.

The new frontier of MaaS addresses sustainable mobility issues, particularly on travel users' behaviors, transport systems organization and new technologies and innovation services. This approach identifies and designs the actions that can facilitate the adoption of Mobility as a Service to better integrate the different transportation services (public transport, sharing mobility, ride hailing) and give tourists and non-residents the opportunity to easily plan, book and pay for multiple types of mobility services. For this reason, the present study considers the percentage of the population which uses transport systems (Road, Rail, Flight) [19] per US. This policy is functional to safeguard public health and well-being through the environmental sustainability of living spaces, which means the development of practices and policies for several aspects: life-improvement, as life expectancy; quality of public services and inclusiveness; social innovation and sustainable mobility.

The proposed Matrix of pillars of circular economy, focuses, literature, and key performance indicators (KPIs) is applicable for both ex-ante and ex-post scenarios in the different USs. However, it is important to underline that the set of KPIs contributes to the achievement of the circular city's objectives only if considered in a comprehensive and integrated manner.

4 Discussion and conclusions

The ecological transition, at local, metropolitan, and regional level, represents a real opportunity to achieve the sustainable development goals and targets, including the European ambition on reducing dependence on fossil fuels and greenhouse gas emissions by 2050.

The need to define metrics to assess the degree of circularity of regeneration projects stimulates several studies involved in the definition of indicators and indices which also allow to test and monitor the effects of policies and projects oriented towards the application of the circular economy paradigm.

Following a comprehensive literature review on the challenge of the circular city in the ecological transitions, with particular attention to the energy transition and its possible integration within urban planning processes, the methodology develops a set of key performance indicators (KPIs) of the 7 pillars of the Circular Economy, declined by 4 focuses, to assess the level of circularity of interventions in the different urban scales (USs).

The study and the proposed methodology derive from previous research that developed a method to calculate the Circular City Index as a first attempt to evaluate benefits of the comprehensive regeneration of clusters of public buildings, which refer to the Small scale - Building area, and the Medium scale - Cluster or District.

From the Small and Medium scale to the Large and X Large scale, the focus becomes Metropolitan Cities and Regions.

As a matter of fact, the ambitious objectives of the European Green Deal require a multidimensional approach which led to consider several aspects and different geographical and administrative contexts. In this sense, the selected KPIs - All recycled materials & Waste Recovery Plants; Green areas and Recycled materials & Coverage of Protected Natural Areas; Renewable Energy Communities-REC & Renewable energy; 15 Minute City & Health and Mobility as a Service (MaaS) - define a Matrix of pillars of circular economy. However, the set of KPIs contributes to the achievement of the circular city's objectives only if considered according to an integrated approach.

The future steps of the research will be dedicated to the implementation of the set of KPIs aimed at building a Circular Index (CI) for each US, capable of measuring the degree of circularity of policies and projects at different scales.

The possibility to assess ex-ante conditions and ex-post scenarios drives future actions and monitor performance such as benefits for the environment and well-being and health of communities, according to the UN-Habitat Agenda 2030.

Glossary

CDDA	Common Database on Designated Areas
CI	Circular Index
EFET	Ratio between energy fed to the grid and energy withdrawn from the grid over a set period
EU	European Union
IUCN	International Union for Conservation of Nature
KPI	Key Performance Indicator
MaaS	Mobility as a Service
NECP	National Energy and Climate Plan
NGEU	Next Generation EU
NRRP	National Recovery and Resilience Plan
PREA	Publi c Real-Estate Assets
REC	Renewable Energy Communities
SCSTC	Ratio between the sum of self-consumed and shared energy over the total energy consumption of the community over a set period
SCP	Self-consumed over the total energy produced over a set period in the city district
STC	Shared energy over total energy consumption of the community over a set period in the city district
US	Urban Scale
WDPA	World Database of Protected Areas

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References

1. Kirchherr, J.: Circular economy and growth. A critical review of “post-growth” circularity and a plea for a circular economy that grows. Resources, Conservation and Recycling, 179, 1-2 (2022).
2. Paiho, S.; Mäki, E.; Wessberg, N.; Paavola, M.; Tuominen, P.; Antikainen, M.; Heikkilä, J.; Rozado, C.A.; Jung, N.: Towards circular cities—Conceptualizing core aspects. Sustainable Cities and Society, 59, 102143 (2020).
3. Harris, S., Weinzettel, J., Bigano, A., & Källmén, A.: Low carbon cities in 2050? GHG emissions of European cities using production-based and consumption-based emission accounting methods. Journal of Cleaner Production, 248, 119206 (2020).

4. Balletto, G., Ladu, M., Milesi, A., Camerin, F., & Borruso, G.: Walkable city and military enclaves. Analysis and decision-making approach to support the proximity connection in urban regeneration. Sustainability, 14(1), 457 (2022).
5. Girard, L. F.: THE EVOLUTIONARY PARADIGM AND THE CIRCULAR ECONOMY MODEL: THE HORIZON 2020 CLIC RESEARCH OUTCOMES. BDC. Bollettino Del Centro Calza Bini, 22(1), 11-21 (2022).
6. Ladu, M.: Patrimonio immobiliare pubblico. Prospettive di rigenerazione per una città accessibile e di prossimità. UNICApress, Cagliari (2022).
7. Balletto, G., Ladu, M., Camerin, F., Ghiani, E., & Torriti, J.: More circular city in the energy and ecological transition: a methodological approach to sustainable urban regeneration. Sustainability, 14(22), 14995 (2022).
8. Gerundo, R., Marra, A., & Grimaldi, M.: A Preliminary Model for Promoting Energy Communities in Urban Planning. INTERNATIONAL SYMPOSIUM: New Metropolitan Perspectives. Springer, Cham, 2833-2840 (2022).
9. Balletto, G., Mundula, L., Milesi, A., & Ladu, M.: Cohesion policies in Italian metropolitan cities. Evaluation and challenges. In Computational Science and Its Applications–ICCSA 2020: 20th International Conference, Cagliari, Italy, July 1–4, 2020, Proceedings, Part VII 20 (pp. 441-455). Springer International Publishing (2020).
10. Beniamino, M., Ginevra, B., Giuseppe, B., Lucia, S., Angela, P., Francesco, S., & Marco, D.: A methodological proposal to evaluate the health hazard scenario from COVID-19 in Italy. Environmental Research, 209, 112873 (2022).
11. Our World in Data, https://ourworldindata.org/energy-production-consumption, last accessed April 2023.
12. European Commission. CLIMATE, INFRASTRUCTURE AND ENVIRONMENT EXECUTIVE AGENCY ENERGY. PCI Transparency platform. Projects of common interest – Interactive map, https://ec.europa.eu/energy/infrastructure/transparency_platform/map-viewer/main.html, last accessed April 2023.
13. Electricity maps, https://app.electricitymaps.com/map, last accessed April 2023.
14. Tutak, M.; Brodny, J.; Bindzár, P.: Assessing the Level of Energy and Climate Sustainability in the European Union Countries in the Context of the European Green Deal Strategy and Agenda 2030. Energies, 14, 1767 (2021).
15. MEF: Circular no. 34 of 17 October 2022. Methodological Guidelines for the reporting and transmission of the common indicators - Attachment to the circular no. 34 of 17 October 2022 (2022).
16. ICLEI: Circular Cities Declaration Report 2022. ICLEI – Local Governments for Sustainability – European Secretariat Leopold Ring 3, 79098. Freiburg, Germany (2022).
17. Eurostat - EU key indicators, https://ec.europa.eu/eurostat/web/main/home, last accessed April 2023.
18. Muscillo, A.; Re, S.; Gambacorta, S.; Ferrara, G.; Tagliafierro, N.; Borello, E.; Rubino, A.; Facchini, A.: Circular City Index: An Open Data Analysis to Assess the Urban Circularity Preparedness of Cities to Address the Green Transition—A Study on the Italian Municipalities. arXiv Preprint, arXiv:2109.10832 (2021).
19. European Commission: EU Regional Competitiveness Index 2.0 2022 edition. Publications Office of the European Union, Luxembourg (2023).
20. Omer, M.M.; Rahman, R.A.; Almutairi, S.: Construction waste recycling: Enhancement strategies and organization size. Phys. Chem. Earth Parts A/B/C, 1*26*, 103114 (2022).
21. Balletto, G.; Borruso, G.; Mei, G.; Milesi, A.: Strategic Circular Economy in Construction: Case Study in Sardinia, Italy. J. Urban Plan.Dev,147, 05021034 (2021).

22. Ministero dell'ambiente e della Tutela del Territorio e del Mare. Decreto 11 Gennaio 2017. Adozione dei Criteri Ambientali Minimi per Gli Arredi per Interni, per L'edilizia e per i Prodotti Tessili.
23. Ferronato, N., Rada, E. C., Portillo, M. A. G., Cioca, L. I., Ragazzi, M., & Torretta,V.:Introduction of the circular economy within developing regions: A comparative analysis of advantages and opportunities for waste valorization. Journal of environmental management, 230, 366-378 (2019).
24. Di Foggia, G., & Beccarello, M.: Designing waste management systems to meet circular economy goals: The Italian case. Sustainable Production and Consumption, 26, 1074-1083 (2021).
25. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance).
26. 2011/753/EU: Commission Decision of 18 November 2011 establishing rules and calculation methods for verifying compliance with the targets set in Article 11(2) of Directive 2008/98/EC of the European Parliament and of the Council (notified under document C(2011) 8165).
27. Shafique, M.; Xue, X.; Luo, X.: An overview of carbon sequestration of green roofs in urban areas. Urban For. Urban Green, 47, 126515 (2020).
28. Vimal, R., Navarro, L. M., Jones, Y., Wolf, F., Le Moguédec, G., & Réjou-Méchain, M.: The global distribution of protected areas management strategies and their complementarity for biodiversity conservation. Biological Conservation, 256, 109014 (2021).
29. Oberč, B.P., de Jong, R., Demozzi, T., Battioni Romanelli, B.,: Towards a circular economy that begins and ends in nature. IUCN, European Regional Office (2022).
30. IUCN: Protected areas programme. Vol 14 No 3 PROTECTED AREA CATEGORIES, 2004 (2004).
31. European Environment Agency, Homepage, https://www.eea.europa.eu/en, last accessed April 2023.
32. Carrus, A.S.; Galici, M.; Ghiani, E.; Mundula, L.; Pilo, F.: Multi-Energy Planning of Urban District Retrofitting. In Proceedings of the 2021 International Conference on Smart Energy Systems and Technologies (SEST), Vaasa, Finland, 6–8 September 2021.
33. Ghiani, E.; Giordano, A.; Nieddu, A.; Rosetti, L.; Pilo, F.: Planning of a smart local energy community. The case of Berchidda municipality (Italy). Energies, 12, 4629 (2019).
34. Terna spa. Homepage, https://www.terna.it/it, last accessed April 2023.
35. Moreno, C.; Allam, Z.; Chabaud, D.; Gall, C.; Pratlong, F.: Introducing the "15-Minute City": Sustainability, resilience and place identity in future post-pandemic cities. Smart Cities, 4, 93–111 (2021).
36. Balletto, G., Ladu, M., Milesi, A., & Borruso, G.: A methodological approach on disused public properties in the 15-minute city perspective. Sustainability, 13(2), 593 (2021).
37. BES2021_byIstat,https://public.tableau.com/app/profile/istat.istituto.nazionale.di.statistica/viz/BES2021_/Regione?publish=yes, last accessed April 2023.
38. Zhang, H., Song, X., & Shibasaki, R. (Eds.). Big data and mobility as a service. Elsevier (2021).
39. Hensher, D. A., Mulley, C., Ho, C., Wong, Y., Smith, G., & Nelson, J. D.: Understanding Mobility as a Service (MaaS): Past, present and future. Elsevier.(2020).