Energy, Resource Circularity, and Retrofitting in Positive Energy Districts

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1 Introduction

Today the world population has reached 7.9 billion people, and it is estimated that this number will exponentially grow over the next few decades to reach 9.7 billion in 2050 [1]. In a so densely populated world, with a limited amount of resources and hit by the climate crisis, pursuing a model of sustainable development cannot be considered an optional solution.

According to "The net- Zero Carbon Cities Building Value Framework," more than half of the world's population currently lives in cities [2]. Therefore, although cities occupy only 3% of the Earth's surface, they are responsible for 60–80% of energy consumption and 75% of carbon emissions [3]. In particular, buildings are responsible for over 38% of global CO2 emissions, which is why implementing concrete and massive actions for an environmental and sustainable design has a primary importance.

2 Adaptation and Mitigation

It is well known that adaptation, defined as adjustment to the current and future effects of climate change, indicates fundamental guidelines for combating natural phenomena that unfortunately we are experiencing more and more frequently and intensely in recent decades. Phenomena such as drought, heat island, and excessive

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summer temperatures, followed by sudden and violent storms and “water bombs” in winter and also more extreme phenomena such as landslides and earthquakes, have become progressively frequent in Europe. It is observed a 1.5 °C increase in average temperatures from the pre-industrial era, accompanied by a 10–30% increase in extreme summer phenomena, such as the increase of water scarcity and the increase of sea level of about 2.8 mm per year [4].

For this reason, it is important to act in a synergic way, both in the context of adaptation and in climate changes mitigation, i.e., the set of strategies adopted to reduce the causes of climate change, ambit in which issues relating to circularity of resources (smart and ecological systems for water management, solid urban waste and various types of waste), the production of clean energy and urban retrofitting converge and intertwine each other.

3 Circularity

As already mentioned, the exponential increase in recent decades of the world population and its growing urbanization lead to the necessity of paying more attention about the circular economy principles: the reduction of the use of resources, materials and energy, and the decrease in waste production and scraps [5]. The corollary of this condition is self-sufficiency (i.e., the achievement of well-being conditions and autonomy without depending on raw materials or external help) thanks to the production of resources, materials and energy as much as possible on site.

In addition to the question of the scarcity of resources, many studies underline the importance of the contribution of the circular economy to the abatement of greenhouse gas emissions, which is why a challenging target of greenhouse gas reduction by 2030 (reduction of at least 55% of CO_2 compared to 1990 levels), has been set by the European Green Deal and the SDGs of the 2030 Agenda. Achieving this target necessarily requires significant measures to reduce the circularity gaps. The scientific community agrees that doubling the current circularity rate would cut about 22.8 billion tons of greenhouse gas emissions globally [6].

Investigating the path of different flows of resources, divided into “materials” (gray water, wastewater, organic waste, urban solid waste, construction processing waste…) and “intangible” (energy, heat or waste heat, gas…), the theme of circularity is strictly linked to energy production, storage and reuse.

4 Energy

Energy consumption is responsible for about 75% of GHG emissions in the European Union. The electrification of consumption, which should encourage the transition to renewable energy sources, is increasing the demand for electricity, too. However, data at the moment is not comforting: in Italy, for instance, the energy sector still uses 80% of fossil fuels, and only 19% of renewable sources; moreover, it represents a fixed value in the last five years [7].

The building sector is one of the most energy-hungry and requires a strong transformative action at different scales, including both single building and urban district, increasing the use of renewable sources, energy efficiency, low-emission technologies and integrated energy systems [8]. For this reason cities, and specifically buildings, have a significant role in the ecological transition [9] and require actions and new solutions to improve life in urbanized areas [10], implementing network flexibility and efficiency, bringing the goal of near zero energy external demand from the building scale to the district scale.

The close connection between energy issues and the reduction of climate-altering emissions, especially CO_2, underlines the need to bring attention to a circular, efficient, and effective management of energy resources, implementing grid flexibility, decentralizing energy systems, and spreading them into cohesive local systems, aiming at the reduction of energy imports and CO_2 emissions [11].

5 Retrofitting

In terms of availability of housing, Italy has one of the highest numbers of buildings available [12]. However, experts estimate that over 1.2 million of new buildings are going to be built in the next ten years, beyond the necessary for the Italian scenario, which has a constant decrease of demography. It is necessary to act on the existing heritage in a double way: on one hand considering the heritage as a resource and not as a waste that need just to demolished and rebuilt (action that would have a significant impact on embedded carbon emissions) and, on the other hand, from a green viewpoint concerning the alarming global climate situation. In this sense the instruments available are varied and include certifications and protocols, such as GHG INVENTORY TOOL, and energy certifications, such as LEED historic building and Passivhaus standard. In addition, the combined use of instrumentation aimed to purely restore and maintain with ones that are focused on consolidation, such as the Technical Standards of buildings 2018, ensures the stability of buildings in front of the increasingly frequent extreme phenomena due to climate change.

By ensuring good bioclimatic behavior and using renewable energy sources, it is possible to achieve good levels of energy saving and reduction in emissions. Referring to the actual energy crisis, the simultaneous use of these strategies is indispensable, as well as part of the 17 objectives of the 2030 agenda: "the path toward a low-carbon economy requires the transition from a high intensity production energy system to a new model of economic development based on energy saving and the diversification of sources, in a context of a broader cultural, behavioral and technological transformation."

6 PEDS: Positive Energy Districts

In the context of urban regeneration projects, it is important to identify the right scale of intervention, which brings individual benefits and, at the same time, contributes to collective well-being in terms of environmental sustainability. The energetic and ecological requalification of a single building is not much significant in the overall budget of a city in terms of emissions reductions. At the same time, thinking of redesigning an entire city could be considered an unrealistic and complex approach.

The most feasible solution, as it is easy to imagine, operates at an intermediate level: to some extent, eco-districts are small-scale Smart Cities, in which it is easier to develop the project, monitor its developments and manage flows and connections between the different components that make up the neighborhood. This strategy represents an excellent opportunity to experiment, with new strategies and urban models, our cities' transformations into more sustainable and livable ones.

Furthermore, at the neighborhood scale it is possible to redevelop or rebuild individual buildings, but also to promote the establishment of sustainable services and communities so-called "smart communities" [13].

Fortunately, there are now numerous examples of Positive Energy Districts around the world, thanks to programs funded by Horizon Europe such as SPARCS + Cityxchange and Making City, with the ambitious goal to create 100 PEDs by 2025. Among these, we have selected three of the most interesting and representative cases in Mediterranean countries (Spain, Italy and France) for which we compared, in particular, three thematic axes: bioclimatic, energy, and resources circularity.

7 Ecobarrio De Trinitat Nova, Barcelona, Spain

Trinitat Nova is located in the northern part of Barcelona and it belongs to the Municipal District of Nou Barris. It is based on the southern slope of the Sierra de Collserola and it is bordered by two large traces of the territory: the Avenida de La Meridiana and Ronda de Dalt, which physically separate it from other neighborhoods. The neighborhood was built in the decade of 1950 to solve the social housing problem. In 1953, the construction of Trinitat began and most of the buildings were built without the presence of projects. The area lacked the minimum equipment (roads, infrastructures). The houses were small (the majority did not reach 50 square meters) and made of poor-quality materials. The physical decay of the neighborhood started almost from the moment of its completion. The neighborhood did not offer any service or specific facility. From a socioeconomic point of view, people that live in the area have a low education and a high incidence of unemployment rate, compared to other districts of Barcelona. Finally, the presence of an aluminosis problem led to the development of a programmatic document, which, by establishing a priority intervention area, pushed to requalification actions. In the area there are four types of blocks, for a total of 891 dwellings.

Various points have been considered in the transformation of Trinitat Nova into an eco-district. In the past, the water loss factor was estimated at 7.8%. The district's regeneration plan provides the reparation of drinkable water pipes, which do not need major maintenance. The solutions proposed for the reuse of water for domestic use are: the installation of water pressure reduction devices compliant with the legislation, the optimization of the section of the water pipes according to the number of inhabitants per single home, the design of DHW systems: generally a short piping system guarantees less waste of heat, correct insulation of the pipes, the presence of a centralized DHW production system. For the urban environment, the solutions proposed are: the application of permeable surfaces for car parks or emergency accesses, the evaluation of the possibility of creating green roofs or, alternatively, the collection of water rain from the roofs, the study of atmospheric polluting factors, such as heavy metals, the maintenance of the natural filtration of the soils of the area adjacent to the water table. Assessments of the filtration capacity of basins and streams, assessments on the naturalization capacity of old wetlands and on the use of collected water were necessary for the quantization and sizing of the retention, accumulation, filtration systems and the application of filter blocks underground. This allowed the collection of up to 20 tons of water, thus increasing the volume of water by approximately 96% of its total volume (950 liters per cubic meter).

Recovery of biodegradable waste through the production of compost, methane and biogas. This gas can be used as an energy source for high performance boilers. The production of biogas varies between 130 and 160 m^3/tons of waste depending on the type. The environmental advantages, compared to composting, pass through a lower CO_2 emission and include livestock waste, sludge from treatment plants (WWTP), effluents, industrial waste, and the organic fraction of municipal solid waste. The methanization of organic matter is the process of recycling or using waste to generate biogas, which is then used for energy production.

The installation of a combined system for heating and domestic hot water supply enabled a reduction of 45% of primary energy and CO_2. The cogeneration of heat and electricity allows a further reduction in consumption of 30%.

The solar thermal appliances installed vary from minimum mandatory systems such as EE-130 ACS, which supply 150 kW per building type, to E-E systems which supply the building type 200 kW. Other air systems are present, such as the E-I and E-X systems that cover 225 m^2 and 2925 m^2, respectively (i.e., 325 m^2 for a typical building). Finally, systems such as EBX-S and EBX-CS were also installed for a total collection area of 1575 m^2 (175 m^2 for a typical building) and 2025 m^2 (225 m^2 for a typical building).

Heat Energy saving is also guaranteed by the presence of boilers with a cogeneration power of 150 kWt for a 300kWt boiler.

Photovoltaic panels are installed throughout the neighborhood. Considering, for the city of Barcelona, an annual yield for a photovoltaic panel of 10% and an annual solar production of a device that is around 1.3 kWhe/Wp, with 125 Wp/m^2, the annual savings in emissions of CO_2 is 623 Kg CO_2eq/kWp. Following a study on what measure could guarantee greater efficiency for the city's climate, small independent appliances with a power of 5 kWp inclined at 30/35 degrees, orientated on south, were set up.

A bioclimatic design on the existing buildings allowed further energy savings and minimization of the waste resources. Systems such as water-saving plumbing systems for dual-flow faucets and toilet drains. These installations, despite being very cheap, have allowed significant savings. The collection and reuse of water from showers, bathtubs, bidets, sinks and washing machines is another strong point for Trinitat. In particular, a LOKUS submersible rotating body type system was used. The elements that make up the system are gray water collection system, treatment system, and sanitation system. The selected plant is semi-centralized, with a treatment plant for every two residential blocks, producing an amount of 10,000 liters per day for every 150–200 people.

Finally Trombe walls, face change materials, solar accumulation systems and double-glass windows have been installed. The good facades' orientation helps to reduce the energy use. Finally the cross ventilation reduces 43% of cooling demand [14].

8 Casanova, Bolzano, Italy

In 2002, the Municipality of Bolzano, a city that has always paid attention to sustainability and clean energy, bought 10 ha of agricultural land in the locality of Bivio-Kaiserau and planned the Casanova neighborhood with the intention of satisfying the need for social houses.

The settlement consists of eight open-type and irregularly shaped residential courtyards, in which have been built 941 apartments, hosting about 3500 people. A public space located in the center of the district hosts mixed residential, commercial functions and facilities.

The architectural project interprets the settlement theme of the "castle," a residential nucleus formed by three or four imposing buildings gathered around a small green courtyard, starting from three elements that characterize it: the fence that defines and delimits the block, the massive envelope that expresses the character of the block, and the court that represents its heart. Architecturally, the desire to accentuate the unity of the project leads to identify a single compositional register of the facade and this characteristic is expressed with different opening solutions for the internal elevations, with large loggias toward the courtyard space compared to the external elevations, underlining the different nature and value of the view.

The integration between the intervention area and the city center was achieved through cycle-pedestrian routes and public transport lines, thus helping to discourage the use of cars. The project area involves the presence of the railway line, a strong element of recognition and a fundamental hub for the mobility of the whole area, thanks to which the public transport system is further strengthened.

The energy sustainability of the neighborhood is certainly the aspect on which the most effort has been devoted. The energy policy was “to produce better and consume better,” a phrase that is often heard, which was then found to be concretely implemented with Casanova.

In 2003, the limits for energy needs for heating were set nationally at about 90 kWh/m^2/yr. (Italian Law 10/91). On the other hand, for the district it was decided to impose stricter limits also taking into account the size of the buildings: for residential buildings smaller than 5000 m^3 the limit is 50 kWh/m^{2}a (CasaClima class B), for larger buildings of 20,000 m^3 is 30 kWh/m^2/yr. (CasaClima class A), for buildings between 5000 m^3 and 20,000 m^3 in volume the limit varies linearly (CasaClima A parameterized). A larger building, in fact, is intrinsically more virtuous since the ratio between the dispersing surface and the volume of the building decreases. For buildings with other intended use (buildings for the tertiary sector, schools, sports, …) compliance with class A is required, regardless of the volume. With these innovative solutions it has been possible to achieve an annual energy savings of 42% compared to traditional buildings.

With the aim of reducing consumption or “consuming better,” dispersion is reduced for all buildings by adopting high insulation values and choosing a compact and regular shape. They are equipped with green roofs, with massive walls (that means high thermal mass), well insulated and with glass surfaces of different sizes depending on the orientation of the facades.

The optimization of solar gains was achieved by varying the height of the buildings, whose decreasing heights toward the south favor natural lighting and radiation, as well as shielding from cold winter winds and channeling summer ones.

As far as “producing better” is concerned, the “castles” are equipped with renewable energy systems: solar and geothermal.

Solar energy is exploited for the production of thermal energy through solar thermal collectors that provide the needs of about 35% of domestic hot water, and for the production of electricity through photovoltaic panels which, with an average capacity per accommodation of about 250 W at peak, contribute to the electricity needs with a global production of 260.000 kWh/yr. [15].

Geothermal energy is used both as an integration to the heating needs and as a cooling system through a water circuit, and as preheating and precooling of the ventilation air of a castle through an air circuit.

For the production and distribution of thermal energy, a district heating system was built, with which it was possible to achieve savings in annual energy requirements of 31% compared to a solution with autonomous boiler systems for each residential unit. This innovative solution has numerous advantages: firstly, the control of polluting emissions which are concentrated in a single point to allow constant maintenance of the minimum values and continuous control over the type and quantity of emissions; secondarily, the possibility of accounting for thermal energy to record the energy consumption of each individual accommodation and dividing the costs based on actual consumption; furthermore, district heating allows for less overall losses and; finally, it becomes possible to recover the heat produced by the nearby Bolzano incinerator (as if it were a large boiler that heats the buildings), which would otherwise be dispersed into the environment, and now redirect it into the district heating network.

A district cooling system also serves the district's tertiary users. A power plant powered by the district heating network located in a barycentric position produces chilled water thanks to absorption machines. In this way, the heat recovery from the incinerator will always be active: in winter for heating and the production of domestic hot water, in summer for the production of domestic hot water and for powering the absorbers.

At the plant level, measures have been adopted to reduce energy consumption such as district heating, geothermal heat pumps, radiant panel heating and cooling, and a controlled ventilation system with heat recovery.

The new district also provides innovative measures for the distribution of drinking water and gas for domestic use, for the disposal of black water, for the distribution of electricity and for the disposal of white water, both public and private, collected in cisterns or tanks, and subsequently used for irrigation and for the conservation of large surfaces permeable to green and for the formation of a humid area along the railway, capable of producing favorable effects on the microclimate.

The rainwater precipitated on the surfaces of the main roads is conveyed into drainage wells and depressions that spread the water underground. The excess water, which the wells and depressions are unable to disperse, is conveyed through a general drainage network to a central pumping station and then fed through a pressurized pipeline into the Isarco River.

The rainwater that has fallen on the surfaces of secondary roads and on the roofs of buildings, and therefore is "cleaner" than the former, is instead conveyed through storm water collection systems to collection and sedimentation tanks and is used for the irrigation of public green areas.

Each "castle" is equipped with a cistern for the accumulation of rainwater collected from the roofs of the buildings, with a capacity of 20,000 liters.

9 Grenoble-Alpes Métropole, Grenoble, France

Grenoble-Alpes Métropole is the first French city to adopt a Climate Plan in 2005. This program was full of initiatives, designed to combat climate change. Soon this Plan morphed into an Air Energy Climate Plan, which sets, among others, specific objectives in terms of greenhouse gasses and principal pollutants, as well as the use of renewable energy. In the period between 2005 and 2010, energy consumption decreased by 5.4%, greenhouse gas emissions were reduced by 18%. Final energy consumption per inhabitant in 2011 was 19.7 MWh.

To take the commitment toward the ecological transition to the next step, Grenoble joined, as a demonstration city, the project City-zen [16]. This program was granted EU-funding "to develop and demonstrate energy efficient cities and to build a methodology and tools for cities, industries and citizens to reach the 2020 targets." The program, rooted in Amsterdam (NL) and Grenoble (FR), had its first official kick-off in March 2014.

The municipality has launched the Éco-cité project in the northern part of the city, bringing together public and private stakeholders around demonstration projects mainly concerning mobility, energy retrofitting of existing buildings and renewable and recovered energy. The overall Grenoble objective of the City-zen project was to transform the Éco-cité area into a positive energy and carbon neutral district.

The reduction of energy consumption is fundamental to support the energy transition, Grenoble-Alpes Métropole has strategies that aim to: energy sufficiency (to reduce wasteful need and loss) energy efficiency (aiming to use less energy to achieve the same result) and thermal renovation of buildings envelops. In fact, 42% of total energy costs is attributed to buildings and they waste a lot of energy due to a bad management of their design and needs: overheated offices, badly insulated housing, poorly designed public facilities, etc. Grenoble-Alpes Métropole is strongly committed to the thermal renovation of public and private buildings built between 1945 and 1970, not only those intended for residential use (social housing and private property) but also office buildings, stores, universities, and hospitals.

The first action taken in this direction is investing in insulating residential buildings: between 2010 and 2015, 5000 private and 5000 social housing units were renovated. Grenoble-Alpes Métropole wants to further extend this policy and, to achieve the aim of a 19% reduction in household consumption by 2030, it needs to double the number of annual renovations. To reach this target City-zen collaborates with several stakeholders, ALEC for the public building, and the Mur|Mur program for insulating buildings. It has already seen the thermal renovation of 5000 private apartments and it has been extended in 2016. Its successor Mur|Mur 2, with the objective of 10,000 extra housing units renovated by 2023, offers a wide range of support and solutions depending on type of housing, household income and level of renovation.

Furthermore, a web platform will be implemented to provide day-to-day access to gas, electricity, and heating consumption data. The data will be compared to the consumption of equivalent houses and flats, allowing the citizens to monitor their own behavior, providing advice and tips to improve the performance and to increase the awareness.

Grenoble-Alpes Métropole aims to change the energy mix, increasing the share of renewable and recovered energy by 35% and reducing the use of fossil fuels by 30%. In the future, heating systems will use more and more renewable energy with the construction of new wood-fired boilers and the use of solar thermal or geothermal energy for heating and cooling. The main heating system will increasingly use wood and recovered heat produced during the industrial process and recovered as an energy resource.

Grenoble-Alpes Métropole will also extend its biogas production, encourage photovoltaic electricity and exploit the full potential of hydroelectricity.

The new biomass power plant, called Biomax, will soon replace an old fuel oil boiler, and two power plants will be modified by 2025, permanently eliminating coal, powering four new district heating networks by 2030. In parallel, the excess heat produced on the Pont-de-Claix chemical platform will be recovered and feed this network. This solution compensates for the expected decrease in heat resulting from waste incineration. The amount of waste incinerated is set to decrease as a large amount has to be sent for recycling, as set out in the new waste action plan.

Since 2016, the local Aquapole treatment plant has been equipped with a biogas production unit, fed with sewage sludge, which generates 20 million kWh, the equivalent of the energy consumption of 2500 families.

By 2025, Grenoble-Alpes Métropole will create a second biogas production unit using food waste that will soon be collected throughout Grenoble in accordance with the new master plan on waste.

To obtain the benefit from this action, also the distribution network must be optimized to be capable to sustain and distribute a higher load coming from renewable energies and to meet the needs of electrification. It needs an optimized control and dynamic management of energy flows, innovative storage solutions and interconnectivity.

The key-action in the Roadmap of Grenoble Éco-cité is the synergic collaboration of local authorities, research and innovation stakeholders, partner associations and citizens to draw up the Energy Master Plan. Connecting people and districts of the city, planning actions in a timeline, empowering citizens in the process boost the shared vision for the future. The results in achieving climate neutrality, realizing a sustainable metropolitan region, are remarkable: CO_2 emission reduction 10900tCO_2/year, Primary energy saving 48,444 MWh/year Final energy saving 35,621 MWh/year.

Grenoble is the European Green Capital of 2022 for its commitment to go further and for everyone in the public and private sectors, nonprofit organizations and residents to look to 2030 together and make Grenoble a city that is more resilient, welcoming and united.

10 Conclusion

The research leads to a methodological tool that can be replicated for other case studies, looking to future investigations and methodology developments.

The first step consists in a comparative table, in which it is possible to highlight every technological solution belonging to each subcategory of the three macro-areas selected (circularity, energy, retrofitting/envelope). Comparing the results, it is possible to understand differences and analogies between the different districts analyzed.

			SPAIN	ITALY	FRANCE
	TYPE OF ENERGY PRODUCED:				
ENERGY	Thermal energy production	Solar thermal collector	☑	☑	☑
		Cogeneration	☑	☐	☐
		Biomass and wood-fire boilers	☑	☐	☑
	Electricity production	Photovoltaic panels	☑	☑	☑
		Hydro-electricity	☐	☐	☑
	Geothermal energy production	Geothermal heat pump	☐	☑	☑
	Heat storage	Heat storage PCM	☐	☐	☑
	Heating production	District heating system	☐	☑	☑
	Smart management	Smart management	☑	☐	☑
CIRCULARITY	Water	Recovery of rainwater	☑	☑	☐
		Recovery of domestic water	☑	☐	☐
	Heat recovery	Heat recovery from incinerator/industries	☐	☑	☑
	Energy from waste	Biogas from waste/seawage sludge	☑	☑	☑
	Smart management	Smart management	☑	☐	☑
RETROFITTING AND PASSIVE TECHNOLOGIES	Envelope		retrofitting	new building	retrofitting
		Ventilated facades and massive walls	☑	☑	☐
		External insulation	☑	☑	☑
		Window replacement	☑	☑	☑
		Green\blue roofs	☑	☑	☐
	Systems	Reparation and optimization of old systems	☑	☐	☑
	Smart management	Controlled ventilation	☐	☑	☐
		Improving inhabitant behaviour	☑	☐	☑

Fig. 1 Comparison between different PED's strategies (authors elaboration)

The three districts largely use sun as a major renewable energy source, adopting photovoltaic and solar thermal systems. Geothermal and hydroelectric energy, on the other hand, are not always used and wind energy was not designed. This choice probably is due to the geographical area and the latitudes in which the districts fall: the Mediterranean climate is characterized by a high percentage of sunny days with no wind per year.

Regarding circularity, the use of waste as an energy resource, especially to produce biogas, is positively underlined. Waste is a secure source of energy supply, significantly contributing to the energy mix and increasing the resilience of grids.

In terms of retrofitting and passive technologies, there are some macro actions in common even if they are applied in different ways depending on the type of project (retrofitting or new construction) (Fig. 1).

Starting from the table it was possible to extrapolate the data into three radar graphs, showing the percentage of action undertaken for each subcategory. The radar charts visually show differences and similarities between the ecodistricts, strengths and aspects that need further implementation.

In conclusion, we can say that the eco-districts selected for their commitment to decarbonization and climate adaptation and mitigation, although they belong to the Mediterranean area, present different applications of the solutions adopted, based on their own regulations and rules dictated by the climate and the local context (Fig. 2).

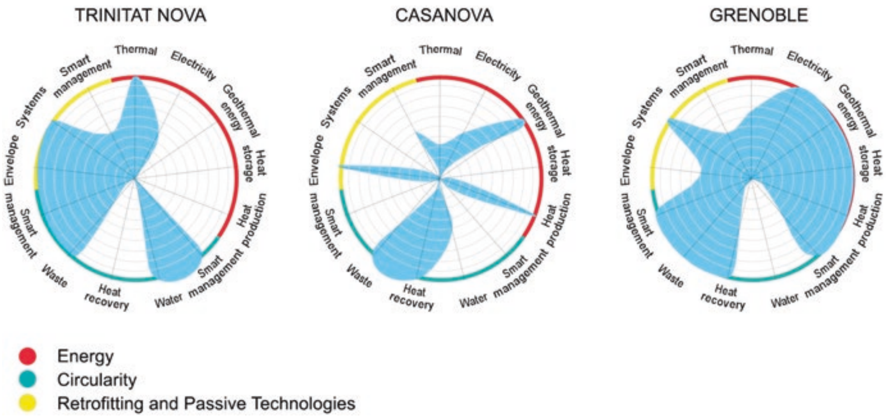

Fig. 2 Strategies radar scheme (authors elaboration)

References

1. United Nations. (2019). World Population Prospects 2019: Highlights, p. 5.
2. World Economic Forum. (2022). Accelerating the decarbonization of buildings: The net-zero carbon cities building value framework, p.3.
3. European Environmental Agency. (2020). *Air quality in Europe – 2020 report*, p. 12.
4. Mediterranean Experts on Climate and Environmental Change (MedECC). (2020). First Mediterranean Assessment Report Climate and Environmental Change, Mediterranean basin, Current situation and risks for the future, p. 3.
5. Circular Economy Network (CEN). (2022). 4° RAPPORTO SULL'ECONOMIA CIRCOLARE IN ITALIA, pp. 7–13.
6. https://ellenmacarthurfoundation.org/circular-examples/the-eus-circular-economy-action-plan, consulted on 16/July/2022.
7. Italy 4 Climate. (2021). La Roadmap per la neutralità climatica dell'Italia, p. 6.
8. United Nations. (2018). *The Sustainable Development Goals Report 2028*, pp. 7, 22, 23.
9. International Energy Agency (IEA). (2019). *Empowering cities for a net zero future*, p. 9.
10. Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate change, mitigation of climate change*, pp. 40, 53, 56.
11. European Commission. (2018). Annual activity report, *Joint Research Center,* pp. 20–21.
12. Housing Europe. (2021). The State of housing in Europe, p. 75.
13. Legambiente. (2013). Comuni rinnovabili, pp. 23–24.
14. Gea21. (2004). ECOBARRIO DE TRINITAT NOVA, Propuestas de sostenibilidad urbana, Documento de síntesis de los estudios sectoriales de sostenibilidad, pp. 24–26, 33, 101, 231–237, 346–256, 269–277, 307, 311–313.
15. Eurac Research. (2013). CasaNova. Nuova concezione sostenibile dell'abitare.
16. http://www.cityzen-smartcity.eu, consulted on 16/July/2022.