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Advanced sustainable design and experimental assessment to address climate neutrality in Mediterranean areas

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Abstract. As for the recent scientific findings, carbon neutrality is no more sufficient within the research for a sustainable development, as climate change effects are becoming crucial factors to be considered. Therefore, in developing strategies and applying design technologies for sustainability in urban settlements, a focus on climate neutrality is required, to build climate resilience together with energy efficiency. This paper presents an experimental methodology applied within the ABITAlab activities for the assessment of the Urban Regeneration Integrated Plan (PIRU) for the Mediterranean city of Taranto. In this experience the Advanced Sustainable Design (ASD) was applied by addressing both energy efficiency and climate resilience for climate neutrality. The importance of the experimentation is defined by the relation upon which, since Regenerative Design principles apply to ASD, the presented assessment methodology is applied to the ASD Process, through which, by studying regenerative scenarios, the goal of production of positive environmental and social impacts overcome the concern for the reduction of negative environmental impacts. The paper is structured as follows: after research reported in the literature section, the proposed assessment methodology is built interpolating three types of validated assessment methodologies to address climate neutrality: (1 and 2) through NbS and SUDS for climate resilience; (3) through PEDs for energy efficiency. Then, the methodology is validated through its application to the presented project experience within a regenerative scenario of transformative resilience. At the end, the experimentation results validate: (a) the workflow methodology divided in three different steps; (b) the scientific contribution of the methodology based on the integration of three different assessment methods. The work presented is validated for the Advanced Sustainable Design for climate neutrality within regenerative scenario, replicable in the Mediterranean area.

Keywords: Climate neutrality / design strategies / assessment / regenerative scenarios

1 Introduction

The climate crisis we are currently experiencing has forced a rethinking of all systems of production, consumption and use of resources, be they energy resources or those related to natural and territorial capital. The human capacity to intervene and provoke transformations on the environment is the evidence that we live in an era that can be defined as "neo-anthropocene" [1], in which the issues of living, environmental safety and the wellbeing of the individual can only be based on the possibilities of a renewed design culture, capable of hybridising knowledge, technical skills and technological innovation [2]. As for the increasing impacts of climate change on the built environment, the importance of the health and the efficiency of ecosystem services is growing and is guiding the new and innovative design strategies and planning policies. In other words, it is a matter of accelerating the transition from an 'energy-intensive' model to a 'climate-neutral' one, in which the transformation of the user from mere 'consumer' to 'consumer-producer' (prosumer) takes place. The concept of 'climate neutrality' goes beyond that of 'carbon neutrality' within the paradigm of sustainable development: the last COP26 in Glasgow, in fact, together with what is envisaged by the New Green Deal [3] and by the policies in place at EU level (such as in Italy, the National Recovery and Resilience Plan-NRRP and the National Integrated Energy and Climate Plan-NIECP) aim to promote strategies to achieve 'climate neutrality' of cities by 2050, with substantial financial investments cascading to regions and municipalities. Certainly, according to the latest IPCC report [4], carbon peaking and neutralisation by 2030 and 2050 is essential, in order to limit the temperature increase to well below 2 °C and avoid the negative impacts of climate change caused by the sharp

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increase in carbon dioxide emissions [5]. Cities become the context on which to focus decarbonisation strategies, operating a reconversion in energy, transport, industry, agriculture and building stock. Although cities occupy only 2% of the total available land, they account for 40% of total energy consumption and contribute 70% of climate-changing gas emissions into the atmosphere. In this perspective, it is worth mentioning that one of the largest sources of energy consumption is the existing building stock, which accounts for as much as one third of total emissions in the entire European Union and that more than 75% of buildings do not meet energy efficiency standards and absorb almost half of the final energy demand [6]. Due to its particular combination of multiple strong climate hazards and high vulnerability, the Mediterranean region is a hotspot for highly interconnected climate risks. In addition to these, there are also impacts of an economic and social nature, with emerging issues such as rising rates of energy poverty and population living in substandard housing. It is no coincidence that these issues are addressed within new global social agendas such as the UN 2030 Agenda [7], in particular with SDG 11 'Sustainable Cities and Communities – Make cities and human settlements inclusive, safe, resilient and sustainable'. On the basis of these considerations, this paper is structured into four sections: the first deals concisely with the issues related to advanced sustainable design towards regenerative design, for the decarburization and climate neutrality of urban systems, referable to the theme of Positive Energy Districts, through case studies located in the Mediterranean area and experimental assessment; the second illustrates the construction of an original methodology for the experimentation of advanced design processes, capable of activating "system specific" adaptation and mitigation strategies for regenerative scenarios, in settlements at the urban and with particular conditions of vulnerability. Focusing on Mediterranean areas, the third part illustrates the results of two design contributions on the Urban Regeneration Integrated Plan of Taranto City (PIRU Taranto). Finally, the last section concludes the contribution by addressing some open questions related to the theme of the transition from sustainable to regenerative design, as an ideal approach for advanced design on 2030/2050/2100 transition scenarios.

2 Literature review

The definition of the project as a tool that, through technique, manages the transformations of the built environment, capable of responding to the global challenges underway in our era, leads us to consider the change triggered by human intervention at all scales and over short, medium and long-term time scenarios. It is therefore necessary to redefine the inter-scalar relationship between functioning models and expected impacts, to define the quality of space in terms of functions and well-being, and thus to adopt a regenerative approach with high performances, for which sustainable design is not limited to the reduction of impacts, but produces positive environmental and social performance. In this sense, the concept of "regenerative development", according to which climate-positive development means designing going beyond impacts reduction, to actually repairing the atmosphere through consuming more CO_2 than it produces [8], which first passes through a "restorative" design phase ("environmental design with resources and sustainable design"), is also important. In regenerative terms, levels of "resilience", as the ability of social-ecological systems to adapt to external transformations and pressures, going beyond the concept of sustainability, while continuing to support human quality of life and well-being, also contribute [9]. In the context of achieving climate neutrality goals for cities, the model of Positive Energy Districts (PEDs) has recently gained deeper attention [10], since they can help to face this challenge into practicable projects. This approach, by addressing energy and climate strategies at the neighbourhood level, can generate important advantages over a 'single building' approach, both in terms of design and the search for an optimised urban morphology based on parametric analyses, and in terms of the design and integration of energy systems (smart grids). Most of the ongoing pilot PEDs are located in Northern Europe. In the Mediterranean area, there are currently 15 pilot cases of positive energy districts, fourteen of which deal with the topic of retrofit of existing buildings and integration between new and existing [11]. The theme of regeneration of the built environment, rather than new construction, is more prevalent in the Mediterranean area than in other parts of Europe. The experiences of PED in the Mediterranean area act on consolidated urban contexts, promoting on the one hand the containment of land consumption and natural resources, on the other hand the improvement and efficiency of the energy performance of buildings, networks and services for the climate mitigation of open spaces with the involvement of the resident community, configuring itself as a strategy valid not only for new construction districts. An interesting pilot case study in this context is the 'Smartmed' district in Via Petralata in Rome, which responded to the Horizon 2020 'Smart Cities and Communities' call for proposals. Promoted by important research centres including ENEA, it aims to be a 'flagship' pilot project in the Mediterranean area to test and disseminate best practices in energy efficiency in urban areas, paying particular attention to the integration of advanced solutions and the possible implementation of electric and thermal smart grids for the creation of energy-independent islands and Smart Energy Districts, as well as to the introduction of an increasing share of energy production plants from renewable sources in urban areas [12]. The 'Santa Chiara Open Lab' pilot case of the city of Trento works on the issue of the climate mitigation potential of open spaces through the redesign of the Santa Chiara Park, by implementing interventions on connecting spaces and accessibility between buildings, rainwater collection, recycling and reuse systems (SUDs), and urban greening strategies, which increase the area's resilience to climate change and are able to mitigate heat island effects in the summer [13]. The application of an advanced design methodology for the sustainable design of spaces and functions for autonomous districts and regenerative and ecological neighbourhoods was conducted in a teaching and research transfer experience as part of the Sustainable Innovation Design Course by C. Nava (dArTe) with the Workshop "Sustainable Advanced Design-SAD II" [14], which involved the 15 undergraduates in the period April-June 2020 for experimentation in seven 'fragile' areas in the southern suburbs of Reggio Calabria (Italy). Among the seven case study projects of the WS-SAD II, "Community & Forest District" proposes the regeneration of the spaces of Viale Europa by acting on three scenarios, which include actions of urban greening and NBS for the mitigation of heat island effects and SUDs (2020 scenario), actions of building replacement and new urban green, implementation of smart energy networks to serve existing buildings and new sustainable mobility services, functional mix of public-private spaces (2030 scenario), actions of new residential construction, new urban forestation and total energy autonomy of the district (2050 scenario). At the end, an experimental assessment of the capacity of generating a social and environmental impact for the improvement of urban quality and the built environment on a building and neighbourhood scale through Agenda 2030 SDGs was applied in terms of quality/quantity of new devices, resources, technologies implied (SDGs Impact Design) [15].

In order to construct an integrated methodology for the proposed experimental assessment of the Advanced Sustainable Design towards climate neutrality, three study cases based on NbS, SUDS and PEDs are considered.

2.1 Assessment to address climate neutrality through NbS

Today, different research studies have contributed to the evaluation and assessment of NbS. Beceiro et al. [16] for example, propose a system of assessment based on 10 objectives, 25 criteria and over 80 metrics of assessment. However, the IUCN defined 8 criteria for the assessment of NbS. The criteria are summarized as follows: (1) NbS effectively address societal challenges; (2) Design of NbS is informed by scale; (3) NbS result in a net gain to biodiversity and ecosystem integrity; (4) NbS are economically viable; (5) NbS are based on inclusive, transparent and empowering governance processes; (6) NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits; (7) NbS are managed adaptively, based on evidence; (8) NbS are sustainable and mainstreamed within an appropriate jurisdictional context [17]. The listed criteria are assumed in this paper as valid criteria for the assessment of Advanced Sustainable Design based on NbS (Table 1).

2.2 Assessment to address climate neutrality through SUDS

SUDS provide benefits for communities, through the management of urban ecosystem services. With urban ecosystem service is intended the benefits that human can have from the high quality of ecosystems in the built environment. For example, as Johnson & Geisendorf clearly state: "green roofs and facade greening not only harvest rainfall and prevent runoff from directly entering sewer and drainage systems but also decrease the energy consumption of buildings through better insulation, reduce the urban heat island effect in densely built areas, and add aesthetic value to buildings" [18]. Table 2 presents the architecture of economic assessment provided by Johnson & Geisendorf. In this paper, this structure is re-elaborated to be used for the construction of the SUDS and PEDs component of the Advanced Sustainable Design assessment.

2.3 Assessment to address climate neutrality through PEDs

In order to organize the assessment to address climate neutrality through PEDs, the parameters proposed by Castellanos end Oregi [12] are considered: project area, land use, tools for energy evaluation, Key Performance Indicators (KPI) and energy data. Furthermore, the same authors consider 3 areas for the analysis of solutions for the implementation of a PED: (1) improvement in energy efficiency of buildings, e.g., the enhanced building envelope, (2) RES (Renewable Energy Sources) to be implemented in the district, and (3) energy storage technologies.

3 Methodology

Based on the considered references, the methodology workflow is summarized as follows (Fig. 1):

3.1 Construction of the assessment workflow component related to SUDS and PEDs

The assessment workflow component related to SUDS is constructed through the elaboration of the structure given by Johnson and Geisendorf [18], thus declining the economic aspects of ecosystem services in performance design aspects; valutation methods in valutation parameters and implementing the structure with the level of contribution. The types of benefits are invariated (Table 3). Following the same assessment structure, the construction of the assessment workflow component related to PEDs is based on some evaluation parameters reported by Castellanos and Oregi (Table 4).

4 Experimentation

4.1 Presentation of the study case: Taranto Urban Regeneration Integrated Plan (URIP)

The experience of the URIP competition for Taranto, coordinated by Prof. di Venosa (Unich), concerned the design of a green 'belt' around the area between the merchant port and Borgo. The design proposal for the belt was that of a 'resilient and circular green belt', which would be capable of responding in an adaptive or mitigative manner with reference to the two city fronts with which it interfaced (the Borgo and the port). To this end, two strategies were developed simultaneously: one performative (a) and the other proactive (b). The performative

Table 1. Brief comparison of study cases in the existing literature. Source: elaboration by G. Mangano (2022).

Name of project	SMARTmed	Santa Chiara Open Lab	Community Forest District
City	Rome	Trento	Reggio Calabria
District	Via Petralata	Santa Chiara Park	Viale Marconi (south suburbs)
Scale of investigated system	Urban 70.000 m² large scale	Cluster 35000 m² medium scale	Cluster 95.000 m² large scale
Sub-System	Environmental - Economic - Social - Technological	Environmental - Technological - Social - Cultural	Environmental - Technological - Social
Environmental Challenges	Responsible use of land&green areas - Reduction of CO_2 rate & air pollution - Energy Self sufficiency	Responsible use of land & green areas - Mitigation of urban heat stress - Reduction of CO_2 rate & air pollution - Reduction of unsustainable material use	Reducing flooding risks/impacts - Mitigation of urban heat stress - Reduction of CO_2 rate & air pollution - Reduction of unsustainable material use - Improvement in waste management - Responsible use of land & green areas
Carbon Neutral Approaches	Renewable Energy Systems - Emission control - Building retrofitting - Citizens Energy Community	Emission control - Building retrofitting - Community actions - Natural conservation - Renewable Energy Systems	Emission control - Building retrofitting - Community actions - Natural conservation - Waste management - Trasportation planning - RES
Relation with Agenda2030 SDGs	SDG7 - SDG9 - SDG11 - SDG13-SDG17	SDG7 - SDG9 - SDG11 - SDG13 - SDG15-SDG17	SDGs Impact Design - SDG3-SDG6-SDG7-SDG9-SDG10-SDG11-SDG 12-SDG13-SDG14-SDG15

Table 2. Ecosystem services valued for the implementation of SUDS from the economic assessment, according to Johnson & Geisendorf (2019).

	Ecosystem services	Type of benefit	Valuation method
Provisioning	Groundwater recharge	Social	Market price
	Drinking water saved	Private	Market price
Regulating	Runoff reduction		
	Rainwater fee	Private	Market price
	Runoff reduction	Social	Benefit transfer (choice experiments)
	Air quality improvements	Social	Damage cost avoided
	CO_2 storage and sequestration	Social	Damage cost avoided
	Energy savings		
	Heating savings	Private	Market price
	Indoor cooling	Social	Replacement cost
	Externalities of heating	Social	Damage cost avoided
Supporting	Increasing building longevity		
	Roof longevity	Private	Market price
	Façade longevity	Private	Market price
	Habitat creation	Social	Replacement cost
Cultural	Aesthetic improvements		
	Property value (with façade greening)	Private	Benefit transfer (hedonic price)
	Property value (with green roof)	Private	Benefit transfer (hedonic price)

strategy (a) deals with managing the performance of interventions along the green belt according to adaptation or mitigation needs. Specifically, mitigation interventions were identified for the northern part of the belt, were a "filter" between the city's polluting productions and the project area is needed. Adaptation interventions were proposed on the southern part of the green belt, permeability on flood risk areas were needed for the reduction of inconveniences in the event of extreme events. Finally, actions to integrate the two strategic components adaptive and mitigation were also identified. The proactive strategy (b), on the other hand, envisaged the definition of 'circular and resilient' devices to be implemented within the green belt, according to the tactics identified and the system of adaptation and mitigation actions defined (Fig. 2).

To answer to the illustrated strategies, the principles of NbS, SUDS and PEDs were applied (Fig. 3).

4.2 Stress and validation of the assessment methodology on the URIP of Taranto City

See Tables 5–7.

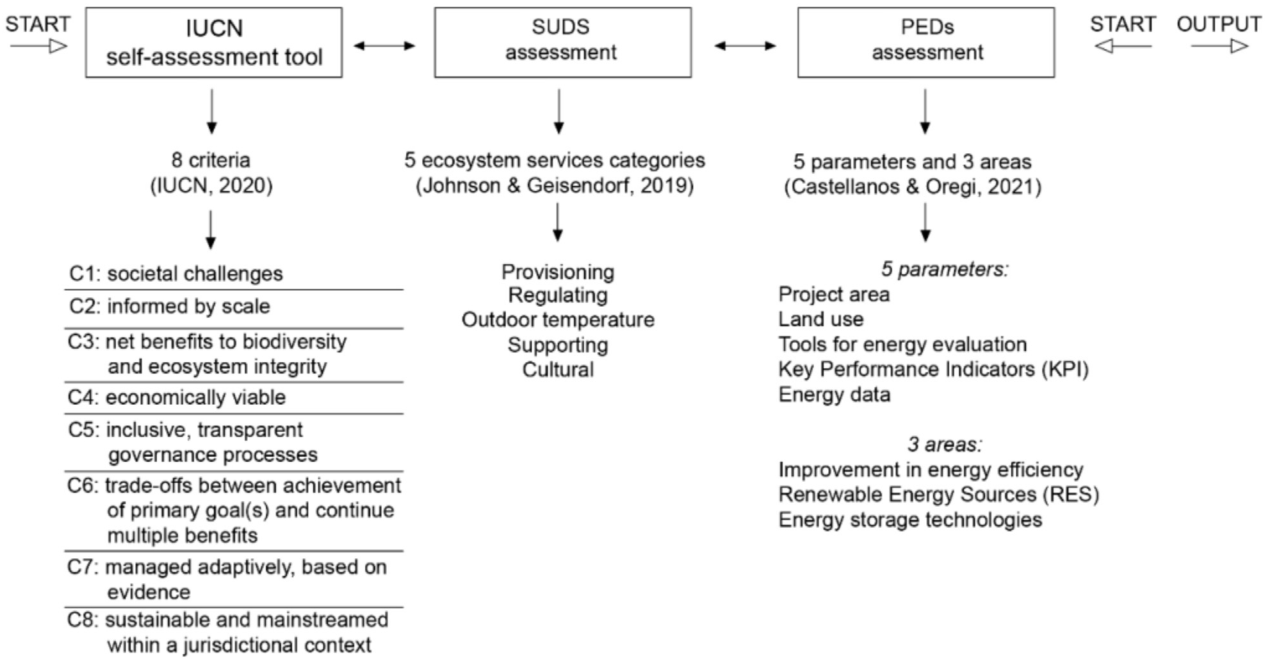

Fig. 1. Methodology workflow. Source: elaboration by A. Leuzzo.

Table 3. Ecosystem services valued for the implementation of Advanced Sustainable Design based on SUDS.

	Ecosystem services	Type of benefit	Valuation parameters	Level of contribution*
Provisioning	Groundwater recharge	Social	n. of connections with the underground systems	
	Water recycle	Private	n. of water recycling systems	
Regulating	Runoff reduction	Social	Increase of water filtration systems (%)	
	Air quality improvements	Social	n. of humid microclimates reduced	* Contribution
	CO_2 storage	Social	Increase in water basins (%)	to climate
	Energy savings	Private	n. of (micro)hydropower systems	neutrality:
Outdoor temp.	Heat islands reduction	Social	increase water basins & permeable surfaces (%)	Very low=1;
Supporting	Longevity	Social	n. of heritage systems targeted	Low=2;
	Roof longevity	Private	n. of roof systems targeted	Moderate=3;
	Façade longevity	Private	n. of infrastructure systems targeted	High = 4;
	Infrastructures longev.	Social	n. of façade systems targeted	Very high=5
	Habitat creation	Social	n. of spaces naturally restored	
Cultural	Aestethic improvements	Social	increase of attractive spaces (%)	
	Social/cultural spaces	Social	increase of space for social/cultural relations (%)	

5 Results and discussion

Basing on the methodology proposed, on the application presented for the elaboration of the scenario of climate neutrality, and on the results obtained, it is possible to build an assessment methodology workflow based on the Advanced Sustainable Design (ASD) Process, the Nature-based Solutions (NbS), Sustainable Urban Drainage Systems (SUDS). Specifically, the evaluation of the methodology, through its application to the Taranto Green Urban Belt has provided positive results that can be summarized as follows: (1) By considering the project area, the land use, and the tools for energy evaluation, we can define the Key Performance Indicators (KPI) and energy data through PED comparison; (2) This approach contributes to the direct increase of the human quality of life and the well-being, by achieving climate neutrality goals for cities, through the integrated model of NbS, SUDS and PEDs; (3) By consolidating the urban contexts, it promotes both the containment of land consumption, the sustainable depletion of natural resources, and the improvement in energy performance for buildings efficiency; (4) In this sense the networks and services for the climate mitigation of open spaces are directly involved in the community forming by configuring a validated strategy in which communities, policymakers and designers can orient any built environment transformation for a sustainable transition.

Table 4. Construction of the assessment workflow component related to PEDs.

	Ecosystem services	Type of benefit	Valuation parameters	Level of contribution*
Provisioning	Energy production	Social/	n. of local PV plants	
		Private	n. of localised devices for electricity production/storage/distribution	* Contribution to climate neutrality: Very low=1; Low=2; Moderate=3; High = 4; Very high=5
		Social	n. of devices for stock of local and renewable energy	
		Social	n. of mini wind turbine plants	
Regulating	Environmental safety	Social	n. of devices for fine dust disposal	
		Social	n. of capturing and filtering devices	
	Urban quality		n. of accessible and safe spaces	
	Runoff reduction	Social	n. of devices for storage, reclamation, reuse of water	
Supporting	Longevity/efficiency	Social	n. of building retrofitting	
	Heat Island Reduction	Social	new permeable soil (mq)	
		Social	Soil change use for new greening (mq)	

Fig. 2. The performative and proactive integrated strategies. Source: ABITAlab elaboration for URIP Taranto Competition (2021), group lead by prof. M.Di Venosa (Unich).

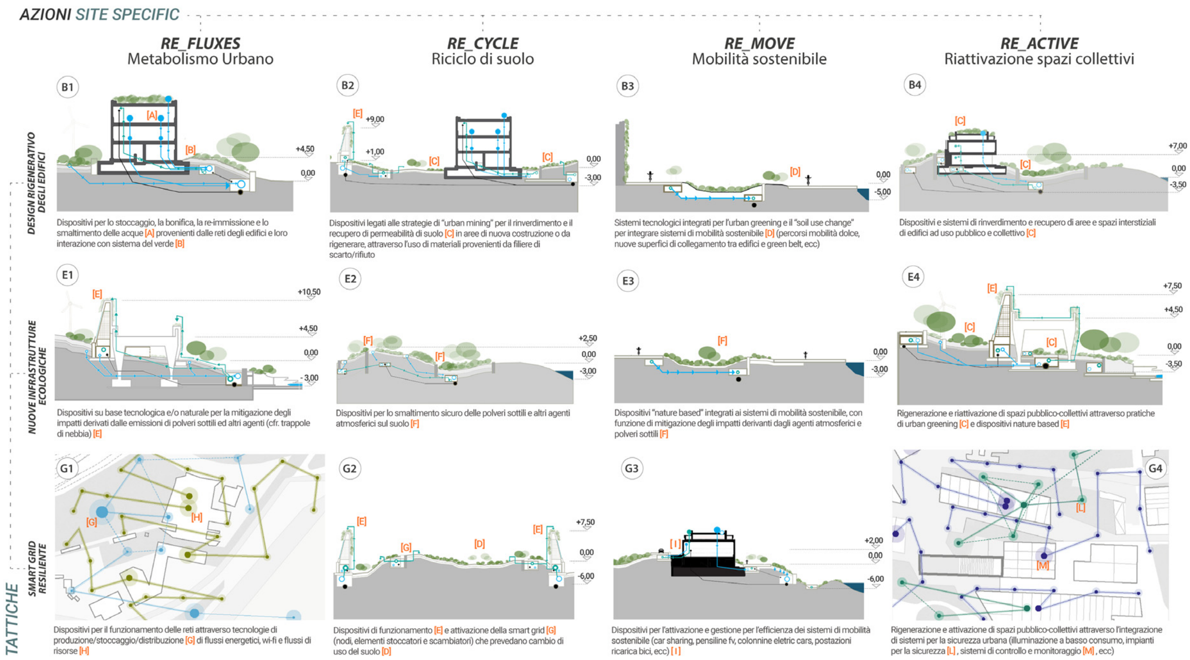

Fig. 3. Matrix of site-specific actions of urban metabolism, soil recycling, sustainable mobility and reactivation of collective spaces. Elaborations: A. Leuzzo, D. Lucanto, G. Mangano for ABITAlab.

Table 5. IUCN criteria defined for Advanced Sustainable Design based on NbS: first assessment results.

Criterion	Your Criterion Score	Maximum Criterion Score	Normalised criterion	FINAL OUTPUT Your Criterion %age
1. Societal challenges	7	9	0,78	78%
2. Design at scale	8	9	0,89	89%
3. Biodiversity net-gain	11	12	0,92	92%
4. Economic feasibility	4	12	0,33	33%
5. Inclusive governance	8	15	0,53	53%
6. Balance trade-offs	7	9	0,78	78%
7. Adaptive management	9	9	1,00	100%
8. Sustainability and mainstreaming	8	9	0,89	89%
Total Percentage match				76%
Is this in adherance with the IUCN Global Standard for NbS?			In adherance	

Key	Output
Strong	Intevention adheres to the IUCN Global Standard for NbS.
Adequate	
Partial	
Insufficient	Intervention does not adhere to the IUCN Global Standard for NbS.

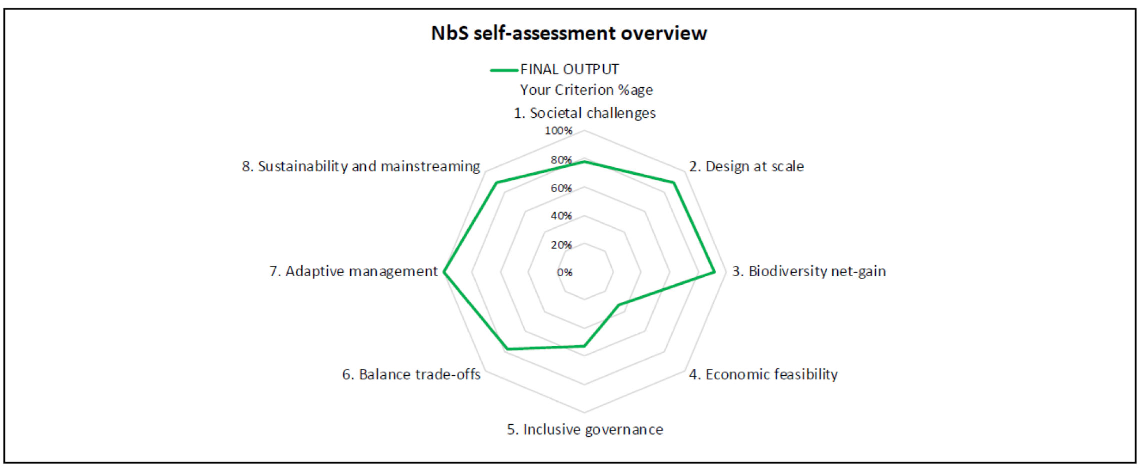

Table 6. Ecosystem services valued for implementation of Adv. Sustainable Design based on SUDS.

	Ecosystem services	Type of benefit	Valuation method	Level of contribution*
Provisioning	Groundwater recharge	Social	n. of connections with the underground systems	5
	Water recycle	Private	n. of water recycling systems	4
Regulating	Runoff reduction	Social	Increase of water filtration systems (%)	3
	Air quality improvements	Social	n. of humid microclimates reduced	5
	CO_2 storage	Social	Increase in water basins (%)	2
	Energy savings	Private	n. of (micro)hydropower systems	-
Outdoor temp.	Heat islands reduction	Social	increase water basins & permeable surfaces (%)	-
Supporting	Longevity	Social	n. of heritage systems targeted	5
	Roof longevity	Private	n. of roof systems targeted	4
	Façade longevity	Private	n. of infrastructure systems targeted	5
	Infrastructures longev.	Social	n. of façade systems targeted	3
	Habitat creation	Social	n. of spaces naturally restored	4
Cultural	Aestethic improvements	Social	increase of attractive spaces (%)	4
	Social/cultural spaces	Social	increase of space for social/cultural relations (%)	5

** Contribution to climate neutrality: Very low = 1; Low = 2; Moderate = 3; High = 4; Very high = 5.*

Table 7. Ecosystem services valued for implementation of Adv. Sustainable Design based on PEDs.

	Ecosystem services	Type of benefit	Valuation parameters	Level of contribution*
Provisioning	Energy production	Social/	n. of local PV plants	4
		Private	n. of localized devices for electricity production/storage/distribution	4
		Social	n. of devices for stock of local and renewable energy	5
		Social	n. of mini wind turbine plants	4
Regulating	Environmental safety	Social	n. of devices for fine dust disposal	5
		Social	n. of capturing and filtering devices	5
	Urban quality		n. of accessible and safe spaces	5
	Runoff reduction	Social	n. of devices for the storage, reclamation, reuse and discharge of water	4
Supporting	Longevity/efficiency	Social	n. of building retrofitting	3
	Heat Island Reduction	Social	new permeable soil (mq)	4
		Social	Soil change use for new greening (mq)	4

** Contribution to climate neutrality: Very low = 1; Low = 2; Moderate = 3; High = 4; Very high = 5.*

6 Conclusions

The methodology proposed is based on research for resilient design applied to positive energy models that require the management of resources and information via green and digital innovations. The experimentation results validate the workflow methodology divided in three different steps and the scientific contribution of the methodology based on the integration of three different assessment methods for the Advanced Sustainable Design. However, the adherence of paradigms and technological considerations in the Advanced Sustainable Design methodology's first validation still needs further integration. For example, further applications for a more specific validation of the methodology can be conducted in order to guarantee the absence of any error in the definition of the valuation parameters, especially for SUDS and PEDs.

7 Implications and influences

The themes of Advanced Sustainable Design and the experimentation of assessment models connected to climate neutrality goals at the urban, neighbourhood and building scale are research trajectories still underway for the dArTe ABITAlab laboratory, on two different levels: (1) research transfer programmes to didactics on the themes of climate and carbon neutrality in the design of the ecological and digital transition (dArTe UniRC thesis workshop, with scient. resp. Prof. Nava); (2) competitive research in which the contributors are engaged, on the topics of Advanced Design for sustainable development goals, through NbS, SUDS and the design of a living lab for the activation of energy self-consumption models with Renewable Energy Communities. Finally, the importance of the experimentation is defined by the relation upon which, since Regenerative Design principles apply to ASD, in the presented assessment methodology, by studying regenerative scenarios, the goal of production of positive environmental and social impacts overcome the concern for the reduction of negative environmental impacts.

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