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VERSO UNA NUOVA ECOLOGIA DELL'ABITARE CONDIVISO
Verde tecnologico e Internet of Nature

TOWARDS A NEW ECOLOGY OF SHARED LIVING
Technological greenery and the Internet of Nature

Oscar Eugenio Bellini, Giuseppe Ruscica, Vittorio Paris

Abstract

La necessità di realizzare architetture ecofriendly spinge sempre più i progettisti all'acritica integrazione del materiale vegetale all'abitare condiviso senza considerare l'importanza del coinvolgimento bottom-up degli utenti. L'abbinamento dei sistemi Internet of Things e della digitalizzazione ai benefici naturalmente prodotti dal verde potrebbe, viceversa, promuoverne una partecipazione consapevole e proattiva, anche dal punto di vista della sua manutenzione e gestione. Richiamando i vantaggi dell'ibridazione fra abitare condiviso e natura, il saggio propone un'articolata tassonomia degli ambiti spaziali inverditi gestibili grazie a un innovativo sistema Internet of Nature sostenendo come, grazie alla vegetazione e alla sensoristica, sia possibile supportare la 'sfida ecologica al cambiamento', promuovere la costruzione di una rinnovata identità sociale e rafforzare il senso di appartenenza.

The need to create eco-friendly architecture is increasingly pushing designers to uncritically integrate greenery into shared living without considering the importance of bottom-up user involvement. The combination of Internet of Things systems and digitalisation with the benefits naturally generated by greenery could, on the contrary, promote conscious and proactive participation, including in terms of its maintenance and management. The present study recalls the advantages of the hybridization between shared living and nature and proposes an articulated taxonomy of the reversed spatial environments that can be managed through an innovative Internet of Nature system, arguing how vegetation and sensors can support the 'ecological challenge for change', promote the construction of a renewed social identity and strengthen a sense of belonging.

Keywords

social housing, verde tecnologico, internet of nature, internet of things, controllo ambientale

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Per rispondere all'innato desiderio dell'uomo di vivere a contatto con la natura, l'architettura residenziale condivisa ha progressivamente integrato al proprio interno il materiale vegetale, passando dal considerarlo un semplice valore estetico o simbolico, al riconoscergli la capacità di produrre vantaggi ambientali, economici e psicologici. La presenza della vegetazione apporta miglioramenti all'abitare in diversi modi: purifica l'aria, mitiga l'effetto isola di calore urbano, migliora la salute fisica e mentale, promuove uno sviluppo sostenibile ecc. (Tab. 1). I benefici prodotti dall'integrazione della vegetazione nello spazio domestico, anche nelle innovative forme di verde tecnologico (Bellini and Daglio, 2015), sono confermati da studi scientifici che mostrano la relazione tra indici di benessere soggettivo e ambiente circostante. Appositi indicatori misurano la soddisfazione di vita o la felicità, a dimostrazione del fatto che esiste una relazione positiva tra benessere personale e presenza della vegetazione (Tsurumi, Imauji and Managi, 2018).

In questi ultimi tempi, le inusuali espressività semantiche e iconografiche del verde tecnologico si sono soprattutto trasformate in un tangibile manifesto di adesione ai principi della sostenibilità ambientale (Roger, 2002). Tale processo è stato favorito dalla presenza sul mercato di sistemi e prodotti a diversi livelli di costo e a complessità variabile di applicazione, a dimostrazione di un fenomeno niente affatto effimero o transitorio (Perini, 2012). L'inverdimento nella residenza condivisa ha pertanto consolidato una fenomenologia espressiva complessa e articolata (Bellini and Daglio, 2015), utile a qualificare i differenti livelli dell'abitare e promuovere specifiche soluzioni morfo-tecno-tipologiche, più che mai richieste dal mercato immobiliare post pandemico (Fig. 1).

Mentre la letteratura scientifica persevera nell'indagare e comprendere le prestazioni che l'elemento vegetale produce a scala urbana e del singolo manufatto, non altrettanto sta avvenendo rispetto alle possibili forme di coinvolgimento e sua presa in carico, in termini gestionali e manutentivi, da parte dell'utenza. Un utile avanzamento potrebbe arrivare dall'integrare il materiale vegetale ai sistemi Internet of Things (IoT) e alle tecnologie digitali, le quali potrebbero concorrere, tramite sensori, attivatori, intelligenza artificiale e reattori fotobiotici a definire innovativi rapporti cibernetici fra naturale e artificiale e fra utenti e vegetazione; un avanzamento che contribuirebbe a produrre maggiore consapevolezza ambientale, a promuovere i principi della sostenibilità e a condividere i vantaggi dell'economia circolare e della transizione ecologica, rimettendo al centro la persona e il suo non sempre facile rapporto con l'ambiente.

Nell'ambito della dimensione ecologica del progetto di architettura, coniugare, a scala domestica, le potenzialità del digitale, in abbinamento ai sistemi di inverdimento, oltre che ricomporre la dicotomia tra ambiente naturale e artificiale, promuove l'opportunità di perseguire e sostenere i temi della biodiversità. Portare la natura online diventa la vera sfida nella gestione degli ecosistemi urbani poiché il verde può realmente migliorare il nostro rapporto con il mondo naturale, aiutare a pianificare la gestione condivisa di città sempre più verdi e intelligenti e, soprattutto, promuovere la transizione da Internet of Things (IoT) a Internet of Nature (IoN).

Tecnologizzare il verde: da IoT a IoN | Gli avanzamenti tecnologici proposti dal digitale, IoT outdoor, deep learning, su minuscoli dispositivi informatici applicati alla vegetazione, consentono di passare dalla semplice messa in opera del verde all'attivazione di forme dirette di controllo dell'habitat in termini di Smart Urban Nature. Tramite dispositivi tecnologicamente sempre più intuitivi è oggi possibile prefigurare nuove visioni, che possano prevedere il diretto coinvolgimento dei residenti nella presa in carico e gestione dell'ambiente urbano, nella tutela fisica e salute ecologica della propria residenza e nella promozione della biodiversità ambientale.

La profusione di dispositivi embedded a bassissimo consumo e a costo contenuto consente la rapida automazione e controllo anche sul processo di crescita e mantenimento della vegetazione. Supporti che forniscono la possibilità di raccogliere un'enorme quantità di dati ambientali, per alimentare algoritmi di apprendimento automatico, così da creare le condizioni ideali per la crescita colturale e anche di quella edibile. La visione artificiale e il cloud computing permettono inoltre l'analisi di migliaia di immagini per identificare variazioni di dimensioni, larghezza, colore, curvatura dei vegetali, verificando in tempo reale la tenuta delle colture da qualsiasi potenziale perdita di resa o minaccia.

L'applicazione IoT agli spazi inverditi domestici consente di tracciare uccelli, monitorare gli alberi (Treemania[1]), contare le api (ApisProtect[2]) e persino ascoltare i pipistrelli (Shazam for Bats[3]). In questi casi ci si può avvalere di appositi dispositivi governati da quello che nel mondo del digitale viene definito, come una nuova soglia: Internet of Nature (IoN). IoN permette di monitorare, in modo innovativo, gli spazi verdi e di promuovere opportunità inusuali per comprendere, in chiave ecologica, il ruolo della natura sulle attività della città densamente abitata (Galle, Nitoslawski and Pilla, 2019; Fig. 2). Verde e IoN collaborano nell'identificare e misurare gli inquinanti indoor e outdoor dello spazio domestico, tant'è che i primi modelli monitoravano particelle sottili (PM), monossido di carbonio, anidride carbonica, benzene e composti dell'azoto, in aggiunta a temperatura e umidità ambientale. Fra le prime applicazioni sul monitoraggio della qualità dell'aria si possono ricordare quelle che hanno coinvolto alcuni sobborghi di Londra (Ma et alii, 2008); tali esperimenti hanno dimostrato come l'inquinamento dipenda dalla dislocazione urbana di alcuni servizi (scuole), in relazione al loro orario di apertura cambiava drasticamente il livello di inquinamento dovuto al traffico veicolare.

Oggi esistono sensori che monitorano in modo affidabile gli indicatori ambientali, anche se fissi (Karagulian et alii, 2019), a integrazione delle informazioni provenienti dalle stazioni ufficiali di monitoraggio a riscontro certo della effettiva qualità ambientale dello spazio urbano. Sulla raccolta e gestione domestica dei dati, tramite la partecipazione diretta della cittadinanza, si è ultimamente assistito a una eterogeneità di approcci, prevalentemente di tipo 'dinamico'. Si possono segnalare diversi progetti: SwarmBike (Corno et alii, 2017) ha proposto di sperimentare sensori su biciclette e bike-sharing, UrVAMM (Rionda et alii, 2013) e Sense Square (Lotrecchiano et alii, 2019) hanno esplorato le potenzialità di questi dispositivi sui mezzi di trasporto urbani, per mappare contestualmente più zone della città.

L'Unione Europea ha finanziato numerose sperimentazioni e ricerche, con l'intento di interconnettere sostenibilità ambientale e Smart City, tra queste: AirSense (Dutta et alii, 2017), CITI-SENSE (Schneider et alii, 2018) e Citi-Sense-MOB (Castell et alii, 2015). Ad oggi, nessuno di questi progetti ha seriamente preso in considerazione l'opportunità e l'utilità di integrare il digitale alla vegetazione direttamente applicata allo spazio domestico. Rispetto alle questioni ambientali, la complessità del territorio, non solo come spazio fisico, ma anche come infrastruttura digitale interconnessa, richiede, oggi un approccio prevalentemente olistico, che tenga contestualmente in considerazione la pluralità dei livelli di riferimento, la condivisione delle informazioni da acquisire e la molteplicità degli attori coinvolti. Per questo è necessaria la promozione di legami fluidi e relazioni mutevoli, che massimizzino l'allargamento della platea dei soggetti coinvolti, e coinvolgibili, sui temi dell'ambiente.

La recente pandemia ha mutato il nostro rapporto con la tecnologia, sempre più presente anche nell'ambiente domestico, stimolando l'attenzione alla qualità dell'ambiente che abitiamo e le ripercussioni che si possono avere sulla salute umana. Per questa ragione, se da un lato emergono studi che provano a mettere in relazione la qualità dell'aria outdoor e indoor con i problemi di salute (Jaimini et alii, 2017), dall'altro si deve cercar di comprendere come la presenza di vegetazione all'interno e all'esterno delle unità abitative non solo produca reali benefici (Han and Ruan, 2020) ma attivi processi educativi su questi aspetti. La distanza da colmare, soprattutto nelle forme dell'abitare condiviso, rimane quella del coinvolgimento proattivo nella comunità. Troppe volte il ricorso all'integrazione domestica dell'elemento vegetale viene celebrato dai progettisti in termini 'verdolatrici', sconfinando nel greenwashing, arrivando a proporre, come è stato per l'intervento Qiyi City Forest Garden, a Cheengdu, in Cina (Fig. 3), della vegetazione inappropriata e non gestita correttamente, che ha reso inabitabili decine di alloggi, a causa dell'invasione di zanzare e altri insetti.

La comprensione di come il comportamento degli abitanti nell'abitare possa incidere sul perseguimento degli obiettivi ambientali, è mutuabile dai modelli sociali assunti nell'ambito del risparmio energetico, che può fare da riferimento per l'attivazione di una nuova ecologia dell'abitare, anche attraverso l'impiego della vegetazione (Gupta and Kapsali, 2016; Aljer et alii, 2017). Approcci che vanno nella direzione della Citizen Science, ovvero del coinvolgimento dei cittadini su base scientifica, in modo che possano verificare direttamente, acquisendone consapevolezza, i meccanismi di causa ed effetto che portano alla modificazione dell'ambiente e al potenziale peggioramento della qualità della vita.

Un impulso 'social' potrebbe arrivare, a livello di edificio, da soluzioni come quelle proposte dal progetto Wiseair[4] che, a partire dall'intuizione di un gruppo di universitari, ha brevettato il

BENEFITS OF GREENING IN SOCIAL HOUSING		
1	Solar shading	Thanks to the foliage, plants can provide shading to the buildings, protecting them from direct solar radiation, thus managing to create a homogeneous microclimatic interaction between vegetation and building surfaces. This mechanism modifies the energy performance of buildings, so as to favour energy saving (Perez et alii, 2014). Many experiments on vertical vegetation systems have shown that the shading coefficient has a linear correlation with the leaf area index (Wong et alii, 2009). Shading can have different effects depending on the season: during the summer, the vegetation, adequately integrated into the building façades, can act as screens to filter solar radiation (Ip, Lam and Miller, 2010). If evergreen plants are used for vertical forest systems, they can positively influence the energy consumption of the building by covering the system both during heating and cooling times. On the other hand deciduous plants, during winter, can have a minor effect on the microclimate between building surfaces and plants. During the summer months, vertical vegetation systems would have the dual effect of reducing the solar energy entering the building and reducing the heat flow (Wong et alii, 2010). With a correct design and selection of the vegetation, the energy performance of shared housing, especially with vertical development, can be improved (Marugg, 2018)
2	Thermal insulation	In vertical vegetation systems, the use of climbing plants and other species has shown to improve the thermal performance of façades during summer (Susorova, Azimi and Stephens, 2014). With vegetation evapotranspiration, it is understood that the external temperature of facade with vertical vegetation systems decreases in the range of 3.7-11.3, by increasing the percentage of plant foliage in the system between 13 and 54% (Besir and Cuce, 2018). Reductions in external temperatures of façades were considerable in warm climates, ranging from 12 to 20.8 ºC during summer and from 5 to 16 ºC during autumn (Pérez et alii, 2014). Other studies have revealed that green walls with an approximately 10 cm thick 'Hedera helix', in sunny conditions and temperate climates such as the UK, lead to an average reduction of 2.5 ºC of internal wall temperature (Cuce, 2017). In Hong Kong, some experiments have revealed that a vertical green wall can save up to 16% of electricity consumption for summer air conditioning, with daily temperatures ranging between 25-30 °C (Pan and Chu 2016). In tropical climates, a reduction in façades temperature by more than 11 ºC can be recorded (Wong et alii, 2010). In Mediterranean latitudes, with a temperate climate, the energetic behaviour of the building, during sunny days, produces temperature differences between the bare wall and the covered wall ranging from 12 to 20 ºC (Mazzali et alii, 2013). It should be noted that while it is possible to quantify the parametrization of leaf movement (Herrero-Huerta, Lindenbergh and Gard, 2018), the thermal benefits of vertical forest systems remain dependent on the intensity of vegetation, orientation, microclimatic conditions between wall surfaces and vegetation
3	Other environmental	Greening systems can influence the acoustic performance of buildings (Wong et alii, 2010) and improve air quality, by purifying it thanks to chlorophyll photosynthesis (Dunnett and Kingsbury 2008; Perini et alii, 2013) and filtering fine particles (Perini et alii, 2017). The improvement in air quality due to vegetation is related to the absorption of fine particles and of gaseous pollutants (Perini et alii, 2013). Technological greenery makes it possible to recreate biodiversity, especially in dense urban areas, by regenerating the habitats for native wild flora and fauna (Perini et alii, 2013), even if the biodiversity at high altitudes is not always adequate compared to that on the ground, considering the lower available soil and the different conditions of temperature, wind, etc. (Tian and Jim, 2011)
4	Social	It is known that people are likely to suffer from a range of medical and mental health problems if they live in areas with no green spaces. By providing a more comfortable living and working environment, it has also been shown that visual and physical contact with plants can lead to health benefits. Plants can have restorative effects that can decrease stress levels and improve work productivity (Sheweka and Magdy, 2011). Trees that grow on balconies can act as a wind barrier and create a more comfortable environment for human well-being
5	Economic	Greening systems, applied to residential buildings, can also produce important benefits from an economic point of view, especially in terms of management costs, since they optimize energy performance during the months in which heating or cooling is necessary. This eventhough energy losses are caused by other factors such as age and type of building, climate, materials of the envelope and behaviour of the occupants. It has been shown that through a vertical greening system, in humid and cold climates, it is possible to achieve energy savings of 18% (Xing et alii, 2019), as in the Hong Kong example

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Tab. 1 | The benefits of greening in social housing according to the scientific literature (credit: O. E. Bellini, 2022).

Fig. 1 | Possible ways of applying vegetation to social housing (credit: O. E. Bellini, 2022).

vaso da balcone Arianna, contenitore per piante dotato di sensori che, non solo rileva alcuni inquinanti atmosferici, ma può fare da base per attivare una comunità digitale sensibile. A scala urbana, il progetto imprenditoriale Airly, di più ampia portata, ha richiesto il coinvolgimento di alcune Amministrazioni pubbliche promuovendo l'utilizzo di una rete di sensori interconnessi così da acquisire dati ambientali e pianificare possibili contromosse (Bielecki and Kaźmierczak, 2018). In questo progetto i dati sulla qualità dell'aria vengono resi visibili tramite un portale web, per cui una serie di sensori diventano parte attiva di un sistema urbano complesso creando un 'tutto' interconnesso, una Smart City, che affronta, in termini adattivi, le sfide ecologiche del futuro.

In questo contesto si inserisce la cosiddetta infrastruttura Smart Urban Garden, che fa uso del digitale in abbinamento alla vegetazione, in modo da condividere, tramite una piattaforma, una pluralità di dati e informazioni. Questo supporto informatico si avvale del Beacon Sensitive Walk, un piccolo radiotrasmettitore Bluetooth interconnesso con specifici ambiti inverditi, attivabile su smartphone o tablet, che restituisce i contenuti sulla biodiversità e sullo stato di salute del materiale vegetale, e del suo immediato intorno. Questi sensori, facilmente applicabili all'organismo edilizio, permettono il monitoraggio, in tempo reale, delle azioni che la vegetazione produce sulla qualità dell'aria urbana, monitorano i flussi di visitatori e controllano gli accessi sui connettivi di distribuzione della residenza, facilitano i processi cooperativi e collaborativi tra i soggetti coinvolti nella cura del verde, studiano lo stato della biodiversità, monitorano specie animali e vegetali. Queste informazioni vengono interpolate con le condizioni atmosferiche e restituiscono informazioni sullo stato di salute delle colture; i dati raccolti possono inoltre essere elaborati, archiviati e riutilizzati.

Sistemi di identificazione a radiofrequenza (RFID) sono stati proposti, a scala urbana, in ottica IoN, per la gestione e protezione degli alberi (Luvisi and Lorenzini, 2014). Contemporaneamente, impianti intelligenti, integrati e connessi all'infrastruttura delle Smart City, sono a tutt'oggi impiegati in Germania (Gimpel et alii, 2021). Il

Fig. 2 | Smart Urban Nature: My NatureWatch camera; Interior of EchoBox showing Intel Edison and Ultrasonic Microphone; EchoBox in Queen Elizabeth Olympic Park by Natures Smart Cities; Arianna, the smart vase that detects air pollution (credit: Nature Smart Cities, 2021).

Fig. 3 | Photos taken with a drone show an aerial view of the Qiyi City Forest Garden residential buildings complex in Chengdu, China, without any tenants to care for them, the eight towers have been overrun by their plants – and invaded by mosquitoes (credit: EPA, 2020).

coinvolgimento diretto della cittadinanza è stato promosso per sistemi automatici di coltivazione aeroponica basati su dispositivi IoT (Kerns and Lee, 2017). Sul tema della coltivazione in giardini verticali, molteplici implementazioni e sperimentazioni sono state documentate in Halgamuge et alii (2021). Questi studi attestano, fra le altre cose, come l'impiego dei sistemi digitali sia oramai collaudato e pronto per coinvolgere l'utenza domestica dell'abitare condiviso.

Inverdimento e sensoristica digitale: configurazioni e fruibilità | L'integrazione fra vegetazione e sensoristica digitale può avvenire negli spazi orizzontali o verticali e negli interni o esterni domestici (Tab. 2). L'eterogeneità delle applicazioni, la diversità dei costi di realizzazione, nonché le articolate modalità manutentive possono essere ricondotte a due macrosistemi: verde tecnologico orizzontale e verticale. Il primo include tetti verdi e foreste sopraelevate (Fig. 4), il secondo facciate verdi, pareti verdi e boschi verticali (Bartesaghi, Osmond and Peters, 2017; Fig. 5). La decodifica degli aspetti figurativi dell'applicazione della vegetazione, riferita al dato percettivo e geometrico/formale, può essere ricondotta a: punto, linea, superficie e volume (Fig. 6). Il verde può essere considerato in relazione alla sua effettiva accessibilità e/o praticabilità e in ragione degli ambiti spaziali di applicazione nella residenza (Figg. 7, 8).

Rispetto all'integrazione fra IoT e vegetazione è necessaria una definizione più articolata, basata sulle classi di unità tecnologiche dell'organismo edilizio, con riferimento alla classe esigenziale della fruibilità (Norma UNI 8289:1991). Questo dato consente l'interpretazione fenomenologica di questa integrazione, definendo il livello di gestione diretta di questi dispositivi: una tassonomia che restituisce l'articolazione dei diversi livelli di accessibilità fisica e spaziale dell'elemento verde, dei sistemi IoT e della relativa unità tecnologica (Tabb. 3-5). Nell'abitare condiviso il rapporto di fruibilità della vegetazione e degli apparati sensoristici è riconducibile a tre gradi o livelli di spazio: privato (soggiorni, camere, ingressi privati ecc.), semi privato (balconi, terrazze, logge, bow-window ecc.), semipubblico (connettivi verticali e orizzontali, spazi comuni ecc.).

A) Fruibilità nello spazio privato – L'elemento vegetale viene introdotto direttamente dall'utente nello spazio domestico in relazione ai benefici che il materiale vegetale arreca e al fatto che la vegetazione produce organismi che fanno bene al nostro corpo in termini terapeutici. Le essenze più usuali sono le 'piante da appartamento' (Hessayon, 2014) e le erbe aromatiche che creano orti indoor domestici. Il bisogno di riscoprire all'interno degli alloggi il contatto con la vegetazione ha promosso il Natural Design, una tendenza avanzata del Green Design, che concorre a diffondere i principi della sostenibilità con oggetti e arredi che integrano la vegetazione (Corrado, Ferrari and Crea, 2013). Le manifestazioni più evidenti sono gli eco-wall o living wall, pannelli modulari a parete, con cui realizzare, negli interni, superfici inverdite o giardini verticali. Questi sistemi arricchiscono la figurazione spaziale, ambientale e biologica degli spazi abitati confinati, generando inusuali paesaggi verdi (Blanc, 2005), che se integrati da sensori, possono monitorare direttamente le condizioni di benessere ambientale e confort dello spazio privato.

B) Fruibilità nello spazio semi privato – La recente pandemia ha evidenziato come nell'abitare condiviso, spesso non siano presenti adeguati spazi aperti in quota, quali surrogati del giardino privato. Le manifestazioni più dirette di questo tipo di spazio sono i balconi, le logge e i patii. In questi ambiti si marca il passaggio di stato tra esterno e interno (e viceversa), cioé il momento in cui lo spazio si coniuga con le istanze dell'urbanità (Kuntscher and Wietzorrek, 2010), defi-

TECHNOLOGICAL GREENING SYSTEMS			
Horizontal greening system	Green roofs and roof gardens have historically been the first forms of integration of vegetation into the built environment. These are the vegetated surfaces endowed with a substrate of organic material. Green roofs are divided into intensive, semi-intensive and extensive, according to the depth of the substrate (which feeds the vegetation) and use of the roof. In highly urbanized areas, they provide different ecosystem services: improved stormwater management, increased regulation of building temperatures, increased sound insulation (Dunnett and Kingsbury, 2008), heat island control (Besir and Cuce, 2018), restoration biodiversity (Oberndorfer et alii, 2007). These environmental benefits are accompanied by limited costs, relative lightness and easy applicability. A recent form of horizontal vegetation is high-altitude forest, trees that grow in sheltered horizontal spaces	Intensive green	
		Semi-intensive green	
		Extensive green	
Vertical greening system	These systems make it possible to place vegetation on the facades of buildings (Pérez-Urrestarazu et alii, 2015). They are called vertical gardens, green walls, vertical green or Green Skyrise (Timur and Karaca, 2013). The system for verticalising the vegetation consists of four components: vegetation, substrate, containers and support systems, which also integrate the irrigation systems. In relation to the growth modes of the plant component, there are: green façades, green walls, green terraces and vertical woods (Marugg, 2018)	Green façade	The vegetation is rooted in the ground and uses the walls as a support for vertical growth (traditional direct systems) or, the facade of the building becomes the mechanical support of independent systems, such as pylons, wires, cables or networks – indirect double skin (Fernández-Cañero et alii, 2018)
		Green wall	Greening system achievable through the use of geotextile, pots, panels, boxes or modular nets. In this case, it is possible to plant previously cultivated vegetation that are subsequently suspended and fixed to the building (Bartesaghi Koc, Osmond and Peters, 2017). Green walls require more complex methods of installation and involve higher installation and maintenance costs, compared to simple green façades (Bellini and Daglio, 2009)
		Green terrace	Open surfaces, placed at a height, on the perimeter of the façade and at the different levels of inhabited floor. These surfaces are completed with shrub vegetation that grows in the open air
		Vertical forest engineering	High-altitude engineered forests, which are a relatively new field for architects, botanists and structural engineers. They require more in-depth studies regarding plant and tree species, nutritional and growth conditions (e.g. root system development in limited soil space, sunlight, prevailing winds, neighbouring façades). In these cases, the engineering aspects necessary for the control of horizontal loads (wind, earthquakes, etc.) and the stability of the trees over time must also be taken into account

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Tab. 2 | The most common greening systems: Horizontal systems and vertical systems (credit: O. E. Bellini, 2022).

Fig. 4 | Examples of horizontal greenery systems: Bjarke Ingels Group, House 8, Denmark, 2010; Agence Engasser + Associés, 104 logements à Ivry-sur-Seine, France, 2017 (credits: J. Lanoo, 2010; M. Denancé and M. Ducros, 2017).

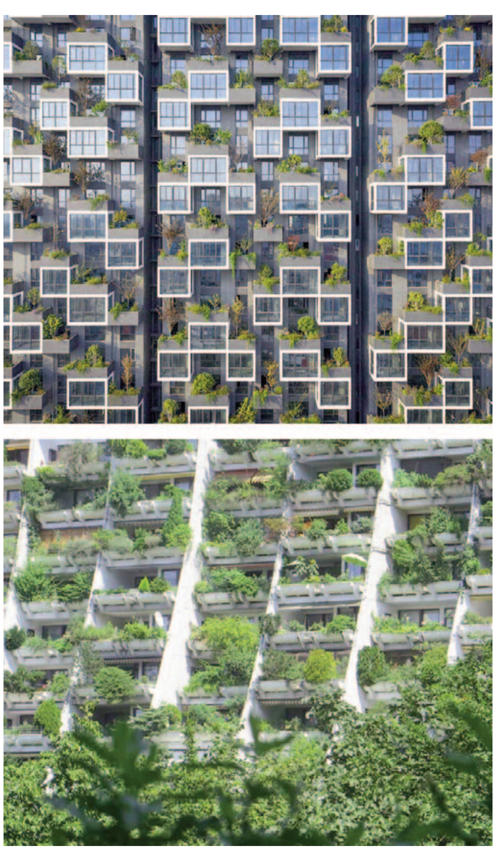


Fig. 5 | Examples of vertical greenery systems: Stefano Boeri Architetti, Easyhome Huanggang Vertical Forest, China, 2021; Harry Glück and Partners, Wohnpark Alterlaa, Austria, 1976 (credits: RAW VISION studio, 2021; H. Glück, 1976).

nendo la situazione ideale per promuovere l'integrazione fra vegetazione e digitale, in un rapporto intimo e diretto tra interno domestico, vegetazione outdoor e ambiente urbano. Questi spazi, spesso considerati, luoghi aggiuntivi, superflui, privi di utilità, sono tornati a essere ambiti indispensabili per il benessere abitativo.

C) Fruibilità nello spazio semipubblico – La dimensione spaziale che connota più di altre la residenza sociale e la dimensione condivisa dell'abitare è quella semi pubblica, che si identifica nei ballatoi, corridoi di distribuzione, pianerottoli, scale ecc., luoghi che raccordano e interconnettono dimensione domestica e collettiva. Gli spazi semipubblici, oltre alla funzione distributiva, definiscono i luoghi delle relazioni fra individuo e gruppo di vicinato, valorizzano l'incontro, la condivisione, il confronto e la cooperazione. L'inverdimento di questi spazi, oltre che riscattarne l'aspetto anonimo e di servizio, li trasforma in luoghi connotati e denotati: ambiti piacevoli e gradevoli di cui, tutti insieme, farsi carico in termini gestionali e manutentivi, perché vi si promuovono relazioni sociali, senso di comunità e di appartenenza.

Considerazioni finali | L'integrazione della sensoristica alla vegetazione può contribuire a delineare i contorni di una nuova dimensione del progetto di architettura per l'abitare condiviso, quale ambito di connessioni multiple e interagenti in grado di risolvere criticamente la dicotomia fra naturale e artificiale. L'abitare con gli altri prospetta sicuramente un contesto promettente di sperimentazione, dove i sistemi tecnologizzati per l'inverdimento possono svolgere un ruolo ecologico importante, anche in termini di coinvolgimento educativo dell'utenza, così da promuovere la consapevolezza e integrazione del ruolo dei cicli biologici, in maniera analoga a quella degli ecosistemi naturali, rendendoli più efficienti e sostenibili.

Le tecnologie digitali stanno modificando, con modalità sempre più pervasive, la comprensione della realtà e i modi di abitare, generando inusuali approcci cognitivi e interpretativi. Il nostro habitat, con la sua straordinaria ricchezza di informazioni, ha sempre meno bisogno di supporti materiali ed è sempre meno analogico. I sistemi IoN offrono inedite e innumerevoli opportunità di sperimentazione per pianificare strategie e soluzioni innovative e per dare risposte concrete alla crescente complessità di un fare architettura fortemente condizionata da crisi e minacce ecologiche senza precedenti.

Il mondo digitale può generare una svolta epistemologica segnando la transizione da una conoscenza manipolatrice della realtà, fondata su logiche deterministiche e riduzioniste, a una 'conoscenza complessa' (Morin, 1993). Una dimensione nella quale l'accrescimento delle relazioni tra saperi, discipline, utenti e attori, anche afferenti a mondi differenti, diventa strategica, per giungere alla comprensione dei fenomeni generativi basilari, non solamente per coglierne la complessità, ma per trasferirne le logiche in processi che sappiano rapportarsi in modo sistemico e adattivo all'ambiente in cui si inseriscono.

Integrare mondo vegetale e mondo digitale prefigura anche uno 'spostamento scalare' delle molteplici discipline che afferiscono al progetto di architettura, quali componenti di un sistema unificato, chiamato a dare risposte non solo all'essere umano ma anche alle altre forme viventi, in un rapporto di profonda conoscenza e comprensione delle rispettive necessità e traiettorie. La relazione tra le differenti componenti dell'ecosistema abitativo assume un'importanza nevralgica quando adottiamo una visione più ampia e sistemica, supportata da un approccio olistico e partecipativo; in questo caso la tecnologia digitale promuove una 'cyber ecology', basata su una 'doppia convergenza', che consente di interpretare mondo naturale e artificiale come un tutt'uno (Ratti and Belleri, 2020).

Molte delle nostre città stanno diventando sempre più digitali (dalle auto che si guidano da sole alle reti intelligenti e ai segnali stradali reattivi): vere e proprie Smart City che mettono i dati e la tecnologia digitale al centro per promuovere l'efficienza e migliorare la qualità della vita delle persone. La natura online è sicuramente la prossima tappa nei processi per la gestione degli ecosistemi evoluti: ciò cambierà il nostro modo di rapportarci con il mondo naturale all'interno dello spazio urbano. L'introduzione dei sistemi IoT può aiutare a colmare il divario tra città più verdi, più intelligenti e la gestione degli ecosistemi urbani. Avvalersi di IoN significa promuovere l'autosufficienza e la resilienza nella gestione di questi ecosistemi, così da migliorare le connessioni fra dimensione urbana, sociale ed ecologica (Fig. 9).

L'integrazione fra naturale e digitale prelude a un avanzamento culturale e ideologico nel controllo e gestione delle informazioni legate all'ambiente secondo una nuova prospettiva: la Smart Nature City. Una nuova ecologia che, soprattutto nelle giovani generazioni, incoraggia sensibilità e modelli di vita ambientalmente virtuosi, a partire dalla definizione di forme innovative per stare insieme, socializzare, condividere, incontrarsi. Un'interazione che potenzialmente supporta possibili nuove microeconomie domestiche e favorisce il coinvolgimento degli utenti nella cura e manutenzione degli ambiti semi pubblici della residenza, a sostegno di forme di integrazione sociale, confronti intergenerazionali e multietnici e momenti di crescita civica e culturale. Nell'abitare inverdito si innescano e agiscono processi virtuosi di partecipazione, identificazione e senso di appartenenza, momenti che attivano sensibilizzazioni verso le tematiche dell'ecologia in ottica di Citizen Science, incoraggiando un approccio al bene casa, anche in termini di sharing economy. La casa diventa così risorsa durevole più strumentale che simbolica, con l'effetto di portare le giovani generazioni a interessarsi molto di più verso l'uso ecologico di tale bene, piuttosto che a detenerne il possesso.

In response to man's innate desire to live in contact with nature, social housing architecture has gradually incorporated vegetation, previously considered a mere aesthetic or symbolic value, and now recognized as capable of producing environmental, economic and psychological benefits. The presence of vegetation improves living in various ways: it purifies the air, mitigates the urban heat island effect, improves physical and mental health, promotes sustainable development, etc. (Tab. 1). The benefits of integrating vegetation into the domestic space, particularly with innovative forms of technological greenery (Bellini and Daglio, 2015), are confirmed by scientific studies that demonstrate the relationship between indices of subjective wellbeing and the surrounding environment. Appropriate indicators measure life satisfaction or happiness, revealing a positive correlation between personal well-being and the presence of vegetation (Tsurumi, Imauji and Managi, 2018).

In recent times, the unusual semantic and iconographic expressions of technological greenery have, above all, become a tangible manifesto in support of the principles of environmental sustainability (Roger, 2002). The market presence of systems and products with varying cost levels and application complexity has favoured this process, demonstrating a phenomenon that is by no means ephemeral or transitory (Perini, 2012). Therefore, greening in shared living spaces has consolidated a complex and articulated expressive phenomenology (Bellini and Daglio, 2015), which is useful to classify different levels of living and promote specific morpho-techno-typal solutions, more than ever required by the post-pandemic housing market (Fig. 1).

While scientific literature persists in investigating and understanding the performance of the green element both at the urban scale and within individual buildings, the same cannot be said regarding the possible forms of user involvement and responsibility in terms of management and maintenance. Useful progress could come from integrating plant material with Internet of Things (IoT) systems and digital technologies, which could contribute, for example, through sensors, activators, artificial intelligence and photobiotic reactors to define innovative cybernetic relationships between natural and artificial as well as between users and vegetation. This advancement would help produce greater environmental awareness, promote the principles of sustainability and share the benefits of the circular economy and ecological transition, focusing on the individual and the sometimes-challenging relationship with the environment.

As part of the ecological dimension of architectural design, combining the potential of digital technology with greening systems on a domestic scale not only recomposes the dichotomy between the natural and artificial environment but also promotes the opportunity to pursue and support biodiversity issues. Bringing nature online becomes the real challenge in managing urban ecosystems. Greenery can genuinely improve our relationship with the natural world, help plan the shared management of increasingly green and smart cities and, above all, promote the transition from the Internet of Things (IoT) to the Internet of Nature (IoN).

Technology for Greenery: from IoT to IoN | Technological advances proposed by digital systems, outdoor IoT and deep learning, on tiny computer devices applied to vegetation, support the transition from the simple implementation of green areas to the activation of direct forms of habitat control in terms of Smart Urban Nature. Through increasingly intuitive technological devices, it is now possible to envisage new scenarios, which foresee the direct involvement of residents in

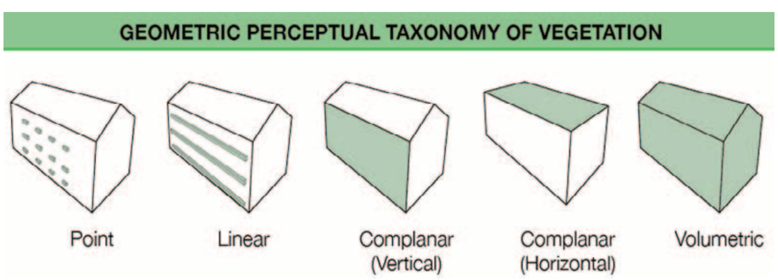


Fig. 6 | Geometric perceptual taxonomy of vegetation applied to social housing (credit: O. E. Bellini, 2022).

Fig. 7 | Easyhome Huanggang Vertical Forest City Complex in Huanggang (China) designed by Stefano Boeri Architetti, 2021 (credits: RAW VISION studio); Ciel Rouge, 131 Logements Sociaux Et Une Crèche Collective, Paris (France), 2014 (credits: Ciel Rouge); Orgues De Flandre in Paris (France) designed by Martin Van Trek, 1980 (credits: Lorenzo Zandri); Le Ray in Nice (France) designed by Maison Edouard François, 2021 (credits: Stéphane Aboudaram | We Are Contents)

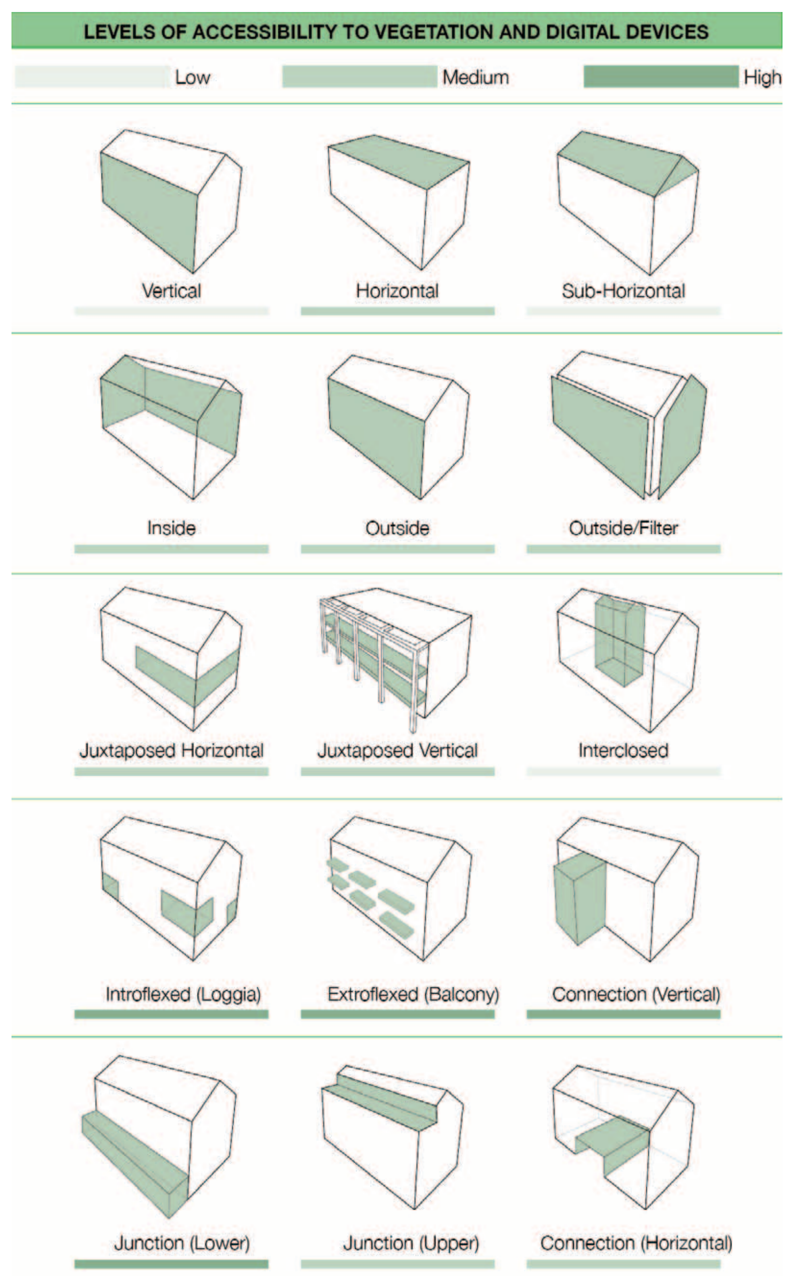
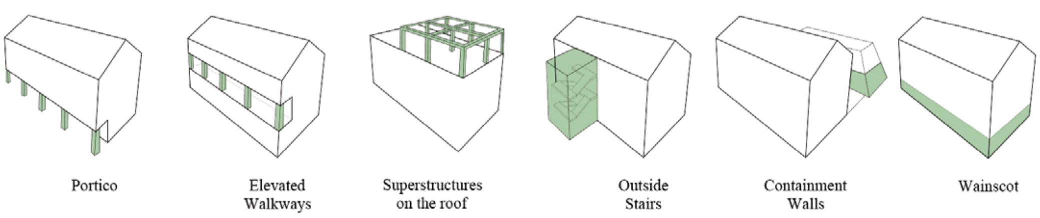


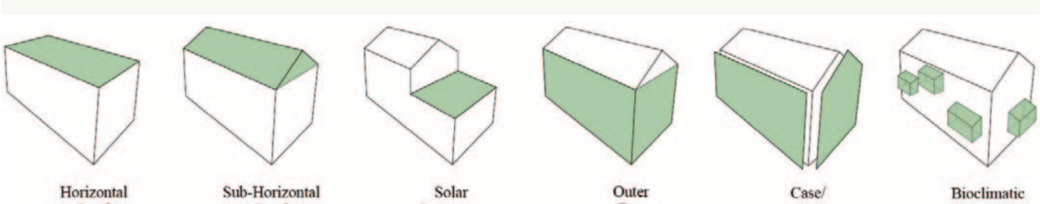
Fig. 8 | Levels of accessibility to vegetation and digital devices integrated to social housing (credit: O. E. Bellini, 2022).

STRUCTURE (UNI 8290)		
Classes of Technological Units	**Technological Units**	**Classes of Technical Elements**
STRUCTURE Set of technological units and technical elements belonging to the building system with the function of supporting the loads of the building and of statically connecting its parts	ELEVATION STRUCTURE Set of the technical elements of the building with the function of supporting vertical and/or horizontal loads, transmitting them to the foundations	Vertical elevation structures Horizontal and inclined elevation structures Structures of spatial elevation
	CONTAINMENT STRUCTURE Set of technical elements functionally connected with the building having the function of supporting the loads deriving from the ground	Vertical retaining structures Horizontal containment structures



Tab. 3 | Phenomenological interpretation of the integration between greening and digital technologies: Usability related to static structure, UNI 8289:1991 (credit: O. E. Bellini, 2022).

Closure (UNI 8290)		
Classes of Technological Units	**Technological Units**	**Classes of Technical Elements**
CLOSURE Set of technological units and technical elements of the building, with the function of separating the indoor spaces from the outside	VERTICAL CLOSURE Set of vertical technical elements of the building having the function of separating the indoor spaces of the building from the outside	Walls vertical perimeter
	TOP CLOSURE Set of technical horizontal or subhorizontal elements of the building having the function of separating the indoor spaces of the building from the external space	Roof



Tab. 4 | Phenomenological interpretation of the integration between greening and digital technologies: Usability related to perimeter closure, UNI 8289:1991 (credit: O. E. Bellini, 2022).

taking charge of and managing the urban environment, in the physical protection and ecological health of their homes as a shared living space, and the promotion of environmental biodiversity.

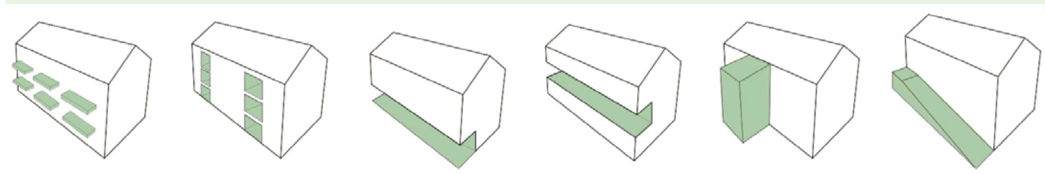
The proliferation of very low consumption and low-cost embedded devices enables quick automation and control even over the process of growing and maintaining vegetation. These devices can collect significant amounts of environmental data to feed machine-learning algorithms and thus create the ideal conditions for crop growth, including edible crops. Machine vision and cloud computing also enable the analysis of thousands of images to identify variations in plant size, width, colour and curvature, while verifying the resilience of crops against any potential crop loss or threat in real-time.

The application of the IoT to domestic green spaces has resulted in the ability to track birds, monitor trees (Treemania[1]), count bees (ApisProtect[2]) and even listen to bats (Shazam for Bats[3]). In these cases, it is possible to employ specific devices governed by what in the digital world is defined as a new threshold: the Internet of Nature (IoN). The IoN allows for innovative monitoring of green spaces and promotes unusual opportunities to understand the role of nature in the activities of the densely populated city from an ecological perspective (Galle, Nitoslawski and Pilla, 2019; Fig. 2). Greenery and the IoN collaborate in identifying and measuring indoor and outdoor pollutants of the domestic space; early models monitored fine particles (PM), carbon monoxide, carbon dioxide, benzene, and nitrogen compounds, in addition to ambient temperature and humidity. The first applications of air quality monitoring involved certain London suburbs (Ma et alii, 2008). These experiments have shown how pollution depends on the urban location of specific services (schools), and that the level of pollution due to vehicular traffic changes dramatically in relation to their opening hours.

Today, specific sensors reliably monitor environmental indicators, including fixed ones (Karagulian et alii, 2019), integrating information originating from official monitoring stations to provide dependable feedback on the actual environmental quality of the urban space. The process of domestic data collection and management, through the direct participation of the population, has recently witnessed a heterogeneity of approaches, mainly of a 'dynamic' type. Several projects are worth mentioning, such as SwarmBike (Corno et alii, 2017), which proposed to test sensors on bicycles and bike-sharing, and UrVAMM (Rionda et alii, 2013) and Sense Square (Lotrecchiano et alii, 2019), which explored the potential of these devices on urban transport, to contextually map multiple areas of the city.

The European Union has funded numerous experiments and research with the intent of interconnecting environmental sustainability and Smart Cities, including AirSense (Dutta et alii, 2017), CITI-SENSE (Schneider et alii, 2018) and Citi-Sense-MOB (Castell et alii, 2015). To date, none of these projects has seriously considered the opportunity and utility of integrating digital systems with vegetation directly applied to the domestic space. Concerning environmental issues, the complexity of the territory, not only as a physical space but also as an interconnected digital infrastructure, now requires a predominantly holistic approach, which contextually takes into account the plurality of reference levels, the sharing of information to acquire and the multiplicity of actors involved. For this reason, it is necessary to promote fluid connections and ever-changing relationships, which maximize the expansion of the target audience of subjects actually and potentially involved in environmental issues.

Partition (UNI 8290)		
Classes of Technological Units	**Technological Units**	**Classes of Technical Elements**
External Partition Set of technological units and technical elements of the building with the function of dividing and conforming the outdoor spaces connected with the building system itself	Vertical External Partition Set of vertical technical elements of the building having the function of dividing and articulating the external spaces connected with the building itself	Protection elements
		Separation elements
	External Horizontal Partition Set of horizontal technical elements of the building having the function of dividing and articulating the external spaces connected with the building itself	Balconies and loggias
		Walkways
	Inclined External Partition Set of the technical elements of the building with a position close to the horizontal with the function of explaining the external spaces connected with the building itself, connecting spaces placed at different altitudes	External stairs
		External ramps



Tab. 5 | Phenomenological interpretation of the integration between greening and digital technologies: Usability related to volumetric partition, UNI 8289:1991 (credit: O. E. Bellini, 2022).

The recent pandemic has altered our relationship with technology, which is increasingly present even in the domestic environment, stimulating attention to the quality of the environment we inhabit and the repercussions on human health. For this reason, on the one hand, studies attempt to relate outdoor and indoor air quality to health problems (Jaimini et alii, 2017), but on the other hand, it is necessary to try to understand how the presence of vegetation inside and outside of housing units not only produces real benefits (Han and Ruan, 2020) but activates educational processes on these issues. Proactive community involvement remains the main challenge, especially in forms of shared living. Too often the use of domestic integration of vegetation is celebrated by designers in 'greenshipping' terms, bordering on greenwashing and going so far as to propose, as in the case of the Qiyi City Forest Garden (Fig. 3) in Cheengdu, China, inappropriate and mismanaged vegetation that has made dozens of dwellings uninhabitable due to the invasion of mosquitoes and other insects.

The social models adopted in the field of energy conservation – an area of reference for the activation of a new ecology of living, including through the use of vegetation (Gupta and Kapsali, 2016; Aljer et alii, 2017) – allow us to understand how people's living behaviour can affect the pursuit of environmental goals. These approaches move in the direction of Citizen Science, i.e., involving citizens on a scientific basis to directly verify the mechanisms of cause and effect that lead to the modification of the environment and the potential worsening of the quality of life, thus gaining awareness.

At the building level, a 'social' impulse could come from solutions such as those proposed by the Wiseair project[4] which, based on the intuition of a group of university students, patented the Arianna balcony pot: a container for plants equipped with sensors that not only detects certain atmospheric pollutants but can also serve as the basis for activating a sensitive digital community. At the urban scale, the larger entrepreneurial project Airly required the involvement of Public Administrations, promoting the use of a network of interconnected sensors to acquire environmental data and plan possible countermeasures (Bielecki and Kaźmierczak, 2018). In this project, air quality data is visualized through a web portal, whereby a series of sensors become an active part of a complex urban system creating an interconnected 'whole', a Smart City that addresses, in adaptive terms, the ecological challenges of the future.

The so-called Smart Urban Garden infrastructure is embedded into this context, using digital technologies in connection with vegetation to share data and information through a single platform. This IT support makes use of the Sensitive Walk Beacon, a small Bluetooth radio transmitter interconnected with specific green areas, which can be activated on a smartphone or tablet and returns content regarding the biodiversity and health status of the vegetation and its immediate surroundings. These sensors, easily applicable to the building organism, enable real-time monitoring of the effects that vegetation produces on urban air quality, track the flow of visitors and control access to the distribution connectors of the residential area, facilitate cooperative and collaborative processes between those involved in the care of greenery, study the status of biodiversity, and monitor animal and plant species. This information is interpolated with atmospheric conditions, thus providing information on plant health. The collected data can also be processed, archived and reused.

Radio-frequency identification systems (RFID) have been proposed, at an urban scale and from an IoN perspective, for tree maintenance and protection (Luvisi and Lorenzini, 2014). At the same time, smart systems, integrated and connected to the Smart City infrastructure, are currently being used in Germany (Gimpel et alii, 2021). Direct citizen involvement has been promoted for automated aeroponic growing systems based on IoT devices (Kerns and Lee, 2017). On the topic of cultivation in vertical gardens, multiple implementations and experiments have been documented in Halgamuge et alii (2021). Among other things, these studies attest to how the use of digital systems is now proven and ready to engage the shared living domestic audience.

Greening and digital sensors: configurations and usability | The integration between vegetation and digital sensors can take place in horizontal or vertical spaces and household interiors or exteriors (Tab. 2). The heterogeneity of the applications, the variation in production costs, as well as the articulated maintenance methods can be traced to two macro-systems: horizontal and vertical technological green. The former includes green roofs and overhead forests (Fig. 4), the latter green facades, green walls and vertical forests (Bartesaghi, Osmond and Peters, 2017; Fig. 5). The decoding of the figurative aspects of the application of vegetation, referring to perceptual and geometric/formal data, can be traced back to: point, line, surface and volume (Fig. 6). Greenery can be considered in relation to its actual accessibility and/or practicability, according to the spatial areas of application within the residential area (Figg. 7, 8).

A more articulated definition of the integration between IoT and vegetation is necessary, based on the classes of technological units of the building organism, concerning the requirement class of usability (Standard UNI 8289:1991). This element enables the phenomenological interpretation of the aforementioned integration, defining the level of direct management of these devices: a taxonomy that conveys the articulation of the different levels of physical and spatial accessibility of the green element, the IoT systems and the related technological unit (Tabb. 3-5). In social

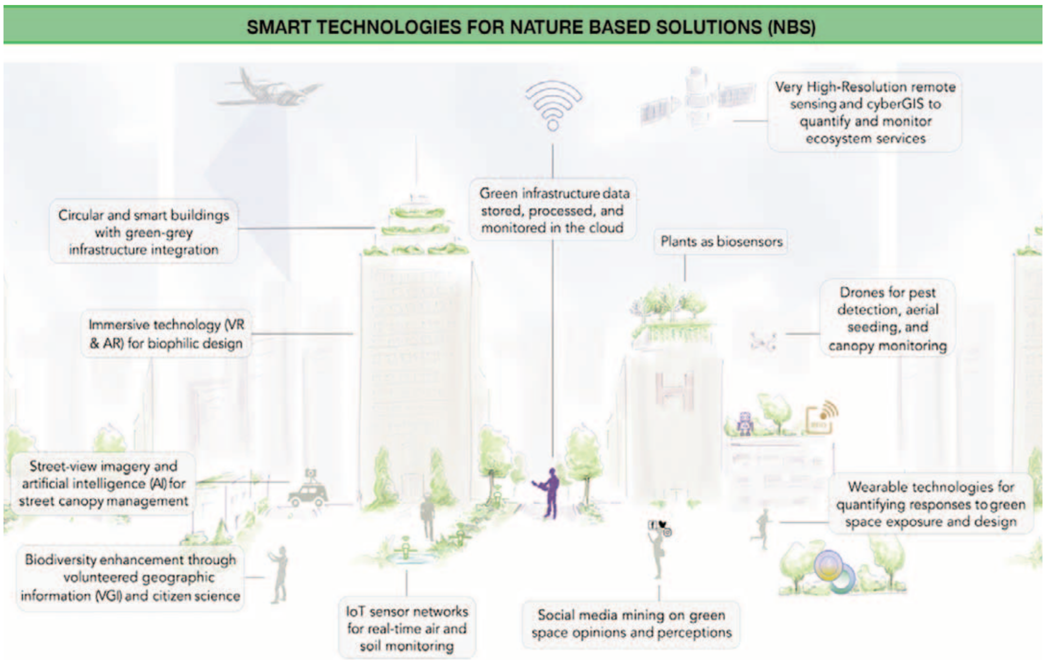


Fig. 9 | Smart technologies for Nature-based Solutions managed via Internet of Nature (source: Galle, Nitoslawski and Pilla, 2019).

housing, the usability relationship of vegetation and sensor devices can be traced back to three degrees or levels of space: private (living rooms, bedrooms, private entrances, etc.), semi-private (balconies, terraces, loggias, bow windows, etc.), semi-public (vertical and horizontal connective spaces, common spaces, etc.).

A) Usability in private space – The technological green element is introduced directly by the user into the domestic space in consideration of its benefits and the fact that vegetation produces organisms that are good for our bodies in therapeutic terms. The most usual essences are 'houseplants' (Hessayon, 2014) and herbs that create indoor home gardens. The need to rediscover the connection with vegetation within living spaces has encouraged the development of Natural Design, an advanced tendency of Green Design, which contributes to the diffusion of the principles of sustainability with objects and furniture that integrate vegetation (Corrado, Ferrari and Crea, 2013). The most conspicuous manifestations are eco-walls or living walls, modular wall panels, which can be used to create green surfaces or vertical gardens in interiors. These systems enrich the spatial, environmental and biological figuration of confined living spaces, generating unusual green landscapes (Blanc, 2005); if integrated with sensors, they can directly monitor the conditions of environmental well-being and comfort of the private space.

B) Usability in semi-private space – The recent pandemic has highlighted how shared living often lacks adequate elevated open spaces as substitutes for private gardens. The most evident manifestations of this type of space are balconies, loggias and patios. These areas mark the transition between outdoor and indoor (and vice versa): the moment where the space is combined with the demands of urban living (Kuntscher and Wietzorrek, 2010), defining the ideal situation to promote integration between vegetation and digital technologies, in an intimate and direct relationship between domestic interior, outdoor vegetation and urban environment. These spaces (often considered additional, superfluous places and devoid of utility) have once again become essential areas for living well-being.

C) Usability in semi-public space – The semi-public dimension is the one that most characterizes social housing and the shared dimension of living, identified in the galleries, distribution corridors, landings, stairs, etc., places that link and interconnect the domestic and collective dimensions. Semi-public spaces, in addition to their distributive function, define the places of relationships between the individual and the neighbouring group, enhancing opportunities for gathering, sharing, comparison and cooperation. The greening of these spaces, in addition to redeeming their anonymous appearance and service function, transforms them into connotated and denoted places; agreeable and pleasant areas which must be cared for collectively in terms of management and maintenance, as they promote social relations, a sense of community and belonging.

Conclusions | The integration of sensors with vegetation can help delineate the contours of a new dimension of architectural design for shared living, as a field of multiple and interacting connections, to critically resolve the dichotomy between natural and artificial. Communal living certainly represents a promising context for experimentation, where technology-based systems for greening can play an important ecological role, also in terms of educational involvement of users, to promote awareness and integration of the role of biological cycles similarly to natural ecosystems, thus rendering them more efficient and sustainable.

Digital technologies are modifying our understanding of reality and lifestyles in increasingly pervasive ways, generating unusual cognitive and interpretative approaches. Our habitat, thanks to its extraordinary wealth of information, requires increasingly less material support and is becoming less and less analogue. IoN systems offer unprecedented and countless opportunities for experimentation, to plan innovative strategies and solutions that provide concrete answers to the growing complexity of an architecture strongly conditioned by unprecedented ecological crises and threats.

The digital world has the power to promote an epistemological turning point, marking the transition from a manipulative knowledge of reality, based on deterministic and reductionist logic, to a 'complex knowledge' (Morin, 1993). A dimension in which the development of relationships between knowledge, disciplines, users and actors, even those belonging to different worlds, becomes strategic to understand basic generative phenomena, not only to grasp their complexity but also to transfer their logic into processes that can systemically and adaptively relate to the environment in which they are located.

Integrating the green world with the digital world also prefigures a 'scalar shift' of the multiple disciplines that pertain to architectural design, as components of a unified system called upon to provide answers not only to human beings but also to other living forms, in a relationship of deep knowledge and understanding of their respective needs and directions. The relationship between the different components of the living ecosystem becomes crucial when we adopt a broader and more systemic vision, supported by a holistic and participatory approach. In this case, digital technology promotes a 'cyber ecology' based on a 'double convergence', which makes it possible to interpret natural and artificial worlds as a whole (Ratti and Belleri, 2020).

Many of our cities are becoming increasingly digital: from self-driving cars to smart grids to responsive traffic signals; true Smart Cities that put data and digital technology at the centre, promoting efficiency and improving people's quality of life. Online nature is certainly the next step in the management process of evolved ecosystems and will change the way we relate to the natural world within the urban space. The introduction of IoT systems can help bridge the gap between greener, smarter cities and the management of urban ecosystems. Taking advantage of the IoN means promoting self-sufficiency and resilience in the management of these ecosystems, to improve the connections between urban, social, and ecological dimensions (Fig. 9).

The integration between natural and digital preordains a cultural and ideological advancement in the control and management of information related to the environment according to a new perspective: the Smart Nature City. A new ecology that, especially in the younger generations, encourages sensitivity and environmentally virtuous models of living, starting from the definition of innovative ways to come together, socialize, share and meet. An interaction that potentially supports possible new domestic microeconomies and encourages the involvement of users in the care and maintenance of the semi-public areas of the residence, supporting forms of social integration, intergenerational and multiethnic exchanges and moments of cultural and civic growth. Green living generates and promotes virtuous processes of participation, identification and sense of belonging, moments that activate awareness of ecological issues from the perspective of Citizen Science, encouraging an approach to the home also in terms of sharing economy. Housing thus becomes a durable resource, more instrumental than symbolic, whose effect is to lead the younger generations to be more interested in the ecological use of property rather than in its ownership.

Notes

1) For more information, see the webpage: treemania.eu/ [Accessed 20 March 2022].

2) For more information, see the webpage: apisprotect.com/ [Accessed 20 March 2022].

3) For more information, see the webpage: naturesmartcities.com/ [Accessed 20 March 2022].

4) For more information, see the webpage: wiseair.vision/ [Accessed 20 March 2022].

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