Do plant traits help to design green walls for urban air pollution control? A short review of scientific evidences and knowledge gaps

Anaïs Hellebaut1 · Sylvain Boisson1 · Grégory Mahy1

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Abstract
It is often claimed that green walls (GW) and living wall systems (LWS) have a positive effect on urban air pollution problems if their plants composition is optimal (design of the LWS). An in-depth review of the knowledge on plants traits maximizing GW effects on air pollution shows that these might be hasty conclusions: there are still some important knowledge gaps. Robust conclusions can only be drawn for particulate matter (PM): the other pollutants are not analyzed by a sufficient number of studies. It can be concluded that leaves with hairs/trichomes are the most effective to capture PM. The rougher and the smaller the leaf is, the more PM it catches. The analysis of the plant composition of six LWS in Belgium indicated that these LWS supported a plant community dominated by only a few species, which do not exhibit in majority the most effective traits to maximize their PM capture. Regarding climbing plants, only three out of seven commonly used creepers in Belgium present hairs/trichomes on their leaves. Studies conducted on other pollutants and other traits are required to optimize the GW plant composition and to maximize their effects on air quality.

Keywords Green walls (GW) · Living wall systems (LWS) · Air quality · Urban air pollution mitigation · Particulate matter (PM) · Plant functional traits · Creepers

Introduction
Urban air pollution is one of the most important environmental risk for human health in Europe (EEA 2020; Vos et al. 2013). One of the most dangerous anthropogenic pollutant for human health is particulate matter (PM) (Ottelé 2011) causing cardiopulmonary diseases and premature mortality (Netherlands Environmental Assessment Agency 2005; Ottelé 2011; Pope and Dockery 2006; Wu et al. 2020).

The development of urban green infrastructures is increasingly advocated as a solution to reduce urban air pollution (Abhijith et al. 2017; Heidt and Neef 2008). Plants are able to accumulate PM deposited on leaves and branches (Sæbø et al. 2012; Vos et al. 2013) and/or to adsorb, absorb or degrade atmospheric pollutants (Wei et al. 2017; Weyens et al. 2015). However, the capacity of vegetation to regulate urban pollution depends on individual plant species traits and plant communities’ composition (Barwise and Kumar 2020; Mo et al. 2015). Traits are “any morphological, physiological or phenological feature measurable at the individual level, from the cell to the whole-organism level, without reference to the environment or any other level of organization.” Plant traits influence ecosystem functions and processes (Violle et al. 2007). Specific plant traits can enhance air pollution mitigation (Barwise and Kumar 2020). Plant traits (vegetation macrostructure and leaf surface microstructures) can play a major role in the deposition process. In addition to being able to bind particles, leaves can absorb gaseous pollutants (CO2,NOX (Ottelé 2011) and NH3) through their stomata (Ottelé et al. 2010). Plants also take up NO2 and O3 primarily through the stomata (Wei et al. 2017).

Green walls (GW) (or green façades, covered by creepers) and living wall systems (LWS) (or vertical gardens, constructed from modular panels or planters, containing soil or other artificial growing media, using balanced nutrient...
solutions to provide the plant’s food and water needs (Perini et al. 2011)) are increasingly considered as important ecosystems for the development of urban green infrastructures. Those two terms will be used equally as GW throughout this paper. GW provide a high potential for developing vegetation in highly mineralized areas where the presence of ground vegetation is not possible and air pollution very high (Alexandri and Jones 2008). Outdoor GW provide many potential benefits as the following: aesthetic, social, ecological and environmental (Ottelé et al. 2010). Among those ecosystem services (ES), GW are reported to positively influence urban air quality (Abhijith et al. 2017; Feng and Hewage 2014; Joshi and Ghosh 2014; Perini et al. 2017; Weerakkody et al. 2019). Nevertheless, little is known about the plant trait composition of GW vegetation and the design of GW plant communities that maximize pollution capture. Considering the potential influence of plant traits on air pollution control (Perini et al. 2017; Pettit et al. 2017; Weerakkody et al. 2018b), to explore the current status of studies on this topic may help to identify key questions for future research as well as to support GW design.

The first goal of this study is to provide an in-depth review of the knowledge (and knowledge gaps) on relationships between plant traits and air quality with a focus on GW vegetation. The second goal is to question whether this knowledge is currently used to maximize the regulating service of air quality when designing GW.

We reviewed studies assessing relationships between GW plants traits and air pollution. We, then, extended the review to other urban ecosystems to provide a thorough synthesis on the selection of plant species with traits that maximize pollution regulation. We finally analyzed the plant community on existing LWS in Belgium to test whether the capture of air pollution is maximized by the composition of plant species functional traits. We also include an analysis of plant traits of the most used creepers in Belgium.

Materials and methods

Review methodology

Relevant studies were selected using both search engines “Google Scholar” and “Scopus.” Using a sequence of keywords related to plant traits and urban air pollution (Table 1), we identified relevant research papers testing the influence of plant traits on air quality in GW and other urban ecosystems. At each search step, one criterion related to plant traits was combined with one criterion related to air quality. The selection of articles was not limited to those addressing GW. We also included papers dealing with the effect of plant species leaf traits on pollutant capture in other urban ecosystems, as those results may be transferred to the design of GW. For all selected papers, title and abstract were first read to check the adequacy of the paper for the present review. The list of references of all research papers selected was checked to integrate any other relevant studies. Filters were not used regarding the year of publication. Articles discussing the effects of pollution on plants (not the effects of plants on pollution) were overlooked. Only results on higher plants were kept. Those on thallophytes and bryophytes were excluded.

Design of existing green walls

To test whether current designs of GW use existing knowledge on plant traits identified in the review, six Belgian GW were studied (three in Brussels city, one in the town of Namur, and one in the town of Ath (Wallonia). Details can be found in (Appendix Table 4) (Name, localization, area, year of plantation and picture).

The lists of plant species composing each GW were either provided by the owners or obtained from high quality photos. For plants covering at least 1/8 of the wall area, values of traits influencing pollution capture (selected on the literature review) were searched in databases and scientific literature. Databases used are referenced in (Appendix Table 5). We obtained for each GW a list with their plant species and their respective traits. We, then, calculated the number of species for each GW with the most effective traits identified in the review. The same databases were used to analyze traits of seven creepers.

Results

Articles content

Forty-four articles were selected based on the selection criteria: seven review papers (not used) and 37 experimental
papers. Most experiments examined relationships among plant traits and trees (62.5%). Ten experiments examined these relationships directly on GW. Two studies focused on ground herbaceous plants and two on green roofs plants. Although keywords used did not target a specific pollutant, most studies (79%) considered particulate matters (PM). SO₂ and CO₂ appeared twice, whereas O₃, NO₂, CO, ethers and PAHs appeared only once. As a result, conclusions will only be drawn for PM. In total, 33 experiments were retained for the next step (Table 2).

The most studied traits for PM fixation (at least 15 studies) were leaf hairs/trichomes, leaf roughness, and leaf area (Fig. 1). More than 10 studies considered the following traits: waxes, leaf shape and stomata. On the other hand, some traits were merely studied: leaf wettability, SLA and LAI. Four traits were handled only once or twice: evergreen foliage (Nowak 1994), the length of the petiole (Leonard et al. 2016; Zhang et al. 2021), the rigidity of the leaf (Weerakkody et al. 2017), the leaf dissection index (LDI) (Muhammad et al. 2019), and the leaf thickness (Chiam et al. 2019).

Table 2  Publications retained, type of vegetation studied, number of species studied and scale of the studies (particle measurements/counting on leaves or ambient air quality measurements)

| Authors                  | Type of vegetation                  | Number of species studied | Particle measurements on leaves (L) or ambient air quality measurements (A) |
|--------------------------|-------------------------------------|---------------------------|--------------------------------------------------------------------------|
| (Barima et al. 2014)     | Tree & herbaceous plants            | 1 & 3                     | L                                                                         |
| (Beckett et al. 2000)    | Trees                               | 5                         | L                                                                         |
| (Blanuša et al. 2020)    | Hedges                              | 7                         | L                                                                         |
| (Chiam et al. 2019)      | Trees                               | 20                        | L                                                                         |
| (Dzierzanowski et al. 2011) | Trees, shrubs & creeper (GW)     | 4, 3 & 1                  | L                                                                         |
| (Freer-Smith et al. 2005) | Trees                              | 5                         | L                                                                         |
| (Chen et al. 2017b)      | Trees                               | 5                         | L                                                                         |
| (Joshi and Ghosh 2014)   | Creeper (GW)                        | 1                         | L + extrapolation                                                         |
| (Chen et al. 2017a)      | Trees                               | 31                        | L                                                                         |
| (Leonard et al. 2016)    | Trees and shrubs                    | 16                        | L                                                                         |
| (Little 1977)            | Trees                               | NA                        | L                                                                         |
| (Mitchell et al. 2010)   | Trees                               | 2                         | L                                                                         |
| (Mo et al. 2015)         | Trees & shrubs                      | 24 & 11                   | L                                                                         |
| (Muhammad et al. 2019)   | Trees, shrubs & creepers (GW)       | 62, 32 & 2                | L                                                                         |
| (Nowak 1994)             | Trees                               | NA                        | A                                                                         |
| (Paull et al. 2020)      | GW                                  | 11                        | L + A                                                                    |
| (Perini et al. 2017)     | GW                                  | 4                         | L                                                                         |
| (Ram et al. 2014)        | Tree & shrub                        | 1 & 1                     | L                                                                         |
| (Räisänen et al. 2013)   | Trees                               | 4                         | L + A                                                                    |
| (del Redondo-Bermúdez et al. 2021) | Green barriers (GW)  | 3                         | L                                                                         |
| (Sæbø et al. 2012)      | Trees & shrubs                      | 22 & 25                   | L                                                                         |
| (Sgrigna et al. 2020)    | Trees                               | 12                        | L                                                                         |
| (Sharma et al. 2020)     | Tree                                | 1                         | L                                                                         |
| (Song et al. 2015)       | Trees                               | 5                         | L                                                                         |
| (Speak et al. 2012)      | Green roofs                         | 4                         | L + A                                                                    |
| (Viecco et al. 2018)     | GW & green roofs                   | 4 & 5                     | L                                                                         |
| (Wang et al. 2013)       | Trees                               | 3                         | L                                                                         |
| (Weber et al. 2014)      | Herbaceous plants                   | 16                        | L                                                                         |
| (Weerakkody et al. 2017) | GW                                  | 17                        | L                                                                         |
| (Weerakkody et al. 2018a) | GW & synthetic leaves               | 4 & NA                    | L                                                                         |
| (Weerakkody et al. 2018b) | GW                                  | 20                        | L                                                                         |
| (L. Zhang et al. 2019)   | Trees                               | 5                         | L                                                                         |
| (X. Zhang et al. 2021)   | Trees                               | 17                        | L                                                                         |
The methods used by the authors focused mainly on counting or weighing the particles on the leaves. Direct measurements and comparisons of ambient air quality were rarely performed in order to assess the efficacy of the trait on reducing PM air concentrations (12% of the experiments) (Table 2).

**Effects of the traits on PM capture**

Each studied trait can either help to enhance the impact of the leaf on air quality (pollutant capture), have no impact or decrease this impact (Fig. 2).

**Epidermis traits**

Twenty-five publications concluded that the presence of hairs/trichomes on leaves was beneficial to maximize the impact of the vegetation on PM capture (Fig. 2). Out of these studies, 18 focused on trees and demonstrated that the presence of trichomes increased PM capture by leaves (Barima et al. 2014; Beckett et al. 2000; Chen et al. 2017a, 2017b; Chiam et al. 2019; Leonard et al. 2016; Little 1977; Mitchell et al. 2010; Mo et al. 2015; Muhammad et al. 2019; Ram et al. 2014; Räsänen et al. 2013; Sæbø et al. 2012; Sgrigna et al. 2020; Sharma et al. 2020; Song et al. 2015; X. Zhang et al. 2021; Zhang et al. 2019). The positive relation between the presence of hairs/trichomes and the capacity to capture PM was confirmed for GW vegetation in six studies (Blanuša et al. 2020; Muhammad et al. 2019; Viecco et al. 2018; Weerakkody et al. 2017, 2018a, 2018b). For instance, Weerakkody et al. (2018b) studied 20 GW plants and found that leaf hairs/trichomes showed a positive relationship with the density of PM10 present on the leaves.

In addition, ten studies demonstrated that higher density of leaf hairs/trichomes increases PM capture. The same conclusion was drawn for trees (Chen et al. 2017a; Chiam et al. 2019; Mo et al. 2015; Muhammad et al. 2019; Ram et al. 2014; Räsänen et al. 2013; Sæbø et al. 2012; Sgrigna et al. 2020; X. Zhang et al. 2021) and confirmed by Muhammad et al. (2019) for GW climber plants having a trichome density of more than 0.58 mm$^{-2}$. On the other
hand, Perini et al. (2017) found that hairy leaves of four GW plants did not allow to collect more fine or ultrafine dust particles than non-hairy leaves. Few studies (two) quantified precisely the magnitude of leaf hairs/trichomes effect on PM capture. Leonard et al. (2016) showed that hair presence increased three times the PM capture by leaves, while Little (1977) reported that hairy leaves are seven times more efficient.

Leaf roughness was related to more PM capture in 18 studies (Fig. 2) (Beckett et al. 2000; Chen et al. 2017b; Little 1977; Mitchell et al. 2010; Mo et al. 2015; Ram et al. 2014; del Redondo-Bermúdez et al. 2021; Sgrigna et al. 2020; Sharma et al. 2020; Song et al. 2015; Speak et al. 2012; Viecco et al. 2018; Wang et al. 2013; Weber et al. 2014; Weerakkody et al. 2018a, 2018b; Zhang et al. 2019). Smooth tree leaves were found to be less effective in capturing PM than leaves with rough surfaces in ten experiments (Beckett et al. 2000; Chen et al. 2017a, 2017b; Chiam et al. 2019; Little 1977; Mitchell et al. 2010; Mo et al. 2015; Ram et al. 2014; Sæbø et al. 2012; Song et al. 2015). That was confirmed in two GW plants experiments (Viecco et al. 2018; Weerakkody et al. 2018a). Roughness was defined by a combination of different morphological features among studies: ridges or grooves densities (Weerakkody et al. 2018b), coarseness of the epidermis (Zhang et al. 2019), furrowed areas (Song et al. 2015) or groove density (Chen et al. 2017a). The relationship between roughness and PM capture varied depending on the leaf side (adaxial or abaxial) (Weerakkody et al. 2018b; Zhang et al. 2019). In contrast, Perini et al. (2017) found that softer leaves were more efficient, when studying four GW plants. Sæbø et al. (2012) did not find any relationship between leaves roughness and PM capture.

Leaf wettability had contrasted effects, as two studies found that high leaf wettability allows to capture more PM (Muhammad et al. 2019; Wang et al. 2013) and two studies (Chen et al. 2017a; Räsänen et al. 2013) conclude the opposite.

Leaf area and shape traits

Fifteen studies examined PM capture in relation to leaf size. Small leaves (area inferior to 200 mm²) were reported to be more efficient in PM capture in the majority of studies (GW: Viecco et al. 2018; Weerakkody et al. 2017, 2018a, 2018b; Trees: Beckett et al. 2000; Chiam et al. 2019; Leonard et al. 2016; Räsänen et al. 2013). Large leaves (area between 1280 and 6990 mm²) were unanimously reported to be less efficient in PM capture (GW: Muhammad et al. 2019; Weerakkody et al. 2017, 2018a, 2018b; Trees: Beckett et al. 2000; Chen et al. 2017b; Freer-Smith et al. 2005; Leonard et al. 2016; Muhammad et al. 2019; Sæbø et al. 2012) (Fig. 2). According to Leonard et al. (2016), large leaves could both increase and decrease PM deposition due to the greater surface to catch PM, but it also increases leaf movement which can lead to PM dislodgement. Three studies on trees did not find any correlation between trees leaf size and PM accumulation on the leaves surfaces (Chen et al. 2017b; Muhammad et al. 2019; Sæbø et al. 2012).

Not enough publications were found about leaf shapes to make solid claims, except for the case of needles. Four studies concluded that trees with needles were more efficient in capturing PM (Beckett et al. 2000; Chen et al. 2017a; Freer-Smith et al. 2005; Räsänen et al. 2013). For instance, coniferous scots pine collected the largest number of particles in the study of Räsänen et al. (2013) on four trees. That was confirmed for Juniperus chinensis L. present on a GW (Weerakkody et al. 2018b).

In addition, three studies on trees found that lanceolate leaves (broadest below the middle) were more efficient to
capture PM (Chen et al. 2017a; Leonard et al. 2016; Muhammad et al. 2019). That was also the case for two climbers in Muhammad et al. (2019).

Few articles evaluated the effect of LAI (Leaf Area Index) and SLA (Specific Leaf Area). Three studies concluded that decreasing SLA was beneficial to capture more PM (Chiam et al. 2019; Muhammad et al. 2019; Sæbø et al. 2012). As low SLA is correlated with smaller and thicker leaves (Chiam et al. 2019), the effect of SLA on PM capture is consistent with conclusions made for small leaves and needles. Large LAI is correlated with dense vegetation cover which is beneficial for PM capture (Joshi and Ghosh 2014; Weerakkody et al. 2017, 2018a).

**Analysis of the presence of traits identified as effective, on six existing GW and on the most used creepers in Belgium**

The six studied GW were composed of nine to 38 plant species (Fig. 3). The plant communities were dominated by a small number of species, from four to seven, each covering >1/8 of the wall surface and up to 1/2 of the wall surface. On one site (ECb), one species dominated 3/4 of the GW.

For the site with the most different species (Pbx), one species was dominant on half of the GW, and 31 were only represented by few individuals. On the Tvs site, species were more evenly distributed, with five species each filling 1/8 of the GW. These species having been planted for less than 1 year (Appendix Table 4), some will probably become dominant in the future.

Among the species covering at least 1/8 of the wall, medium and broad leaves were dominant (Fig. 4). On two sites (Sbg and ECb), there was no species with small leaves. The maximum was 43% of the species with small leaves (RSn). Species having hairs/trichomes generally represented less than 30% of the dominant species of the wall (Fig. 5). The maximum was 29% of the species having trichomes (Pbx and RSn). For the ECb wall, all were annual and horticultural species. Hence, no information was found in the databases. In total, we did not find information about the presence/absence of hairs/trichomes for 30% of the studied species.

Among the most used creepers in Belgium, several studies identified *Hedera helix* as an efficient PM catcher (Dzierzanowski et al. 2011; Ottelé et al. 2010; Perini et al. 2017; Sternberg et al. 2010). In terms of plant traits, this species

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**Fig. 3** Number of species per wall and number of species covering a percentage of the wall (Dominance structure of the plant community) (some species overlap which explains a surface of more than 100% when calculating the sum)
present medium leaf areas but with trichomes (Table 3). Two other commonly used creepers have hairs/trichomes on at least one side of their leaves: Jasminum officinalis and Lonicera xylosteum. Among the seven creepers studied, none display small leaves.

Discussion and conclusions

Despite the general assumption that GW have a positive impact on urban air quality (Abhijith et al. 2017; Barwise and Kumar 2020; Feng and Hewage 2014; Joshi and Ghosh 2014; Ottelé 2011; Perini et al. 2017; Weerakkody et al. 2018b), our study shows that large knowledge gaps limit our abilities to optimize this impact through functional design of plant communities using plant traits. Knowledge on the relationships between plant traits and air quality is almost limited to PM. Very few experiments have studied the link between plant traits and other pollutants, despite the diversity of urban air pollution components. Few plant traits have been analyzed in details by a significant number of studies. A more comprehensive list of effective traits to capture pollutants is needed to design more effective GW to tackle urban air pollution issues.

Among the functional traits of plants, not all are equally well studied. We identified three traits that are reported to influence PM capture: hairiness, roughness and leave size. The presence of hairs/trichomes on the leaves is the most studied trait, and the results converge. Leaves with a higher density of hairs/trichomes capture more PM than those with little or none. This effect is related to the fact that leaf hairs increase the surface area for PM interception and at the same time decrease the chances that PM will be resuspended with leaf movements (Zhang et al. 2019). The presence of leaf hairs/trichomes is reported to be the most influential traits for PM capture, compared to others (Muhammad et al. 2019; Weerakkody et al. 2018a). Leaf roughness is the second most studied trait with a general conclusion that a rough leave surface (containing ridges, grooves, or striations) is more efficient than a smooth one to catch PM. Large leaves are reported to present low efficiency in capturing PM while small leaves are generally reported to capture more PM. In this sense, needles are good PM catchers.

Not only the number of traits studied in details is low but they were studied mostly individually. Yet, combination of traits seems to be critical when looking at PM deposition and accumulation. A single leaf trait cannot override all other leaf traits to determine PM capture. Select species that combine most of the effective traits (e.g., smaller leaves with a complex shape and a rough, hairy surface) in addition with a high LAI could maximize the effect on PM capture. On

| Creeper                     | Leaf area | Presence of hairs/trichomes |
|-----------------------------|-----------|-------------------------------|
| Clematis vitalba            | Broad     | No                            |
| Hedera helix                | Medium    | Yes                           |
| Jasminum officinalis        | Broad     | Yes                           |
| Lonicera peryclymenum       | Medium    | No                            |
| Lonicera xylosteum          | Medium    | Yes                           |
| Parthenocissus quinquefolia | Broad     | No                            |
| Wisteria sinensis           | Medium    | No                            |

Fig. 4 Proportion of small leaves and medium/broad leaves among the dominant species present on the wall.

Fig. 5 Proportion of species having trichomes/hairs among the dominant species present on the wall. NA means that the information was not find for the species.

Table 3 Leaf area and presence of hairs/trichomes on seven commonly used creepers in Belgium
the other hand, different traits can have antagonistic effects. For instance, leaf hairs/trichomes are important, but their effectiveness can be reduced by the presence of other traits. Macro-characteristics (e.g., leaf area and shape traits) and micro-characteristics (e.g., epidermis traits) of leaf should be considered simultaneously (Baraldi et al. 2019; Leonard et al. 2016; Muhammad et al. 2019; Weerakkody et al. 2017, 2018a; Xu et al. 2022). Besides optimal combinations of traits, leaf traits are not independent. For instance, leaf wettability is dependent of epicuticular wax type and is based on surface roughness caused by different microstructures (trichomes, wax, etc.) (Muhammad et al. 2020; Neinhuis and Barthlott 1997).

The effect of the traits will not only depend on the effect at the scale of the leaf but also on the total leaf area developed. In addition, conclusions on the effect of plant traits on PM capture are drawn from experiments carried out on the scale of the leaf (most often it is a question of counting PM present on the surfaces). Very few studies have measured pollutant levels in ambient air. The question may therefore arise as how can conclusions drawn at the leaf scale be extrapolated to ambient air quality?

While our review reports evidence that hairiness and leaf size can enhance the capture of PM by GW, these evidences are not transferred to GW design. The six GW studied supported a plant community dominated by only a few species, which do not exhibit in majority the most effective traits. This highlights the need to select species with more appropriate traits in the future. Moreover, even when the number of species is high, plants communities tend to be dominated by a small number of species. Even if they present efficient traits, the PM capture function of the GW is linked to the survival of a reduced number of species which makes the system less resilient to environmental disturbances. Increasing the diversity of the plant community with species associated to favorable traits to capture pollutants is the recommended design.

While LWS still have limitations (high maintenance and installation costs, need for irrigation, etc.), climbing plant turn out to be an alternative way to obtain GW and are currently promoted by many local governments (e.g., the City of Brussels grants a bonus for the planting of a honey-bearing and/or indigenous creepers on facades located on the street front). The most used creepers in Belgian do not display small leaves, and only three out of seven present hairs/trichomes on their leaves. This would not replace a LWS for which each plant could be selected for these traits.

In conclusion, while this review points out the potential of using plant traits to provide operational designs for GW with the goal of improving their effect on air quality, the current knowledge extent makes it premature to conclude on operational guidelines. Further researches are needed to increase the diversity of traits and pollutants studied, the effect of trait combinations and the scalability of leaf effect to ambient air quality. Nevertheless, knowledge on the effect of leaf hairiness, leaf size and leaf roughness should be included in current design of GW, which does not seem to be the case. An optimal selection of species should be done in accordance with biogeographical areas, orientation of the GW, wind velocity, drought and frost resistance, potential cooling effect and contribution to biodiversity in addition to traits enabling PM capture.
## Appendix

### Table 4 Information about studied GW

| Number | LWS            | Abbreviation | City       | Area | Year of plantation | Picture |
|--------|----------------|--------------|------------|------|--------------------|---------|
| 1      | Sibelga        | Sbg          | Brussels   | 305 m² | 2016               | ![Picture](https://example.com/image1.jpg) |
| 2      | Brussels Parliament | PbxB        | Brussels   | 74 m² | 2007               | ![Picture](https://example.com/image2.jpg) |
| 3      | Street Traversière | Tvs          | Brussels   | 44 m² | 2021               | ![Picture](https://example.com/image3.jpg) |
| 4      | Royal Snail hotel | RSn          | Namur      | /     | 2013               | ![Picture](https://example.com/image4.jpg) |
| 5      | Docks Bruxsel  | Dks          | Brussels   | /     | /                  | ![Picture](https://example.com/image5.jpg) |
| 6      | Street Ernest Cambier | ECB   | Ath        | /     | 2021               | ![Picture](https://example.com/image6.jpg) |
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Author contribution Anaïs Hellebaut, Sylvain Boisson and Grégory Mahy contributed to the study conception and design. Material preparation, data collection and analysis were performed by Anaïs Hellebaut. The first draft of the manuscript was written by Anaïs Hellebaut, and Sylvain Boisson and Grégory Mahy commented on previous versions of the manuscript. Anaïs Hellebaut, Sylvain Boisson and Grégory Mahy read and approved the final manuscript.

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Data availability The datasets generated during the current study are not publicly available due to their current usage for the FSO-program MURVERT to create decision support tools for green walls implementation. The data are however available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare no competing interests.

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