POLITECNICO DI TORINO

Faculty of Architecture
master of Architecture for Sustainability Design

Master degree thesis

DEVELOPMENT OF A GREENER ROOFTOP GARDEN SYSTEM IN THE POLYTECHNIC OF TURIN

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ABSTRACT

The potential of vegetated roofs as instruments for the enhancement of urban landscapes has gained relevance as cities incursion into sustainable development. It is well known how the application of green rooftops leads to a variety of benefits such as the reduction of air and noise pollutants, runoff mitigation, biodiversity promotion, among a wider listing. However, green roof literature is in most cases centered on the advantages they can provide, excluding their limitations and life-cycle stages. Modern green roof systems production relies on the manufacture of prefabricated stratification elements and complementary accessories that require the implication of diverse production processes. Whereas emerging initiatives of lower production ecological impact are fewer.

This dissertation offers a review of the design process of the proposal of a more ecological green roof in the Polytechnic of Turin, exploring alternatives to mass manufacturing processes and evaluating the feasibility of the proposal for a real-life application. For this, the pre-existent site conditions were taken into consideration. Results were contrasted to commercial models and based on the regulations of competence. Demonstrating how it is possible to create a greener rooftop system from mainly waste materials and integrating this system to space it occupies as more than an aesthetic finishing but as an accessible instrument of interaction and as an integrated architectonic object. Establishing as well a proposal for the future to navigate through the path of sustainability.

CONTENTS

INTRODUCTION

Even though green roofs are known as a relatively new technology, green surfaces on the rooftop have existed for centuries. One of the earliest examples are the Babylon Hanging Gardens, constructed around 500 B.C (Stormwater Institute, 2020). Nevertheless, this technology popularity has seemed a growth in the recent years due to their vast range of benefits for either building and urban spaces. The pluses around green covers utilization involve lowering of air pollution (European Commission DG Environment News Alert Service, 2008), runoff diminution (United States Environmental Protection Agency, 2020), heat island effect amelioration through a heat reduction of around 4°C in contrast to black roofs (GSA, 2011), the promotion of the biodiversity and further advantages. This raise of popularity in the modern days has cause their mass production and commercialization, providing simple installation processes and claiming to be a full advantage product and the key of sustainability. The real interrogation is: How sustainable can green covers really be?

Nowadays fewer commercial garden rooftop companies endeavor to lighten the ecological impact of their products. Multiple of these corporations increase the durability of their items or even incorporate recycled materials in some of their productions. Nonetheless, transportation and manufacturing still remain unsolved issues in the topic. The transference of the diverse materials (raw and waste) from numerous sources to their center of production, the posterior application of synthetic substances and diverse chemical, mechanical and physical processes, and lastly, the carriage of the final product to storage points are phases of concern. Non-commercial investigations, reviewed in this paper, also seek better solutions, exploiting the waste resources to create their own version of a green surface for the building tops.

This thesis seeks to create a non-commercial proposal of a green cover. The main aim is the development of a greener rooftop garden on a determined building area inside of the Headquarter of the Polytechnic of Turin, fulfilling the specific requirements of the university and determining the proposal feasibility. Seeing that the current thesis encompasses predominantly investigation and design, it is a secondary objective to serve as a basis for future researches to deepen the present content and incorporate the required experimental phase. Furthermore, other objective is to present a proposition for future, involving other dimesions and creating establishing a path for sustainability.

The hypothesis is that it is possible to conduct a strategy for the projection of a greener cover, taking advantage of the local situation and issues and following preestablished parameters by commercial industries, existing regulations and similar investigations. However, this proposal of a more ecological green surface will lead to a group of disadvantages such as time issues and an installation of minor practicality in contrast to commercial versions. Yet, it is expected to combine the flexibility of a personalized project with existing situations to achieve a system of adequate performance and viability, reaching the sustainability. Naturally, to reach the last point, it is expected an expansion of the green roof and suggesting a whole system around the campus instead of an individual target. The pretentions of this paper are not to surpass the performance of products created especially for a specific aim but to propose an alternative of a minor impact for the environment.

The project importance not only relapses in the design of a green cover on a specific building but in exploring alternatives to reduce the human footprint in the environment. Seeking in parallel another possibility to the commercial versions, the decreasing of landfill just as the referenced researches, the amelioration of the zone quality (In terms of environment and the generation of new spaces) and in particular, serving as baseline for future researches and perhaps being replicated in other communities.

The current thesis is structured by a framework, references, case study and the project proposal. In the framework part, relative general information regarding green roofs knowledge will be collected, apportioned and synthesized. Followed by the review of specific green roof cases with competent technological solutions and posterior the presentation of the particular study case. The mentioned case study will be split in diverse scales to reach a better understanding of the context and the diverse variables influencing projectual decisions. Finally, the illustration and description of the proposal and its viability regarding economic, environmental and technical topics.

Regarding the methodology, the research type is essentially a case study and exploratory investigation. The data collection involves either primary and secondary research method, focusing in a case study, literature review and observation and utilizing quantitative and qualitative information. The employed analysis method is primarily thematic. Nonetheless, metanalyses are also incorporated. A main support of the investigation is the comparison between a few commercial green roof versions and the proposed one and the utilization of the UNI normative and FLL Guideline as a standard. The utilized tools and programs during the whole investigation include a phmeter and hardness measurement apparatuses for the quantification of meteoritical values, the implementation of Q GIS, Geoportale Torino, Geoportale Piemonte, Google Earth and Google Sketchup for the site analyses information collection, and AutoCAD and V-Ray as the main tools for the representation.

CHAPTER I
THEORETICAL
FRAMEWORK

THEORETICAL FRAMEWORK

GREEN ROOF CONCEPT & ANATOMY

A simple way to categorized roofing systems is through the use of particular colors that correspond to their defining characteristic. For instance, black roofs are the typical bituminous membrane -or waterproof coating- over the edifices which are also generators of adverse effects for the atmosphere such as the heat islands effect (Saber, Swinton, & Paroli, 2012). Green roofs (GR) in contrast, have their place in the ecological roof spectrum, as well as the white[1], blue-green[2] and brown[3] kinds. Specifically, green covers tend to be wrongfully conceived as a new technology. However, the phenomenon of greenings over the buildings is an ancient method implemented for hundreds of years. The Hanging Gardens of Babylon, constructed centuries ago, are the earliest example of this phenomenon. But what are green roofs with precision?

Green roofs are roofing systems employed for the growing of vegetation. Named also living roofs and rooftop gardens, these systems are usually known by their aesthetic aspect. Nonetheless, they carry out further advantages for the environment and the building itself. This means that they have a scope in building and urban scales. Besides of that, the green roof term involves an ecological, economical and a social implication depending of its performance and use. For example, following the same order, greenings on tops may encourage the biodiversity, reduce energy expenses and be used as recreational points by people.

In urban contexts, hardscapes[4] interfere with natural processes as the infiltration of water and biodiversity development. Although, living roofs in cities act as a green skin capable of counteract those symptoms and enhance the whole landscape panorama. This strategy is valuable to regain the lost qualities by paved constructions. In fact, the generation of green surfaces can significantly reduce the vegetal footprint, attenuate heat islands impact, diminish flooding risks and further additional benefits.

In general, green roofs structure is composed by layers that include a vegetated soil stratum, protection shells, filter cloth and drainage (Green Roofs for Healhty Cities, 2019). The summation of its individual components is the feature that provides advantageous properties to green roofs. A green cover may not work properly in absence of the minimum required layers, damaging the building or system. For this reason, the decomposition of the

1 Roof system for cooling using a bright surface to reflect a consideble part of solar radiation. (Saber, et. al)
2 Is defined as a green roof with an extra drainage layer. Oriented to the storm warter managing. (Shafique, Kim, & Lee, 2016)
3 Brown roofs are a particular variation of Green Rooftops oriented to enhace biodiversity for a wildlife-friendly environment (Ito & Ishimatsu, 2011).

4 Defined as manmade horizontal impervious surfaces. (Butt, Harvey, Saboori, & Ostovar, 2018)

GR elements is vital in order to understand the functional roll, conformation and importance of each piece. The green roof layers are:

1. Vegetation course:

External layer, representative of green roof systems. This superficial stratum is accountable of restoring nature over the place it is emplaced, support biodiversity, keep the roof on good aesthetics and provides oxygen. The choice of which plant species select will rely upon the placement environmental situation, the specified performance, the situation and structural load capacity of the building, etc. Generally, the soil of the rooftop systems are planted with specialised mixture of plants that may thrive within the harsh climates, drought, elevated temperature conditions of the roof and tolerate short periods of inundation from storm events. Wildflowers, grasses, and sedums are common alternatives for creating a "roof meadow." (Worden, Guidry, Alonso & Schore, 2004)

Vegetation is the main green roof layer; additional layers are responsible of ensuring the care of the plants and the existing structure.

2. Growth media:

Organic and mineral key stratum with aggregates adopted for the greening's sustentation. The growing medium should maintain specific physical and chemical properties in order to permit the provision of essential nutrients, aeration exchange and the storage and drainage of water (Nelson, 1991). Complementary, the medium's depth in conjunction with its bulk density, pore spacing and particle size distribution are critical factors. They all participate on the water drainage, retention and aeration. For instance, the depth depends on the typology of the plants but it must be enough to allow an appropriate water storage and drain. Variations on a container height will not affect the percentage of solid material but the ratio of water and air spaces (Argo, 1998). Papers rationalise that shallower substrates implicate a reduced root insulation against low temperatures whilst deep ones augment the H_2O holding capacity but could affect the building structure (Getter & Rowe, 2006). A proper proportion of particles with variations on the dimensions can contribute to the control of water storage and air circulation. Thicker materials augment aeration and finer to the retention of the water (Raviv & Lieth, 2008; Spiers, Fietje). Pore spacing also allows the growing of roots (Latshaw, Fitzgerald, & Sutton, 2009).

The composition of the substrate may include natural, artificial and modified constituents (Ampim, Sloan, Cabrera, Harp, & Jaber, 2010). If the growing media is entirely natural, the desirable distribution is 50% of mineral and organic components and a 50% of pore space in which must be an equilibrium between water and gases (Brady & Weil, 2004). Employed minerals might be sand, gravel, pumice and scoria while modified elements comprise calcined clay, expanded shale, perlite, vermiculite and rock wool. These materials furnish lightness, porosity and an effective anchorage for the roots. Crushed bricks, tiles and concrete are recycled materials that could be added as well (Ampim, Sloan, Cabrera, Harp, & Jaber, 2010; Latshaw, Fitzgerald, & Sutton, 2009).

3. Filter element:

Its function is to retain soil materials by delimitating the root media from the subsequent layers. Basically, the filtrating layer holds the growth media to avoid a wash-through effect but allowing water to drain

(Eco Green Roofs, 2018). Added to this, it impedes the transference of particles that may block other system's parts. For example, a lack of an appropriate filter could provoke the drainage obstruction by particles accumulation. As a consequence, the entire system may be damage (Sempergreen, n.d.)

Aspects to consider for the selection of filtrating layer include the amount of water to drain, the growing medium composition - in case of including sharp elements capable to perforate it - and the kind of vegetation (determining their root impact over the sheet). Filters are manufactured with a woven or non-woven method. Nonwoven filters are significantly resistant to the root infiltration and could act as a barrier (Growing Green Guide, 2014). They are created from fibers, bonded through mechanical, thermal and chemical processes and have the appearance of a felt while woven consist as its name indicates in weaving the materials. Commonly used materials include polypropylene. Geotextiles can be woven or nonwoven materials.

4. Water storage:

Destined to reserve water for its eventual vegetation absorption. Designed to reduce the irrigation need. This layer is not mandatory but could improve the green roof quality.

The main limiting factor on any green roof structure will be the way water supply is ensured. The type of vegetation and its water needs would be the main factor to take into account in the decision of which water storage have to be installed. Green roofs significantly decrease the amount of runoff from rooftops, storing much of the precipitation volume for later evaporation and transpiration. Water can be stored on various modes, some of them are:

- Use of substances that improve the storage capacity of the vegetation substrate of retaining water
- Use of open-pore type aggregate materials in graded granular sizes
- Pre-formed drainage boards with partial retention characteristics

Current knowledge about green roof systems, in the context of intense structure types, assure that the most efficient way of storing water is a combination of retention in the vegetation support and in a specific drainage course.

5. Drainage element:

Layer responsible of the drainage of any excess water off the roof, preventing waterlogged system with a significant increase in weight. In some cases, the drainage develops the function of hydric storage as well, accumulating only part of the water and draining the excess. The main typologies are granular aggregates (natural or artificial) and prefabricates elements (geosynthetics or preform elements). Different shapes and materials can be used to build this layer, but nowadays most green roof companies use a corrugated plastic drain mat with a structural pattern resembling an egg carton (G. Wark & W. Wark, 2003). Although this is a very technical layer usually made from plastic components, recycled containments can also be used, avoiding the utilization of a commercial and non-reused material. The high porosity of the drainage layer in general allows the dewatering of the substrate and accelerates the lateral flow process (Uhl, Schiedt, 2008).

6. Root inhibitor membrane:

The roof's membrane requires protection, primarily from harm throughout the green roof installation, however conjointly from fertilizers and potential root penetration (G. Wark & W. Wark, 2003). so as to shield the cover againts this last agent, a protecting surface against root perforation, and as a consequence, against possible damages to the structure might be installed. This inhibitor layer might be a protective sheet or a surface treatment. Categorized as mechanic and chemical (additives) barriers. In most of the cases, the sealing and root barriers are integrated and bituminous membranes or synthetic membranes can be used as in the case of sealing barriers.

7. Mechanic protection stratum:

Protection for the sealing layer against damages by static and dynamic loads during the installation and the entire service lifetime. When the stresses are moderate, as in the case of thin green roof structures a nonwoven fabric may be suitable. Heavier structures would need to have thicker and more resistant protection layers. The inclusion of a barrier system, against root penetration or other agents, is essential when providing protection to the waterproof membrane (Carroll, 2010).

8. Sealing layer:

Its main requisite is avoiding the water passage. The most used typologies of water sealing are bituminous membranes and synthetic membranes -polyolefin or polyvinylchloride-. The compartmentation of the sealing layer in reduced parts could simplify its maintenance, since it is necessary remove upper layers to replace the sealing, damaging the vegetation (FLL Guideline, 2002).

Additional layers can be installed on the structure to assure additional protection against specific agents. These are not required components, but they could help on applications where the conditions are especially harmful to the system:

- *Thermo isolation:* Additional layer to increase thermal isolation. In order to ensure the thermal protection of green roofs, it is important to maintain healthy plants and enough moisture in the substrate or soil. (Hui, 2006)
- *Steam barrier*: Additional layer to avoid humidity.
- *Slope layer:* The inclination for the water drain is 1% as a minimum but 2% the recommended.
- *Antibonding:* Prevents undesired bondings between incompatible materials.
- *Separation layer:* Used to divide chemically incompatible materials

CATEGORIZATION & TYPOLOGIES

Officially, the established greening top typologies are extensive and intensive. Both determine aspects as the roof depth, maintenance, and use. However, after the spreading and popularization of green roofs, a third typology emerged spontaneously: The semi-extensive or semi-intensive covers, compiling elements of the originals. Added to this, non-pre-established formal categories came to light, responding to the installation method and the surface inclination.

1. Typologies by depth, maintenance, and use.

1.1 Extensive:

Essentially, extensive covers could be described as green carpets with ecological purposes. Denominated eco-roofs or brown roofs as well, they allow access exclusively for installation and maintenance. Distinguished by low height plants that can resist high temperatures and strong winds. Vegetation of these roofs is not usually diverse and may include: alpine types, succulents, herbs, some grasses, and mosses. Deep root plants are not compatible.

Extensive coverings have lightweight and minimal maintenance requirements. Suitable to cover large surface areas, these kind of green roofs generally do not require structural strengthening (Bass, Lundholm & Coffman, 2007). Water needs are below the average and if irrigation is necessary, it is only in summer or during drought periods. In addition, the soil layer on extensive roofs is not just lighter but thinner. Its preservation consists of a few visits per year for membranes inspections and the prevention of invasive species apparition. This design is frequently developed by the desire of eliminating maintenance since that is one of the biggest benefits provided by the typology.

Extensive roofs are easily added to most of the existing structures. They are characterized by relatively low capital costs and short-time installation. Because of its shallow depth, energy efficiency and rainfall water retention capability are less than in deeper green cowlings. The reason for this is a thinner isolation by the thickness and a limited drainage system.

1.2 Intensive:

Accessible for people, this kind of green roof is usually used for gardening, agriculture, and socializing. Characterized for heavier load support due to a deep substrate requisite. This covering's installation is suitable for superstructures built with considerable loads capacity (FLL Guideline, 2002). Generally, they have high costs and strict maintenance needs owing to the irrigation and fertilization exigencies. Despite the loads supporting demands, the energy efficiency and stormwater capability associated with intensive roofs are truly favorable.

The ecosystems carried by this typology are often more complex because of the diversity applied to them. Also named roof gardens or podium roofs, these structures are highly engineered landscapes. About the vegetation, they can cope with hardier flora, shrubs, coppices, and even trees (FLL Guideline, 2002). Furthermore, the species planted on the top are commonly higher than 50 centimeters tall and the maturation period could endure years.

1.3 Simple intensive

Green rooftops characterized by the incorporation of elements from both extensive and intensive covers. This typology arises recently for the reduction of distinctive boundaries between the two main types (Dunnett & Kingsbury, 2008). They usually uphold perennial plants and growing medium vegetation. Maintenance and watering are needed and their frequency and difficulty depend on the features. The characteristic that defines if the component is semi-extensive or semi-extensive is the closeness with one or the other. Also called semi intensive or semi extensive green roof.

2*. Categories according to the installation method:*

2.1 Modular systems:

Green modular components are usually pre-fabricated plastic tray systems with convenient dimensions. The proportions, layers content, and installation vary according to the commercial brand. The method's simplicity allows flexibility and design's gaming due to the fact of the uncomplicated manner for translation, installation, and replacement. Forasmuch as containers are filled like flowerpots, sometimes come up pre-vegetated and pre-matured. The installation can be done directly on an existing roof on waterproofing systems.

Some brands classified the modules as intensive, and extensive, bringing similar characteristics from those described previously. On one hand, extensive modules are lightweight, include native low maintenance vegetation and have lower watering requirements. Sometimes are adaptable to the biodiverse type. On the other hand, intensive modules have ample drainage holes, higher water and maintenance needs and higher weight supportive capability. However, intensive modules cannot hold taller plants like trees or big bushes.

2.2 Mat systems:

Green mats consist of rolled "carpets" of pre-grown vegetation with a minimal substrate depth. This technique is suitable for buildings with low weight

Figure 1
Extensive roof cover

Extensive green roof with a mix of Sedum vegetation.
Designed by Gardens in the Sky.
[328 Euclid extensive green roof]. (2018).
Retrieved May, 2021, from greenroofs.com

Figure 2
Simple intensive green cover

Simple–Extensive roof in Brooklyn Botanic Garden's new Visitor Center planted with grasses, flowering perennials and bulbs
(n.d.). [Simple Extensive green roof].
Retrieved May, 2021, from greenroofs.com

Figure 3
Intensive roof cover

Intensive cover of Vancouver Public Library
(n.d.). [Simple Extensive green roof]. Retrieved May, 2021, from greenroofs.com

Table 1
Green roof typologies

INTENSIVE		SEMI - INTENSIVE		EXTENSIVE	
Semi vegetated	Vegetated	Semi vegetated	Vegetated	Semi vegetated	Vegetated
Green roof w/ trees Admit: ①②③④	Green roof w/ trees Admit: ①②③④				
Green roof w/ shrubs Admit: ②③④	Green roof w/ shrubs Admit: ②③④	Green roof w/ shrubs Admit: ②③④	Green roof w/ shrubs Admit: ②③④		
Green roof w/ grass Admit: ③④	Green roof w/ grass Admit: ③④	Green roof w/ grass Admit: ③④	Green roof w/ grass Admit: ③④	Green roof w/ grass Admit: ③④	Green roof w/ grass Admit: ③④

Trees (max 2m) ①   Big size shrubs ②   Small size shrubs ③   Grass ④

Elaborated by the author

Table 2
Green roof typologies characteristics

VARIABLES	EXTENSIVE	SEMI INTENSIVE	INTENSIVE
WEIGHT (Kg/m^2)	60 - 150	120 - 200	180 - 500
HEIGHT* (mm)	60 - 200	120 - 250	150 - 400
FIRST COST	Low	middle	High
MAINTANANCE	Low	Periodically	High
IRRIGATION	No**	Periodically	Regularly
VEGETATION	Mosses, sedum, succulents, herbs and few grasses	Selected perennials, sedums, ornamental flowers, herbs and little shurbs, some food plants.	Perennials, lawn, putting green, shurbs, some trees, rooftop farming.

(*) Taking as reference build up systems
(**) Variable affected by the place climatic situation.

Adapted by the author. Data from International Green Roof Association (2015) capacity and large roof areas. The sizes and vegetation vary by brand. The material for the mat's base can be made for instance of nylon mesh or another textile. Installation is often about the preparation of proper water and root barrier, followed by the unrolled on-site of these elements. Since initially planted coverage percentage is not 100%, uniformity is reached after the plant's growth. As a result, it is obtained an instant, easy, regular, low maintained green coverage.

2.3 Continuous systems:

The also called build-up method consists of the installation, layer by layer, of a continuous vegetative cover but directly in the construction place. It is similar to regular gardening and fits on both categories; intensive and extensive. It is the slower method in terms of installation.

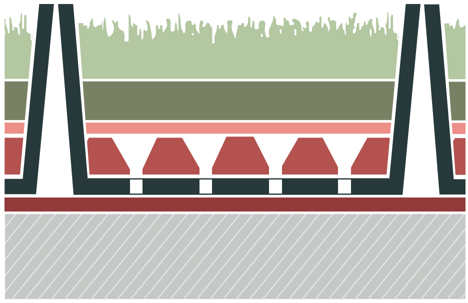
3. Categories by the surface's angle

Green roof geometry shape varies in concordance with the architectural design. In present days, technology allows playing with a huge range of possibilities and even more if the building is not constructed yet. If the construction is already erected and the structure is supportive, vegetation can be adapted to the existing shape. In general terms, living covers can be flatted, inclined, or curved: Any shape fits with an installation method and roof typology.

3.1 Flat:

Roof structures with a maximum of 10°, are considered flat roofs (Wilkinson & Dixon, 2016). However, the terminology "flat" is misleading considering that an inclination of 0 degrees

Figure 4
Tray or module. Illustrative section



Re-elabolared by the author. Original by Lundhold, J. (2007, November) Green Roofs as Urban Ecosystems: Ecological Structures, Functions, andServices. American Institute of Biological Sciences.Vol 57 num 10 pp. 827

Figure 5
Mat system. Illustrative section

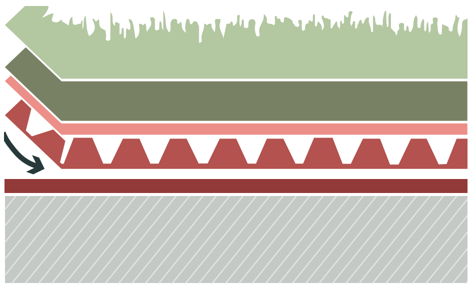


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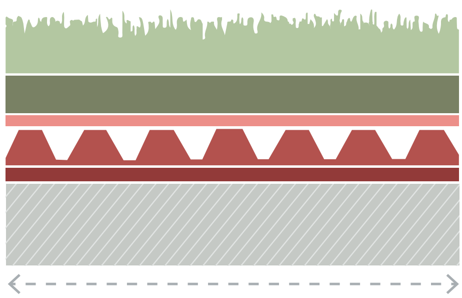
Figure 6
Build in system. Illustrative section



Re-elabolared by the author. Original by Lundhold, J. (2007, November) Green Roofs as Urban Ecosystems: Ecological Structures, Functions, andServices. American Institute of Biological Sciences.Vol 57 num 10 pp. 827

is not realistic. a. A minimal pitch of 2% is required for the rainwater drainage (FLL Guideline, 2002). Lesser inclination causes the pooling of water, damaging roof, and plants. Flat roofs are the most applied shape since they are suitable with all the typologies and do not require extra considerations as slope forms do. Installation is suitable also with all methods, depending on the building's structural capacity.

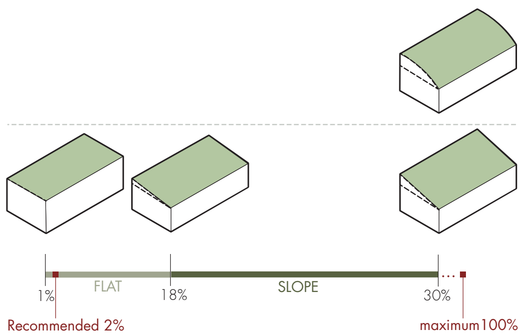
3.2 Slope or pitched:

It is possible to generate an initial idea of slope roofs meaning by the name, but which are the actual limits between slope and flat covers? The answer is that all green structures with 10° degrees of minimal inclination are considered pitched rooftops (Wilkinson & Dixon, 2016), including curves or waves. The maximum pendant that can be faced for extensive green roofs is up to 45° [5], but the average is commonly between 10° and 32°. In contrast, intensive slope roofs must be relatively flat, otherwise, they would not be supportive.

Roofs with this particularity require additional precautions to keep away from slippage due to the very own weight of the green cover stratums or other loads. One significant point to be taken into consideration to the installation of a durable green cover structure is certainly the degree of the pitch. Whereas higher is the degree of inclination, the greater its susceptibility to natural movements thereon the precise area. Natural factors as heavy precipitation, erosion, and snow loads. Seeing that precipitation water runs at a higher velocity due to the angle of inclination of these surfaces, water retention capacity is reduced, requiring additional irrigation systems. Variables as the drainage, thickness of the vegetation support course, and plant types can neither be affronted as a flat coverage.

Accessibility for installation and maintenance is challenging. Appropriate installation methods may include the implementation of extra supports as shear barriers and eaves edging, which are load-absorbing elements. Shear blankets are anchored to the roof and covered with the green substrate while eaves work in a similar way. Additionally, to prevent soil erosion is recommended the insertion of high densities of vegetation. Another consideration is the cowling's orientation and how this could affect the growth of vegetation.

Figure 7
Green roof categorization by slope



Elabolared by the author.

5 Please notice that according to the commercial brand 'Sepergreen', their GR can reach 45° degrees of inclination. (Sempergreen, n.d.)

BENEFITS

This paper reports a literature review of the large-scale ecosystem services (ESS) and about what green roofs and walls can provide for cities. A summary of 17 ESS's is given. A lot of research has been done on ESS's accomplish immediate physical human needs and providing long-term physical and socioeconomic security. Services providing social and psychological needs have been less studied. Mostly, ground-level urban vegetation like parks can provide a higher level of ESS's than green roofs and walls, but the latter are a valuable addition where ground-level room is scarce. Between roof and wall types, intensive green roofs provides the highest level of ESS's. Extensive green roofs mainly satisfy physical needs, and green walls mainly satisfy social and psychological needs. Green roofs and walls can certainly contribute the most to the reduction of the Urban Heat Island effect, and to the processing of annual rainfall. Right now, It is not possible to translate all ESS's into a economic value, for easy comparison of their impact. Recent research points to health benefits and savings on energy and emissions as candidates for the largest effects of green roofs and walls in financial terms.

1. Moderation of urban heat islands

Urban Heat Island Effect (UHIE) is a macroclimate and a negative phenomenon in today's cities. Some of the consequences are for instance the temperature rising and the air pollution increasement. The explanation is a concentrated density of concrete and asphalt in urbane contexts. Those particular surfaces that predominate in cities have an elevated conversion percentage from solar radiation energy to heat, which means that they re-reflect huge amounts of solar radiation. On account of that, if it is compared with the surroundings, urban areas have a higher temperature average. In fact, "re-radiated heat, waste heat generated by industry, vehicles and mechanical equipment and increased levels of air pollution, have combined to raise urban temperature levels up to 8°C warmer than their surroundings on warm summer evenings" (Kuhn, 1999). This temperature difference will increase even more with time.

A cooling strategy to normalize the temperature in the cities is providing vegetation on horizontal and vertical surfaces. One reason is that plants generate evapotranspiration, which humidifies the environment and cools the air around the building. Another reason is that water is stored by the substrate, this causes temperature moderation. Furthermore, plants per se transform a lower quantity of radiation to heat than other materials, only 20% of the solar light energy is reflected (Kuhn, 1999). Shadowing generated by trees is also caused by the decreasing of the temperatures. As a result, a reduction of a couple of degrees on the temperature of the cities may be reached if this strategy is applied otherwise heat probably would be re-reflected.

2. Habitat creation for fauna and flora.

In general, green rooftops can potentially be a live-giving tool. Biodiverse green roofs in particular are able to provide a natural habitat for fauna (birds, bees, butterflies, bats) and flora attraction and sustain. Additionally, green roofs can purify the air and water, improving natural living.

3. Air quality improvement [6]

6 Note that: "Air pollution is different from other forms of pollution ill that, once the pollutants are in the air, exposure cannot be easily avoided. If high levels of air pollution are occurring in a city, therefore, it may be expected that a large proportion of the population will be exposed" (Office of Global and Integrated Environmental Health, 1996)

Green roofs vs Dark roofs

Compared to conventional dark roofs, GR initial costs tend to be superior. This is a minor issue if the wide list of benefits of vegetated surfaces is considered. In addition, the service life of GR is argued to be longer due to a minor exposure of the layers to the radiation, a reduced water ponding and more rigorous protection standards. (Dunnett & Kingsbury, 2004)

Air in cities is extremely polluted by human daily activities as driving, housing, industrial production, etc. All these activities create carbon dioxide and other pollutants. In addition, the existence of huge constructed surfaces heats the environment, generating also thermal air movements which spread particles and dust. The absence of enough greenery areas in cities and the previous causes listed first deteriorates life quality.

Living roofs can potentially moderate the air pollution levels. On one hand, plants have the ability to capture and filter the dust, the particulate matter and also clean some noxious gases as through photosynthesis. These pollutants get trapped in leaves and are cleaned later with the rain. Moreover, regulation of temperatures, not only reduces thermal air movements but also the demands of energy and as a consequence, the CO2 generated by the energy consumption.

Considering an extensive covering, grass could take out 0,2Kg of dirt per m^2 of surface per year (Pieper, 1987). This amount of eliminated particles could increase if the volume of the vegetation is higher. Added to this, plants increase oxygens levels during their photosynthetic process. For instance, 27g of oxygen per hour are released throughout the day from 25 m^2 of the leaf surface. This is equal to the amount of oxygen human intakes in the same time lapse (Kuhn, 1999).

4. Health improvement

According to models studied by the Health World Organization, green spaces are related to the improvement of health and well-being (WHO Regional Office for Europe, 2016). One of these models (Hartic, Mitchell, & De Vries, 2014) underlined the existence of pathways through which green spaces may contribute to the mentioned issue as air quality improvement, promotion of physical activities, reduction of stress, and greater social cohesion. In particular, green roofs are proven to participate in the cleansing of the air -as was explained above-. Nevertheless, the rest of the pathways may not necessarily apply to green roofs, since it depends on their use and accessibility.

As it was said, air quality and health are extremely linked. If air pollution is reduced, demands on health care could be reduced as well. Cleansing of the air has direct effects on people with respiratory decreases. Plus, visual aspects, contact with nature, and 'white' noise produced by crashes between wind and vegetation can bring positive impacts on phycological well-being.

5. Increasment of city's functionality

Most of the rooftops in cities remain as residual spaces. The conditioning of those unexploited spaces could serve to transform the urban landscapes, providing also a smart growth up for the cities and their communities. Besides, greening on the tops could save terrain to add new spaces for the building. Living roofs can be linked to potential functions such as recreational, commercial educational, and social. Some examples may be the generation of new vegetable lungs through green parks, the addition of green terraces for restaurants, local urban food production centers, research centers, and more.

Moreover, green roofs on buildings can improve social exchange. A project could be combined with community participation, involving the neighbor or people of the surroundings. New job opportunities are as well another advantage that surely will bring this cowling: Workforce may be needed for design, installation, maintenance, growth, and manufacturing.

6. Flood risk reduction

Instead of infiltrating on the ground, stormwater arrives at non-porous structures from cities. As a result, this can cause sewage overflows and the increment of the volume on natural water bodies. Both situations can augment the flood risk. However, the stormwater retention capacity of green roofs delays the runoff and reduces the amount of stormwater. This reduction can also decrease stress on sewer systems, moderating flood risks. It is important to notice that some green roof typologies have a lower stormwater retention capacity due to the pitch and a thin soil layer.

7. Energy savings

A key benefit from the living roof acquisition is energy efficiency. Buildings with poor natural ventilation and poor isolation risk have higher daily energy demand and as a consequence elevated cost. Fortunately, green roofs act as insulation able to reduce the amount of energy needed to regulate internal temperature. Green covers can lessen summer's energy demand for air conditioning by even 75% (Liu K, 2003). Furthermore, as external air is warmer and most of the mechanical cooling systems need to pre-cool this air, living roofs can shade their intake valves, reducing the amount of energy required.

8. Water management: Stormwater absorption and water benefits

Stormwater management is another key benefit of roof greening. City landscapes are full of paved surfaces that are replacing vegetation which in another case would absorb the rainwater. Those paved surfaces are usually non-porous, carrying problems as (1) Flood risks, (2) erosion on building's infrastructure by the accumulation of water and moisture, (3) water contamination due to the contact with dirty surfaces, and (4) water's temperature raising by the contact with warm surfaces at summer. Many possibilities to solve this issue exist in discussion today, but the implementation of living roofs is one of the most viable alternatives.

But how could vegetative roofs solve this problem? Water is infiltrated into the soil's membrane; this water is temporarily stored and later absorbed by plants that finally return humidity to the environment through evapotranspiration. Moisture is also absorbed by plants, eliminating often the need for complex drainage systems. Water retention is influenced by a number of variables as the temperatures, the pitch, the depth, and the drainage porosity and section (Schiedt & Uhl, 2008). An investigation data show runoff retention for green covers of 80,8% on average, varying by the angle of the roof. For example, a 25% slope cover arrived to 76,4% of retention while a 2% slope reach 85,6% (Getter, Rowe, & Andresen, 2007).

Stormwater retention isn't the sole living roof profit connected with water. Greenings moderate water temperatures and act as a natural filter, removing pollutants like heavy metals and dust. Researches have reflected how vegetative roofs removed a 95% of cadmium and 16% of zinc from precipitation water (Johnston & Newton, 1996).

9. Augmentation of building's durability

Greening installation on roofs brings the advantage to serve as a protective screen for buildings, shorting aging effects. Green layers act as a direct defense against ultraviolet radiation, erosion, and other climatic impacts. Besides, temperature regulation onto the surface achieves the reduction of the expansion and contraction stress on materials, ensuring lesser possibilities of cracking. By improving air quality is possible to increase the structure duration avoiding degrades due to direct contact with pollutants. Absorption of humidity decreases damages owing to degradation for moisture as well.

10. Comfort enrichment

Improvement of both, indoor and outdoor building's qualities is reached thanks to vegetated covering's insulation capacities. These insulation capacities are present in vegetation and growing medium. Some of the benefits related with internal comfort include regulation of temperatures, noise reduction and air filtration.

In summer insulation keeps a fresh internal environment. "Under a green roof, indoor temperatures (without cooling) were found to be at least 3-4°C lower than hot outdoor temperatures between 25-30°C." (Kuhn, 1999). In contrast, during winter heat-losses are reduced. Presence of evergreen plants would be idoneal to maintain green roof's advantages during the entire year, but if trees with seasonal foliage losses are selected, this could serve as a passive method to ensure solar gains in winter.

About noise, an extensive green cover of 12 cm layer can reduce sound from outside by 40 decibels, while one of 20cm can reduce sound by 46-50 decibels (Kuhn, 1999). Substrates usually blocks low frequencies whereas plants tend to block higher. During investigations it was proven that sounds absorption and transmission is affected by the moisture -content in plants and soil- and by the depth and texture of the soil (Hodgson, 2013).

11. Economic savings

Even when the initial investment necessary to construct a green roof can be elevated, the entire life time savings are relevant can could make the project economically favorable. The economic benefits are multiple and variate with the scale of the project, some of the main advantages are listed below:

- Installation of greening increases economic value of buildings, providing spaces of quality and rising up the marketability.
- Energy savings due to the regulation of the building's internal temperature involve a monetary profit.
- The life-expansion of a GR by its innumerable protective capacities over the building, reduces maintenance costs and future re-roofing needs.

The typology of the GR is also a determinant on the prices. "An extensive green roof is 50-80% cheaper than an intensive green roof" (Johnston & Newton, 1996).

12. Aesthetic improvement

A beautifying strategy for buildings and cities is the application of these particular covers. As an advantage, this brings a positive visual impact for the building and the entire city, approaching in a certain way the nature to an urban context. Greening a roof helps to blend the building with the surrounding.

ISSUES & CHALLENGES

Drawbacks of GR are fleetingly highlighted since they are fewer in contraposition with its benefits. Nevertheless, the comprehension of negative issues and difficulties during its service life is a vital point for the decision making. In both cases, advantages and disadvantages are linked in a great measure with the design choices such as typology, drainage, material selection and vegetation. It is important to notice the lack of studies about this point which also leads to a lack of technical information.

1. Structural limitations

A GR installation over existing constructions implicate its load increasement. This occur in different measures according to the selected typology of GR and materials. The weight of growing medium and storage with their maximum water capacity must be considered likewise. A roof overloading could lead to a collapse.

In some cases, buildings cannot resist additional loads. The solution is their structural reinforcement but it cost could be elevated. Fortunately, in most cases, edifices count with an extra load capacity and may not require structural interventions.

An extra structural limitation is the roof inclination. Greening on tops are able to resist slight slopes. Typically, the maximum inclination affordable is 25°. This inclination can be increased employing an auxiliary internal structure, approaching the 45° degrees.

2. Economical disadvantages

Initial commercial GR costs is an investment. Even if it is considered elevated, its energetic savings and other advantages could counterbalance this expense.

The cost of green covers will mostly depend on the typology of the GR, being intensive the highest one. The reason is rigorously maintenance requirements to avoid damage on the structure by the roots and higher water requisites. The initial cost of intensive surfaces for roofs is also elevated because the size and kind of held vegetation involves certain complexity. Requiring extra material and supplementary layers. Extensive GR are by the contrary structures of a minor complexity and if they are dotted with the right vegetation, their maintenance cost is low.

Scarce vegetation selection

In spite of the depth of the growing media, election of vegetation is restricted. Even if an intensive roof is settled; the weight of the plant, the direction of the roots develop and the tree maximum size are factors with limitations in this kind of structures. In conjunction, if the better optimized green cover is desired, only some resistant and native low-growing grasses, mosses and sedums could be accommodated on the building top. This still leave a considerable spectrum for the selection but less attractive for some subject's view.

3. Maintenance

A minimum amount of maintenance is always required and with a major frequency on intensive surfaces. If the correct maintenance is not applied, the growing vegetation could potentially damage the building from leaks. Plants roots could penetrate the root barrier layer, affecting the roof structure. Moreover, finding the damage to repair it could be challenging due to the complexity of some green roof assembly. The duration and the aesthetic aspects of a green surface is related to the maintenance as well.

4. Uncertain contribution to sustainability

Green roofs could potentially or not contribute to the ecological and economical pillars of sustainability depending on its features. The problem is how variable living roofs characteristics are and therefore how variable their impact is. For example, the ecological impact of the cover depends on its total mass. A major total mass will improve the internal performance. It is also influenced by the area of the system, the kind and size of its vegetation and the water holding capacity (Ente Italiano di Normazione , 2015). Following this idea, intensive roof should fill satisfactorily this requirement. However, intensive covers require frequent maintenance and bigger amounts of water which means a lack in the production of own resources to be sustain. Added to this, the procedence and kind of materials, the life cycle assessment, the duration, are also determinant factors for the sustainability in terms of ecology. In relation with economy, an evaluation of the expenses for installation, materials and maintenance versus the building savings should be considered too.

CHAPTER II
REFERENCES REVIEW

REFERENCES REVIEW

REHABILITATION OF THE ORPHANAGE ELISA ANDREOLI

Context:

The orphanage is placed in the town of Oruro, Bolivia. A town that occupies near 5% of the country's surface. Situated 3708m over the sea levels, the place is for the most part a plain terrain but with mountain chain formations due to the Andes. Oruro's main financial basis proceeds from mining, farming, and agriculture. Spiritualism and traditions make an important part in the place dynamics, and most of the touristic attractions of the city are deeply attached to both, mining and religion (Zrazhevskyi, 2018).

Being a South America, the climatic conditions are opposite to those of Turin. Nevertheless, in this case, it is expected to study the employed techniques more than the implantation per se.

The climatic classification according to Koppen's is coded as BSk which means 'cold semi-arid climate'. This is associated with scarce precipitations, dryness in the environment, and an average annual temperature below 18°C. Compared to Turin, Oruro is colder in a yearly average context and the seasons act opposite; being Winter in the middle of the year and Summer from October to March. The yearly media temperature reaches 9°C, implying a three-degree difference in contrast to Turin. According to historical data, Summers reach 20°C and colder seasons arrive at temperatures below zero, arriving at -10°C (Climate Data, 2018). However, other fonts point out that maximum temperatures could reach 32°C, which in fact happened one single day in October of 2007. Annual precipitation is approximately 394mm which means a disadvantage of 452mm if it is compared to the annual rain of Turin (Weather underground, 2018).

Getting into the specific, the building is found at the interception of Quintana's and Ejercito's avenues. The building lies in a block conformed by active constructions and a second orphanage for younger children. Both institutes belong to the same complex. Regarding the surroundings, nearest volumens reach a maximum of six floors and constructions of concrete with bricks walls are predomint. Vegetation at the zone is poor, excepting for one or two of very little trees and the recent green roof addition on the orphanage.

Background and budget:

The renovation project was born as an initiative of two Italian entities: The religious order 'Serve di Maria', managing the project, and the association 'La Gotita Onlus' which supported it. Rehabilitation design ran by the firm ARCò (architecture and cooperation), Alessio Dionigi, Luca Trabattoni, Carmine Chiarelli, Diego Torriani and Valerio Marazzi. At the project, the materialization phase participated in both local private and public institutions.

The original structure was presumably erected in 2002 and the rehabilitation employed from September 2014 to December 2014. The building had double slope roofs in the lateral wings and flat covers the central spaces. The total roof was composed of a single thin layer with no isolation. This cover allowed water and humidity trespassing, causing internal and external damages.

Seeing the latitude, the solar incidence, the temperature variation, the poor materiality, and some additional conditions, it was determinate the vitality of the rehabilitation for the building. Additionally, the building shape and orientation did not provide enough solar light especially needed for educational programs. The existing roof also was a problem due to the infiltrations by rain, damaging the building structure and the electrical system.

A faced situation during the materialization of the project was the budget. The exact amount is reserved, but we know it was a short budget. Excluding the new roof structure, it was reached a zero-cost green covering. The materials implemented for the waterproofing and filtration were leftovers, ergo reused. Earth, rocks, and plants were donated by the municipality. Surprisingly, the green roof is the first one employed in the country. According to the local media, the technology was unknown in Bolivia.

Building description:

The orphanage was created to host and educate emarginated children from ages ranging from six to twelve years old. Internal spaces include dormitories, classrooms, corridors, and a central common space at the South with the main access. A pitch is also found as an empty space for children's recreation. The entire building occupies a constructed area of 1500m^2 and a total area of 3000m^2 approximately.

The building involves the pitch, creating a sensation of security. The basic geometry is configured by a perpendicular axis that recalls a "U" shape. These axes respect the direction of the streets and the plot. In another hand, the shape is generated by a game of angles that allows shadowing during different day-timing. Finally, the resulting volume is predominated by perfect symmetry, having the central common double height body and two wings at East and West each, with a single level.

Mixed structures and materials conform the building. For instance, the general structure is composed of columns and beams of reinforced concrete. On the contrary, the top possesses trusses and beams in metal or wood format. Those structural mixes correspond to different finishing: Some translucent for the light trespassing, the greening for the isolation, and some opaque finishing. Instead, the walls are entirely done of bricks.

Green Roof:

As it is explained at the background part, thAs it is explained in the background part, the building was erected years before the insertion of an ecological cover. A posterior application of different techniques was employed in order to resolve two main situations: the illumination absence and the uncontrolled internal temperatures.

Architects managed to solve the isolation deficiency by applying a green horizontal surface upon the roof. The replacement of a zinc shelter for a new covering brings the improvement of internal conditions, regulating the temperatures and as a consequence, improving the indoor comfort. The application of this strategy is also linked to the simplification of the establishment's geometry. By simplifying the shapes, it is obtained a better structural base to support the weight of the ecological shelter.

The roof is a semi-vegetated one, being the greens a minority. Only 10% of the surface corresponds to greens. The cover typology is an extensive top, this can be determined by the architect's statements and the superficial heights of the greens. Nonetheless, results necessary to collect the characteristics to deeply understand it.

Analyzing the building is evident that the architects desired to provide natural solar illumination, and parallelly, sun radiance mitigation. An irregular roof with three different slopes was disposed to allow both situations. As it is seen in the image, the green slope receives direct solar rays of the South which is the most exposed surface. While the vegetation reduces the heat exposition, the light trespasses the opening generated by a difference of inclination and position between the surfaces. The illumination is mitigated through a façade gaming, the roof's cantilever, and opaque material implementation.

A light inclination for all the covers provides the possibility of right drainage. The water drains, reaching a system of pipes for the leftovers. Thanks to the different layers, the water over the green cowling are filtrated. On another hand, some of the water is stored for a lately growing media absorption.

The interesting part of this particular project is the inclusion of a sociological and educational factor. In this case, those are referred to as community participation, involving regular people in the construction process. Planification included tools to allow regular civilians with or without previous experiences to understand and encourage the operation. The idea is to offer a simplified instruction guide book with graphic basic information. Thus, every person with different levels of knowledge in the matter might be able to easily participate.

Aside from saving costs, community participation gives extra value to the final result, increasing the appropriation feeling and reducing timing. Moreover, educational architecture brings countless opportunities for future structure development, especially in countries with fewer resources.

Atdditionally, active participation was noticed during the material collection. Materials, as was mentioned included reused 400.000 plastic caps for the drainage layer, which partially retain rainwater that could be needed in dry periods. The plastic caps collection was promoted by local churches and schools. For the thickness stabilization, some bricks in the plastic caps layer. Above, as a barrier between the growing media and the drainage, a non-woven fabric coat used as a water filter and a root barrier.

Figure 8. Installation of the new roof structure.
© ARCò Architecture & Cooperation (2014). [Photography of Elisa Andreoli roof]. Oruro, Bolivia. Retrieved, 2021, from https://divisare.com/

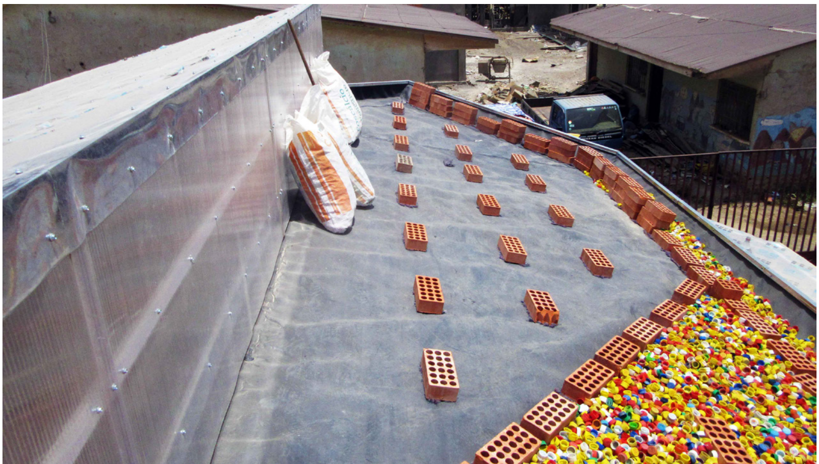


Figure 9. Addition of the plastic cap bottles
© ARCò Architecture & Cooperation (2014). [Photography of Elisa Andreoli roof]. Oruro, Bolivia. Retrieved, 2021, from https://divisare.com/

Figure 10. Final result of the extensive green cover
© ARCò Architecture & Cooperation (2014). [Photography of Elisa Andreoli roof]. Oruro, Bolivia. Retrieved, 2021, from https://divisare.com/

PROJECT OF SUSTAINABLE GREEN ROOF MADE OF SEWAGE WASTE:

General view

The idea emerges from a group of students participating in the BlueCity Circular Challenge competition, in Rotterdam. The competition goes in pursuit of encouraging a circular economy, offering to students and new professionals the possibility to develop fresh concepts for a prosperous city. To be precise, the competition's concerns are related to residual flows from organizations. The task is to design a viable product for a circular economy, starting from their wastes (Divisare, 2018).

Designers

The group conformed by a multidisciplinary team: Jelle Scharff, Bas van der Leeden, and Anne Korthals won the competition. Their proposal was a blue roof from water waste materials of the regional Water Authority 'Schieland en de Krimpenerwaard'. The proposal leads them to create a potential commerce product for new green roofs.

Context

In the city of Rotterdam, more than 130.00Kg of waste is annually thrown through the toilet. This cipher is reached solely taking into consideration the content in the plant of 'Schielanden de Krimpenerwaard'. The solids block the sewages, avoiding an accurate water flow, chiefly in the middle of strong rain periods (Scharff, Leeden, & Korthals, 2018).

Material

The final product is a tile adopted as a green roof component. Constituted by materials from common usages, such as used tampons, condoms, sanitary towels, toilet paper, leaves, and other remains. That discarded matter without apparent value owns particular properties. Most of them possess qualities as lightness, a non-degradable situation, water absorption, and content of organic matter which in other words is translated to fertilizer (Scharff, Leeden, & Korthals, 2018).

The created tiles serve as growing media and replace the typical lava rock use. The lava rock is extracted in different countries than Holland, having major transport costs. Also, this material is not entirely sustainable while proposed tiles enlarge some material lifecycle. The created media is perfect for plant development due to its high water retention capability and fertilizer content (EFE Agency, 2017).

Green roof application

The created tiles serve as growing media and replace the typical lava rock use. The lava rock is extracted in different countries than Holland, having major transport costs. Also, this material is not entirely sustainable while the propose tiles enlarge some material lifecycle. The created media is perfect for plants development due to a high water retention capability and the fertilizer content (EFE Agency, 2017).

Cost

The project was originally created using a specific agency as a study subject. However, the designers plan to scale and massify the product creating a "global solution for a global problem" and spreading the circular economy implementation (Scharff, Leeden, & Korthals, 2018). In fact, sewage wastes are everywhere and companies usually burn the matter, generating energy and economic losses.

Thinking of the project as an idea and not as a commercial object, production costs may be minimal. Even if technically the basic components are secondary raw material, in Europe those are legally actual waste (Commission of the European Communities, 2007), carrying no primary costs. Regarding the process expenses, production is not as invasive and complex as many recycling processes and the required energy is enormously minor than burning. Concluding, costs may be incredibly low.

Figure 11. Propotype of the Blue Roof.
Compresed green cover base made from waste.
© Blue Roof (2018). [Photography of Blue Roof substract]. Rotterdam, Netherlands. Retrieved, 2020, from: www.facebook.com/blauwdak/?tn-str=k*F

Figure 12. Prototype of Blue Roof.
Prototype being tested
© Blue Roof (2018). [Photography of Blue Roof green cover]. Rotterdam, Netherlands. Retrieved, 2020, from: www.blauwdak.nl/voorbeeld-pagina/

PRODUCTIVE SYSTEM OF GREEN ROOFS IN VULNERABLE COMMUNITIES

General view:

This project started with the master thesis of Carolina Forero Cortés, and the participation of the professor Carlos-Alfonso Devia-Castillo, of the Universidad Javeriana of Bogotá. Three green roof systems have been designed and installed on high-priority houses placed in Altos de Cazucá, Colombia. The goal of the project was to quantify the social and economic earnings, together with the contribution to the daily vegetable dietary requirements of a person.

Context and study area:

The environment has suffered a progressive degradation in the last decades, partly a consequence

of the increase of urbanizations with a successive accumulation of deficits of services in urban areas of Colombia. The lack of vegetation is particularly concentrated in the peripheries of main cities as in Altos de Cazucá, in the municipal sector of Soacha. Due to this, it is necessary to propose new alternatives to partially overcome or minimize this situation, such as ecotech production systems or green roofs as a technology that can deal with the problems of the urban environment. Urban agriculture contributed to food security and maintains the link between the rural and the urban, increasing the amount of food available through domestic production, the freshness, and the nutritional value of the food that arrives in the urban area. In addition, it offers opportunities for productive or complementary employment, as the participating families. Some other energetic advantages can be taken into account, as a lowering in the energy demand for space conditioning in the building is accomplishes generally with these systems (Liu & Minor, 2005)

Three vegetable production systems have been designed on the roofs of priority interest houses in Colombia, Altos de Cazucá, belonging to the upper basin of the Bogotá River and sub-basin of the Soacha River. The climate has an average temperature of 11.5 ºC (maximum temperature of 23 ºC and a minimum of 8 ºC) and an average annual rainfall of 698 mm, with a rainfall distribution of two defined periods, from April to July and from October to December.

Method and materials:

The main purpose was to quantify the benefit, economical and human, of the proposed system. Several relevant aspects were taken into account, as the climate of the place, the resistance of the building structures, and the economic characteristics of the people living in the chosen houses and participating in the project.

The three systems (treatments) installed in the study area were the following:

a) Lettuce and radish
b) Green onions, coriander, and lettuce
c) Spinach and parsley

A complete study has been performed evaluating the viability of the project. Afterward, a workshop has held with students and teachers of the career of Industrial Design of the University Javeriana, to exchange ideas about the process. An analysis is necessary to be performed after obtaining the results, as uncertainty is always present around the benefits.

Figure 13. Green roof installation.
Supported on the mentioned thesis.
© EcoInventos (n.d.). [Photography of ecological green roof proposal]. Bogota, Colombia.
Retrieved 2021, from: ecoinventos.com/ecotecho/amp/

Figure 14. Green roof installation.
Design supported in the mentioned thesis. Installed over a slope roof, in a borrought which lacks of resources and water.
© EcoInventos (n.d.). [Photography of ecological green roof proposal]. Bogota, Colombia.
Retrieved 2021, from: ecoinventos.com/ecotecho/amp/

The installation of the green roofs has been carried out following the activities listed below:

1. Approach and presentation of the proposal to the people of the sector of Altos de Cazucá interested in the project, both the owners of the houses and the entities that would support during the development of the project.

2. Characterization of the roofs of the selected houses, especially their load capacity and functional characteristics for the support of the green covers.

3. Identification of containers, substrates, plant species, rapid growth, and superficial roots, in a preliminary assembly of the system.

4. Definition of technological adjustments for the productive system of green roofs and requirements of management for the water supply. In the quantification of economic earnings and contributions, it was considered a life cycle analysis of the project of two years, determined for the useful life of the irrigation system. These two years allow the realization of 12 cycles of production.

5. The total costs were quantified (including labor) and income (estimating sale prices to the local market); In addition, the gain was calculated in case the system was installed in the total roof, that is, 24 m^2.

6. In order to quantify the contribution to food security, the weight of each plant species was determined in grams with a digital scale reference in the proposed system of 12 m^2 (one water) and per 24 m^2 (two waters); finally, it was compared with the daily demands of vegetables recommended for consumption.

Results:

The life cycle of the project was two years, and during this time a comparison of the monthly earnings with the value of the Minimum Monthly Legal Wage (SMMLV) has been carried out. One positive result, common after the installation of these types of green roof systems, is the reduction of the peak temperatures during the studied period. (Sonne, 2006)

The results are a contribution of (a) 16% ($94.796) (b) 9% ($51.596) and (c) 18% ($109.196). Thanks to this system, 100% of the daily vegetable dietary requirements for an individual are supplied. However, some adjustments have been proposed, making it possible to achieve an income increase of (a) 33%, (b) 18%, and (c) 36% compared to the SMMLV, also supplying the diet requirements of three individuals.

The system favors the food security of the participating families. In addition, there are also labor earnings of $130,000, which can be contracted with another person, or added to the crop earnings for each family during the same period of two years.
It was shown that the most profitable treatment of plant species is spinach (Spinaca oleracea) and parsley (Petroselinum crispum) with a profit of $ 2,795,669 during the two years in accordance with the price of the local market.

On the contrary, the treatment that has the greatest nutritional contribution is the one containing long onion (Allium fistulosum), coriander (Coriandrum sativum), and lettuce (Lactuca sativa), although its gain economic is the least

The proven advantages of the proposed ecotech system were the following: the low cost of investment, the use of recycled materials, the possibility of being manufactured by people from the community in a very short time, easy to repair the structure, and also offers the opportunity to potentiate the human qualities of the participating children, youth and adults because it generates a process of permanent dialogue and cooperation, which can be projected on a regional and global scale.

CHAPTER III
CASE STUDY

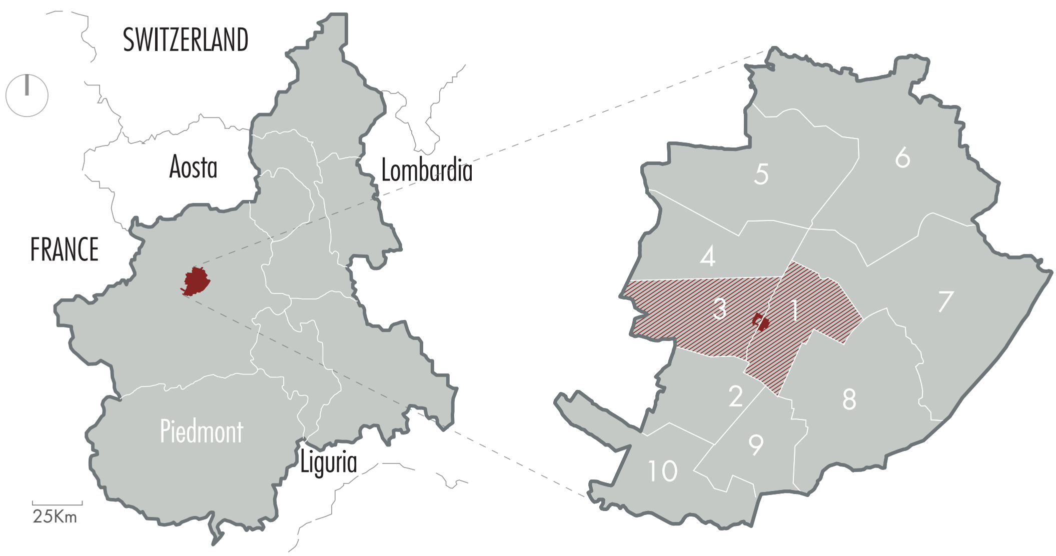
The knowledge and detailed study of the area to intervene is vital to generate an approach of future steps. Matters of interest for the project's development are going to be touch. Overall, the analyses and collected information in the following chapter have the purposes of contextualize, evaluate recommended parameters by the FLL Guideline and Italian normatives about green cover's installation and serve as basis for the proposal and design. The compiled data is organized in three scales: urban, campus area and the specific target building.

STUDY CASE

URBAN SCALE

The proposed object is located in the northwest of Italy, in the Metropolitan City of Turin, between its boroughs 1 and 3, as it is shown in the figure 16. The city is positioned at an altitude of 239 meters above sea level and is surrounded by the Alps on the northern and western sides, and by the Po river and its bifurcations. In general, the place is known for its economical strength, its wealthy cultural value, and host of relevant universities. Including the Polytechnic of Turin, the target of the study. To sum up, this urban center is an integral part of a plan to transform Turin into a Smart City.

Figure 16
Location - Regional and urban scale



City of Turin, located in the region of Piedmont, at NW of the country.
Note: Figure elaborated by the author. Referenced on Regione Piemonte (2020)

Turin and its internal politic division. The location of the study area is highlighted in red.
Note: Figure elaborated by the author. Referenced on Regione Piemonte (2020)

Torino Smart City

The Municipality of Turin created the foundation Torino Smart City to redirect the politics and transform the place into a sustainable city, seeking the reduction of the environmental footprint of their citizens while covering the population needs. The foundation counts with the collaboration of Polytechnic of Turin (the study case), the Università degli Study, and additional entities. The plan includes goals for the reduction of emissions as CO_2 (Sanseverino & Vaccaro, 2016).

Vegetation in Turin

1.1 Greenings in Turin

Turin is considered a privileged urban environment by its vast green extension. In fact, the city is denominated as one of the greenest urban centers of the country and its current flora is the result of spontaneous growth in combination with a sum of interventions across time. These interventions started in 1559, after the transference of the Duchy of Savoy to the city, which ordered the requalification and expansion of the new capital. As a consequence, several green areas were designed during the following years, to be used as guide routes for hunting and as royal gardens.

Significative green areas belonged to the royalty by the end of the eighteenth century. Inclunding the ones in the suburban royal buildings as Stupinigi Palace, Venaria Reale, and Valentino's Castle. By the time, the Royal Gardens conform the most relevant green surface inside the city borders. Green area tha was conceived by André Le Nôtre[1]. The gardens, located behind Palazzo Reale, were designed with parterres, lanes, and fountains but the French influence was covered by classical touches in the nineteenth century. In addition to the Royal Garden, a tree-lined public passage of some relevance was found inside the walls, between the Citadel and the Military Arsenal.

In the early XIX century, Napoleon ordered a group of interventions. Among these, he requested the demolition of the city's fortification, as well as the construction of a system of 'promenades publiques', and the instauration of the characteristic tree lines in streets around the city. By this period, the concept of green public spaces was established in Turin with the opening of one of the first public gardens of the country; Valentino's park.

Nowadays, the total surface of public managed greens in the municipal area reaches 19.569.000m^2, representing 16,5% of the total surface (Comune di Torino, 2018). Today's greens distribution comprises gardens, cemeteries, sports fields, parks, street tree lines, agricultural areas, and natural formations around the Alps and the rivers.

Overall, the graphic glimpse the first signs of a well-endowed number of green spots spread over the town. Their superficial distribution seems to be reasonably regular. It is remarkable

1 André Le Nôtre was the landscape architect of the king Louis XIV. He also created notable green spaces as Versailles and the Tuileries.

the presence of hills at East. Added to this, a higher greening surface next to the rivers and town limits. In contrast, industrial zones with a lack of vegetation at South and North of the city.

1.2 Surface of green area per capita

A minimum green surface area per inhabitant was established by the World Health Organization. This minimum surface should be at least 9m² (European Comission, n.d.) while the optimum UGS[2] value should be higher. Some papers (Bell, et al., 2018; Cirella, Russo, 2018) quote 50m² per capita as the ideal value and 15m² as the recommended one. However, further regulations embrace extra factors as accessibility and space quality (UCL Institute of Health Equity, 2014; WHO, 2016).

More regulations:

- The Accessible Natural Greenspace Standard -ANGSt- has a criterion of 300m walking distance -5 minutes walking- from the residence to the green space (Mathey, Rink, 2010) this space should be at least of 20000m² (UCL Institute of Health Equity, 2014).

- The Bristol Council developed accessible green space standards in which proposes 400m or 9 minutes walking distance to the nearest green area (UCL Institute of Health Equity, 2014).

- The European Common Indicator for open spaces, which are not specifically green areas but are based on similar metrics, proposes a 300m distance or 15 minunes walking to a 5000m² place. This last indicator is the concept implemented by the Istituto Nazionale di Statistiche Italiano and The Environmental European Agency (Ambiente Italia Research Institute, 2003).

In Turin, the greening per inhabitant is 21,93m², excluding agricultural areas[3] (Comune di Torino, 2018). This is in a global and general vision a value that fits with the WHO recommended indicator. None the less, seeing that a factor of distribution and accessibility is also considered, is precise to be more specific. For this reason, the guideline was appliyed over the different boroughs -ciscoscrizioni- of the city. The figure 27 shows the greening per capita and illustrates the political distribution with the green areas and population by zone.

It is visible how the boroughs 1 and 3 count respectively with just 7,63m² and 8,83m² of green areas per person (Comune di Torino, n.d.). This implicates a relevant deficit taking only into consideration the WHO value and not additional factors[4]. Consequently, green spaces should be added to at least reach the minimum value. Also, indicates which zones accomplish or not with the mentioned limits.

As it is shown in the figue 27, boroughs like the number 10, have visibly lesser area of UGS, but the number of people is less, meaning they are inside limits.

2 Urban Green Spaces, defined “as urban space covered by vegetation of any kind” including green roofs and facades (WHO, 2017).

3 Although the governance does not specify if green roofs are contemplated in their data, there is no public documentation from the entity mentioning the structures, which presumably means they are not considered. With the exception of two green roofs parks: the Environmental Park and the Living Art Park.

4 If additional factors were directly considered, probably more boroughs were demonstrate out of limits. However, by segregating the city in its political division, it can be say that the distrubution is indirectly considered.

GREENING PER CAPITA (sqm)	
CITY	VALUE
Barcelona	5,60
Turin	21,93
Rotterdam	28,30
Berlin	37,84
Krakow	65,45
Zurich	111,91
Edinburgh	144,59

Table 3. Cities exceeding the limited value of greenings. Turin has acceptable values but not the desirable. Source: (Haq, 2011; Vázquez, 2011; Levent and Nijkamp, 2004; Comune Torino, 2018)

Due to their several advantages, various cities around Europe have implemented greens on tops, initiatives for their construction and law regulations. Cities as Basel, Zurich, Berlin Stuttgart, Rotterdan and Paris are good examples of green roofing.

For 2013 Stuttgart counted with around 2.000.000m² of these systems (Peck, 2012).

Paris is implementing a plan to green 1.000.000m² of roofs and walls for 2020 (International Green Roof Association, 2015)

Rotterdam is expecting to reach a goal of 600,000m² of Green Roofs by 2025 (International Green Roof Association, 2015)

1.3 Green Roofs in Turin

Even though space is a valuable resource for cities, some areas are not properly exploited yet; rooftops exemplify this. Depending on the density of the city, 5% to 30% of the surface are rooftops (Peck, 2012) and usually, most of them are solely implemented as impervious coverages lacking additional functions.

Turin is a place of considerable constructed density and the majority of its roofing surfaces are underutilized spaces[5]. These coverings could be harness for productive use and by being "activated"[6], rooftops have the potential to be employed as environmentally friendly tools.

Around the territory, a scarce group of edifices holds greenings on their tops. Almost each of them belongs to young constructions, from the 2000s onwards. Actually, the first experiment with green covers in Italy was the Environmental Park one, which opened in Turin in 1999 (Environmental Park, 2019). The total area of greening over Turin's roofs is no more than 60.000m² [7,8], from which 20.000m² (Greenroofs, 2019) belong to the Environmental Park cover. Representing more than 30% of the total in the whole city.

5 "If we think flat roofs sealed with tar in a city as Turin covers over 20% of the surface and they are not used or accessible, we understand we are in front of a enormous potential, which exploded turns into a sustainable gesture and advantage for the comunity" (Bürklein, 2017)
6 Activated by green roofing, water haversting, intallation of photovotaic systems, etc.

7 Value stimated through the portfolios of the main designers and installation systems in Turin and also through satelital explorations. See table with the area in the appendix.
8 Compared to the Green Roof surface of Stuttgart, Turin has a poor area. Despite of the fact that Turin counts with twice Stuttgart's population density.

Figure 17
Casa Hollywood. Year 2013. Project form: Luciano Pia; Stefania Naretto, Chiara Otella (greens).
Retrieved 2020, from: www.openhousetorino.it

Figure 18
25 verde. Constructed in 2012 with 4000m2 of green roofs and terraces. Architect Luciano Pia (linee verdi, 2019). Retrieved 2020, from: www.due.to.it

Figure 19
Intensive green roof of Casa tra gli Alberi.
Retrieved 2020, from: www.openhousetorino.it

Figure 20
OrtoAlto Fondieria Ozanam.
Retrieved 2020, from: www.openhousetorino.it

Figure 21
Ludoteca il Panguro (2015). One of the firsts projects inside the ambit of Turin Smart Cities (Comune Torino, 2018)
Retrieved 2020, from: www.openhousetorino.it

Figure 22
Lavazza S.P.A. Intensive & extensive green covers (2017) covering a surface of 3000m^2.
Retrieved 2020, from: www.idealista.it © Cino Zucchi Architetti

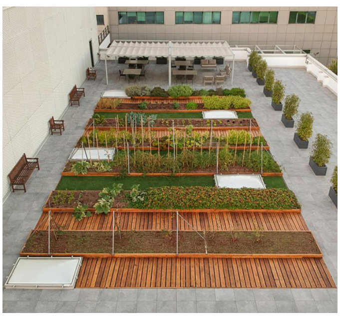


Figure 23
Codebò hanging garden for cultivation of various fresh vegetables
Retrieved 2020, from: www.codebo.itl © 2016 Codebò Spa

Figure 24
Environmental Park (1999). "...First eco-technological park in Europe dedicated to addressing problems of the built environment" (Ambasz, nd). Flat and pitched roofs, considered the largest one of Italy. These covers are publicly accessible and create a unitary landscape.
Retrieved 2020, from: www.greenroofs.com © 2019 Greenroofs.com, LLC.

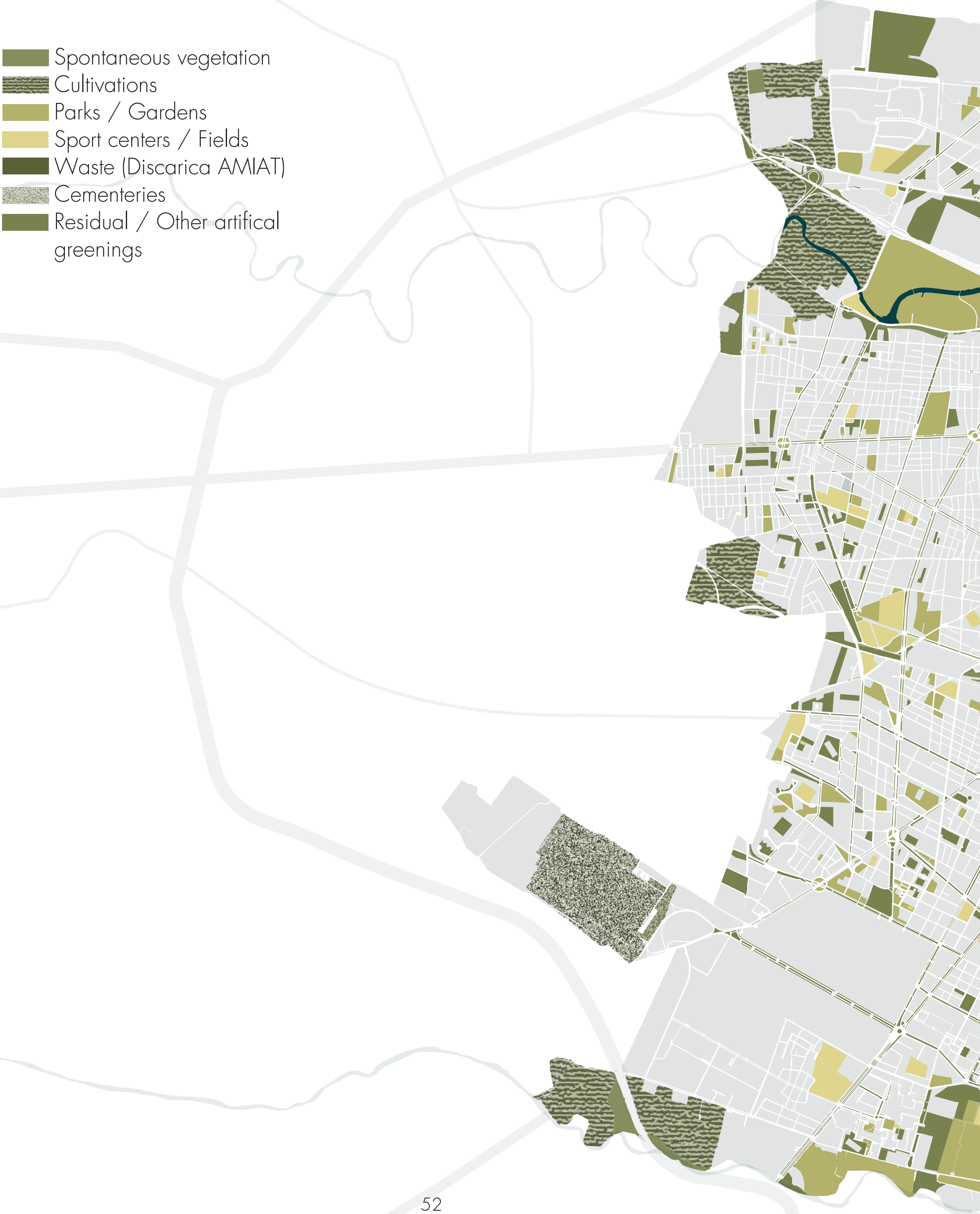
Figure 25
Living Art Park or Parco Arte Vivente (2008). Gianluca Cosmacini. The park is a green space in continue evolution
Retrieved 2020, from: www.parcoartevivente.it
www.culturaitalia.it © Cultura Italia

Figure 26

Green Areas in Turin

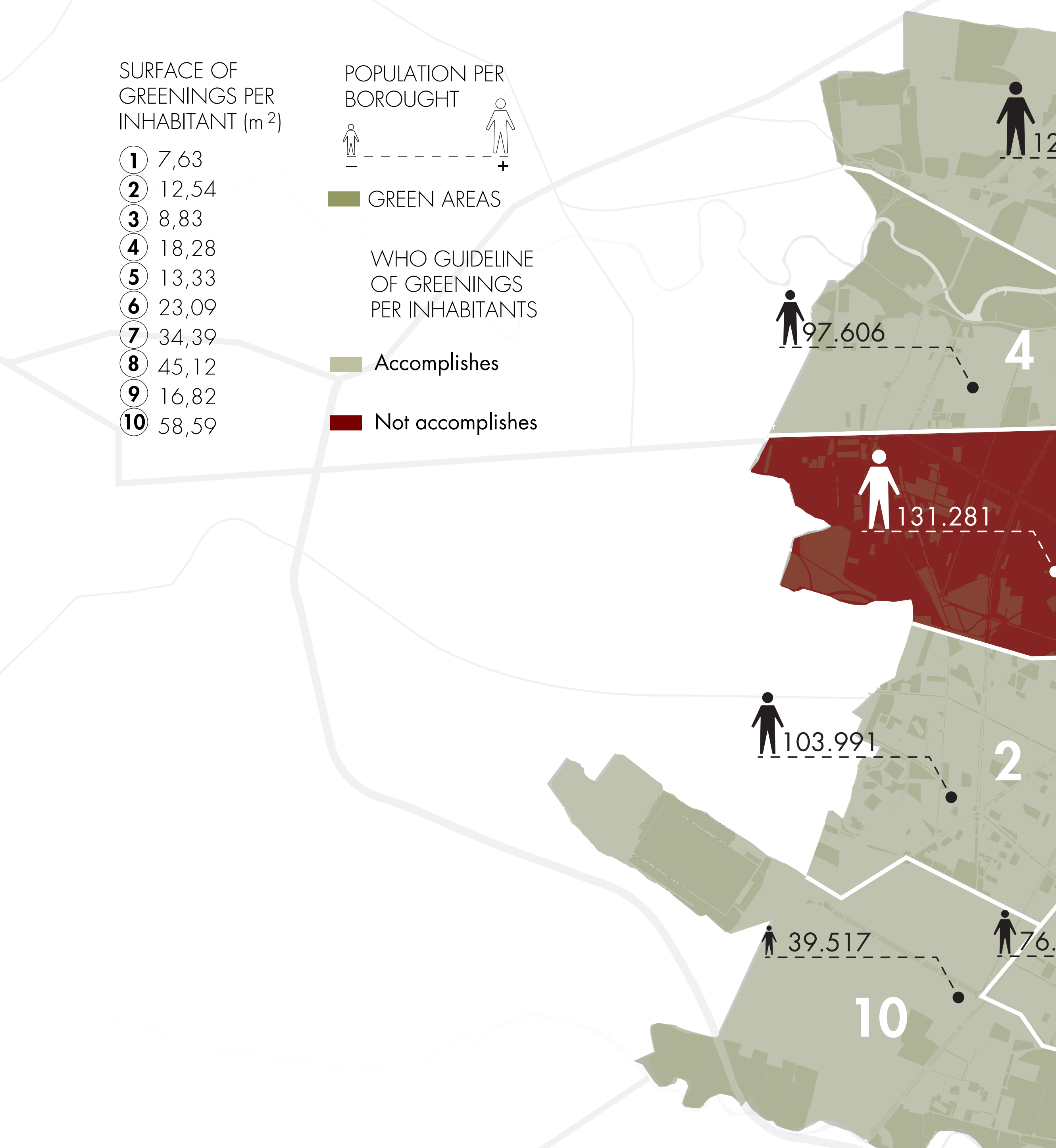
Green spaces in Turin, categorized for this report as: (1) Spontaneous vegetation which refers to naturally growth vegetation, (2) cultivation areas for agriculture, (3) parks and gardens, (4) sportive centers or fields, including Stadiums and sportive clubs, (5) waste management camp, particularly referred to the AMIAT area, (6) cementeries and (7) residual and other artificial areas in which are represented spaces outside the previous categories.

Note: Elaborated by the author based on Google Earth (2020) and QGIS. Vectors extracted from the Regione Piemonte (2019). Identificator: c_l219:62260436-0fda-49f0-8faa-f31f7a314c22_resource




1Km

Figure 27
Green area per population per borough. Turin.
The illustration shows the political areas that accomplish the minimum limit according to the cited WHO guideline, according to the European Commision (2016). It is considered the vegetation and the population per place.
Elaborated by the author. Based on ZinCo (2020); Harpo group (2020); Design Tanzi Architetti (2021); Open House Torino (2019); Google Earth (2020); Regione Piemonte (2020); Comune di Torino (2019) and European Commision (n.d.).



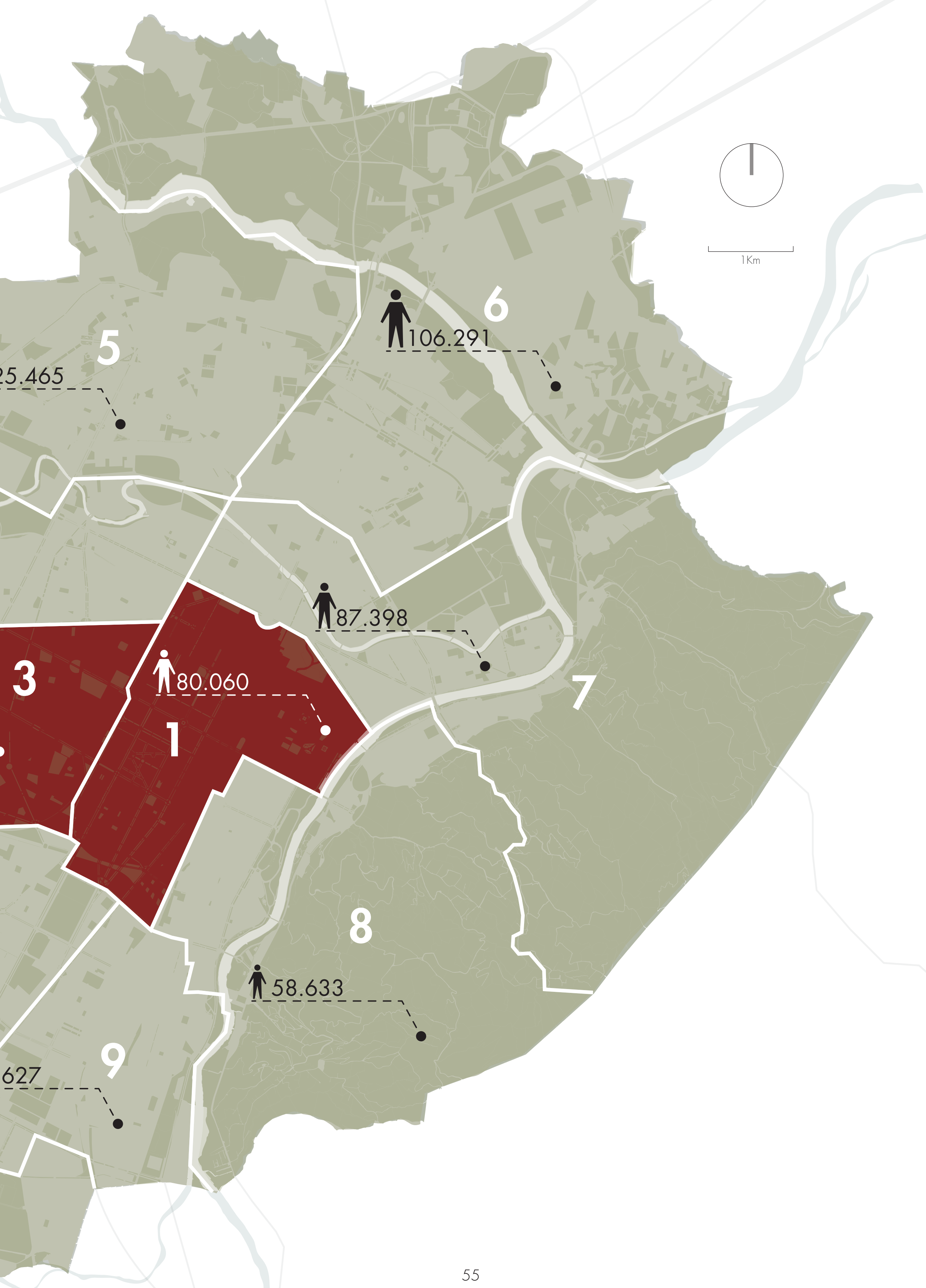
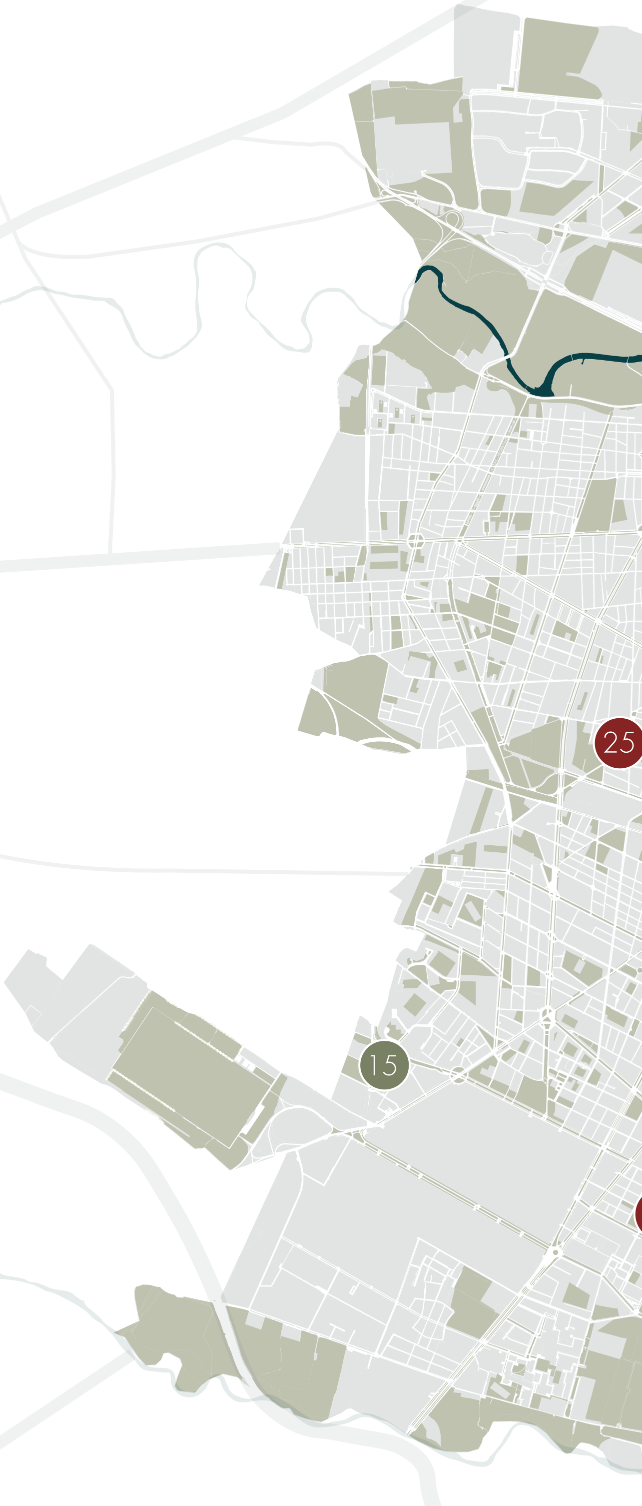

6
106.291
5
25.465
87.398
3
80.060
1
7
8
58.633
9
627
1Km

Figure 28
Living rooftops in Turin.
Localization of currently existing green roofs around the territory, future projects, feasability assessments and hypothesized green cover spots. These last ones refering to living gardens found through satelital visualizations which cannot certainly be identified as artificial or natural.
Elaborated by the author. Based on ZinCo (2020); Harpo group (2020); OrtoAlto (2020); Studio 999 (2020); Open House Torino (2019); Google Earth (n.d.); Geoportale Torino (2020); Comune di Torino (2019) and European Commision (2016).

GREEN ROOFS
GR PROJECTS / FEASIBILITY STUDIES
GREEN ROOFS (HYPOTESIS)
VEGETATION
BUILDED

1. Casa Hollywood
2. Environment Park
3. Condominio 25 verde
4. La casa tra gli alberi
5. Ludoteca il Paguro
6. Ortoalto
7. Ecocentro Amiat
8. Studio 999
9. Basic Village
10. Hotel NH Carlina
11. OrtoAlti Via Baltea
12. Scuola Materna Bay
13. OrtoAlto Mercato Metropolitano
14. Lavazza Spa
15. Codebò S.P.A
16. Living Art Park
17. Palazzo Casana
18. Privato - Via Luigi Chiala
19. Santander Bank
20. UnipolSai Assicurazioni
21. Games Center
22. Privato - Corso Massimo d'Azeglio 53
23. Ente di Formazione Professionale
24. Privato - Via Garessio
25. Privato - Via Issiglio
26. Privato - Via Monte Pasubio 39a
27. Sports Center College of St. Joseph




1Km
6
11
2
14
9
7
1
13
5
17
10
27
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8
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18

2. Climatic context

A place's climatic context is correlated to the agronomic capacity. Its analysis stands as an integral part of the instructions for roof greening design, according to the Italian Normative UNI 11235. Conditions as humidity, temperature, precipitation, and sun path affect plant's enhancement. Whilst strong winds, light absence, and further extreme conditions may reduce their survivability rates. Overall, Turin belongs to a Cfa group in Köppen's[9] climatic classification (Dahl, Pollo, Thiébat, Micono, & Zanzottera, 2019). Indicating a temperate climate with humid warm summers – average mean temperature during the warmest month lower than 22 °C - and absence of dry months at the mentioned period (Riva, Riva, & Vaccaro, 2012). Actually, precipitations happen to be evenly distributed throughout the year (Encyclopædia Britannica, 2020).

2.1 Hydrometeors:

The action of watering vegetation plays a role in the photosynthetic process and the acquisition of nutrients and sugars. For this action, the consideration of H2O quantity and frequency are as essential as its quality. Variables as pH[10] and hardness[11] acquire relevance to establishing the last mentioned point. The desirable pH for succulent irrigation should be slightly acid, ranging from 5 to 6,7. Instead, the recommended hardness degree must stand beneath 10°dH[12] (Becherer, 2005). Additional sources approve the implementation of a maximum of 18°dH of tap water (Uhlig, 2005). Fortunately, stormwater is soft and accomplishes both qualities, which is why is perfect for the purpose.

An overnight harvested rain sample [May 8th, 2020 from 21:00 to 7:00] was tested to define its quality. The use of ethylenediaminetetraacetic acid (EDTA) titrant solution, brand Titrant ® was implemented to test hardness. In order to recognize the nature of the water, drops of the solution must be applied in 5ml of the sample until color changes from red to blue. In doing so, it is possible to measure the degrees of hardiness. Each drop represents 1 °fH. By applying one drop to the sample, the water turned immediately blue, meaning <0,562 °dH and implying the collected water is soft[13]. Subsequently, the pH was tested through a pH Meter pen from the brand ATC ®, resulting in 7,09. This value overpassed slightly the cited recommendation, by + 0,39. The procedure was repeated in a sample of regular tap water, resulting in 8,02pH and moderately hard water [around 7,9°dH]. As a consequence, stormwater appears to be more favorable.

Sedums demand diminished amounts of liquid as they possess their own hydration storage tank in leaves and stems (Kellum, 2008). Drought does not adversely affect their performance and results unnecessary to water them during

9 Wladimir Köppen system are codes representing an empyrical classification of terrestrial climates, based on average monthly or annual precipitacion and temperature data. The major groups classification include [A, B, C, D & E]. (Koppen, 1936)
10 Although pH definition is widely discussed, in this case pH is intended as the logarithmic value that exhibits the alkalinity and acidity of an aqueous substance (Cambridge University Press, 2020)
11 Water hardness indicates the measured content of divalent cations; mainly calcium and magnesium ions (Boyd, 1979).

12 [°dH] German degrees - Deutsche Härte. [°fH] French degree. French degree conversion factor = 0,562 °dH
13 One °dH is esquivalent to 17,8 mg/L as $CaCO_3$ and one °fH to 10 mg/L as $CaCO_3$. Based on mg/L $CaCO_3$, water is classified as soft [0 - 75], moderately hard [75 - 150], hard [150 -300] and very hard [>300] (Spellman, 2009).

the winter season[14] (Uhlig, 2005). In fact, these plant's survivability on extensive green roofs is satisfactory in the absence of irrigation since they can withstand over 3 weeks of dry, maintaining their visual aspect (Sharma, Gardner, & Begbie, 2018). Respecting the quantities, potted sedums are highly endorsed to water until the soil soaks thoroughly (Tuttle, 2015), whereas sources suggest stormwater is enough for local plants (Sharma, Gardner, & Begbie, 2018). However, it is advised to irrigate in summer if precipitation depth is shallower than 1 inch every 7 days (National Gardening Association, 2019) while Coronado establishes to irrigate hardy Sedums every 2 weeks in the same season if weather is dry and states soaking is unnecessary (Coronado, 2014). It also exists a relation between the growing media depth and watering; test concluded that succulents in a 2cm depth needed water after 14 days while the ones in 6cm media lived within a regime of water each 28 days[15] (VanWoert N., Rowe, Andersen, Rugh, & Xiao, 2005). Naturally, a greater volume implies a width storage room.

To sum up, green coverage will require a minimum water presence at least every 14 days (2 weeks) during summer and every 28 days (4 weeks) the remaining time, excluding the dormancy period. For the establishment of a referential value, it was determined the soaking point[16] of a potted *Sedum* substrate of 119,32cm^3 volume. In this case, the needed aqueous content to allow water to soak was 0,037L, meaning by proportionality[17] that the required value for an 8cm depth substrate will be approximately 24,8L/m^2. This value matches the recommendation of 1inch[18] (National Gardening Association, 2019).

Is of utmost importance to acquainting the amount of precipitation in the zone to ensure vegetation productivity. By collecting rain records and comparing them to the referential value, it is expected to establish an approximation of the sufficiency of natural water discharge for plant feeding. As can be seen, the following bar chart in figure 29 illustrates days of rain and fallen millimeters per week, plotted throughout a three-year lapse [2017-2019]. In the graphic, scarce water periods in regard to the recommended frequency are highlighted[19]: (a) In summer, if the reference value was not reached for two or more consecutive weeks and (b) in the remained seasons if the reference was not reached through four or more continuous weeks.

The moments of major relevance for sedum's hydration are the vegetative

14 Uligh states that is preferred to avoid irrigation during winter for local hardy Sedums in view of the correspondance of the period with their natural media. By reducing the water input in the mentioned season, the minerals and nutrients concentrate in the plant tissue and cells, difficulting freezing process.

15 The authors assert that Sedums in extensive green covers migh survive 88 days drought, but is recommended a 28 days period.

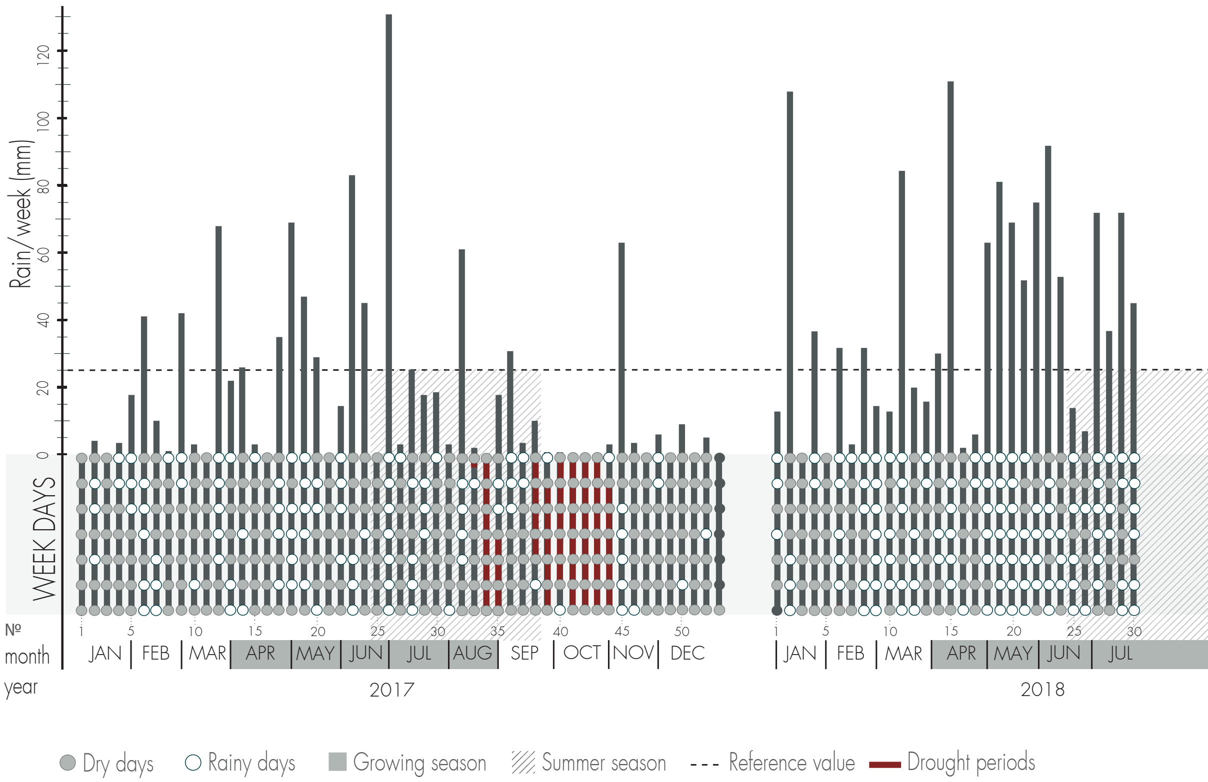
16 The term is defined as "Extremely wet; wet through." (Oxford, 2020). For this investigation, the soaking point was defined as the quantity of liquid necessary to make soil soaks.

17 The volume of 1 square meter with 8cm depth is 80000cm^3. Cross-multipliying, it is possible to obtain the amount of water needed to reach the soaking point of that volume of substrate. However, the value is only referencial because the soil compositon and root space variates.

18 [1in]=25,4mm. In mm of stormwater it represents 25,4L of water per square meter. Rounding down this is equal to 25L/m^2. While if the 24,8L/m^2 of water needed to soaks are rounded up, the result is the same.

19 Highlighted to generate a visualization (approximative) of insufficient rain periods.

Figure 29.1
Analisys of precipitation depth in Turin from 2017 to 2019



The figure shows the precipitation during a three year period in relation with *Sedum* irrigation requisites of frequency of irrigation and quantity of water. The bargraph indicates days of rain, periods of absolute water lacking and the amount of the weekly precipitation depth. Based on the quantity of water needed for the named plant specie.

Note: Elaborated by the author. Based on the collected information in the current chapter about watering requisites for Sedum and in climatic data from the meteorological agency 3B Meteo (2020).

growth season and summertime; moments defined by their productivity cycle and higher environmental temperatures. In the course of both periods, stormwater was recurrent (almost weekly rain events) and the precipitation depth tended to be elevated. Then, the guideline was exceeded in nearly all cases, having a few exceptions. Some of the highlighted cases in that lapse were together days of enough water accumulation. For instance, in 2018 [from week 33 to 35], rain depth rose near the limit and their accumulative mm in a 10 days interval surpassed it. In contrast, periods of critical drought were present the rest of the seasons. 2017 had especially lesser precipitation depth along with the record of the greatest number of consecutive dry days ever registered in Turin (Stazione Meteo Amatoriale, 2019). Twelve continuous days of devoid took place that year during summer [from weeks 33-35], but the highest scarcity of all three years elapsed in winter and/or spring, meaning that those drought periods happened essentially during

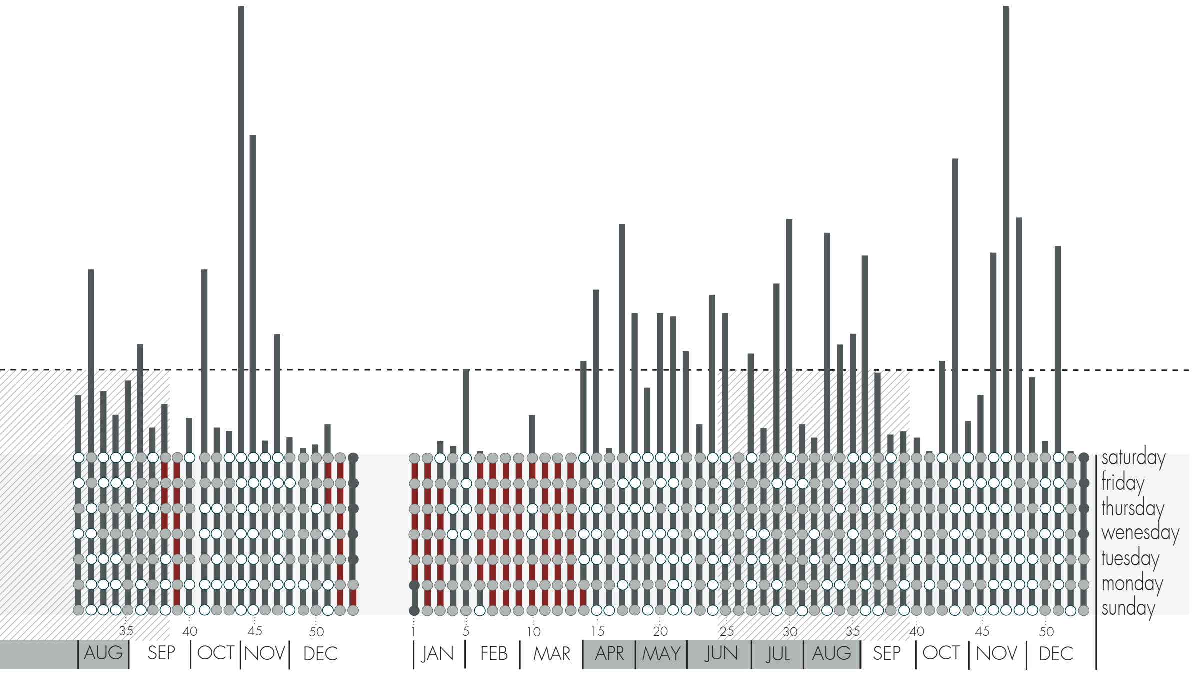
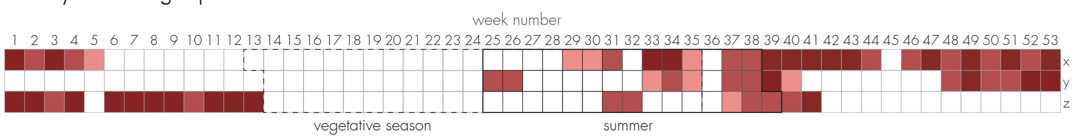


Figure 29.2
Analisys of drought periods



■ Total drought ≤ 2,9 mm ■ Partial drought A (3 - 14,9) mm ■ Partial drought B (15 - 25) mm [x] year 2017 [y] year 2018 [z] year 2019

Note: Elaborated by the author. Based on weekly precipitation of Turin [fig. x.1] and complementary to it

sedum's dormancy when less water is required. Thus, precipitation alone might not be enough for watering and it might need to be complemented with the existence of a storage layer or a water tank, which will perhaps eliminate manual irrigation needs.

For years, the influence of humidity upon vegetation development was not confirmed. However, recent findings have proven how atmospheric moisture is an environmental factor of significance in plant enhancement.

Relative humidity[20] (RH) has a direct effect on the stomatal opening[21] and transpirational water loss. As well as a more indirect effect in the regulation of nutrient translocation and plant water potential.

20 The relative humidity is a percentual value, denoted by the amount of water vapor in the atmosphere, in a particular moment, and the maximum that could be contained in the same moment. In saturation point, RH is 100% (Cortés Enríquez, 1994)
21 The stomatal aperture indicates the level of opening or closure of the stomas - micro pores in the epidermis of leaves or stems (Oxford, 2020)

Evapotranspiration (ET) is a phenomenon that includes the transpiration of water vapor through the plant leaves and the evaporation of contained water in the soil surface. This is a necessary process for correct vegetation functionality and consequently, a greater green coverage performance.

A lower RH in combination with other parameters as the temperature may enhance the evapotranspiration process (Cascone, Coma, Gagliano, & Pérez, 2018). In specific, lower moisture in the atmosphere augments the vapor difference[22] Δe between the air and moist in the leaf surface that parallelly increases Additional changes of slight relation with humidity are water potential and nutrient presence. Experiments have demonstrated how a more negative water potential was reflected on most of the plants with a greater Δe (Tibbitts, 1979). Different tests demonstrated that nutrient translocation for particular vegetation species could be modified due to their relation with the atmospheric moisture. The nutrient content of Ca and K in plant leaves was reduced by moisture increasing (Mortensen, Selmer-Olsen, & Gisleröd, 1987).

Since it is required a satisfactory stomatal circulation and an adequate ET, it is better to avoid constant exposure to extreme humidity. Essentially during productive seasons. In Turin, the levels of RH stood moderate through the whole year in general, as it is visible in table 4. In particular during summer and the growing season. Only one month each year exhibited mean moisture rising to 80% or above. This last value is relatively a high humidity rate, which took

Table 4

Relative humidity [%] in Turin. (2017-2019)

01	02	03	04	05	06	07	08	09	10	11	12	MTH/Yr.
60	80	56	56	59	59	55	58	60	61	68	67	2017
74	70	71	60	71	60	61	58	66	74	84	72	2018
61	60	44	60	63	58	60	66	68	77	85	75	2019

■ Growing period ■ Summer time ■ RH ≥ 80%

Levels of monthly mean relative humidity over a three year period + *Sedum's* productive epochs.
Note: Elaborated by the author. Based on climate data from the Meteorological Station of the Università degli Studi di Torino. (Stazione Meteorologica di Fisica dell'Atmosfera, 2020)

place in colder seasons. Moments of minor interest for hardy sedums processes.

2.2 Atmospheric temperature and sun derivated effects:

Environmental factors as temperature and light intensity are extremely correlated with plants metabolic processes. The level of sun radiation is the key component for respirational and photosynthetic operations, whereas temperature is mainly linked to respiration, but it also might limit the photosynthesis if low temperatures are combined with other factors. For example, if low temperatures occur during short growing periods (Cascone, Coma, Gagliano, & Pérez, 2018; Tooley & Sheail, 2019).

A greater solar radiation will improve the mentioned vegetative processes. Especially if it is presented within the proper sky condition, seeing that the turbidity of the atmosphere defines the amount of sun radiance absorbed by clouds and the one reaching earth surface. Insolation contributes at warming the atmosphere and parallelly, a rise of air temperature causes an incrementation of transpirational cooling rates. By augmenting the heat, the vapor pressure difference (Δe) between plant and air increases. Also, warmth

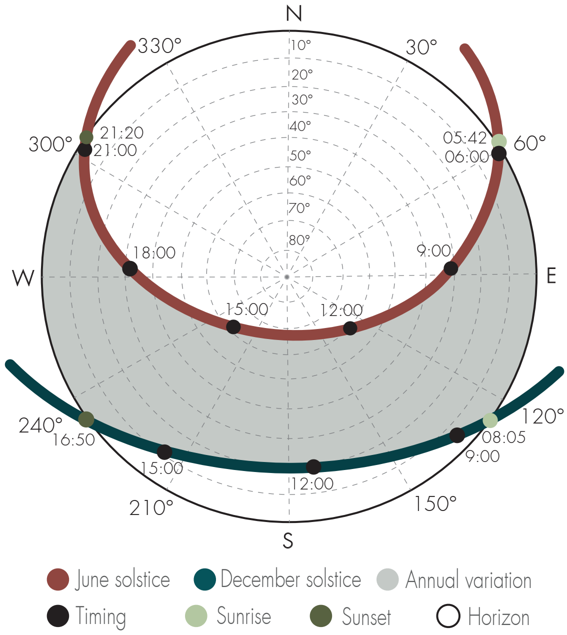
22 The vapor pressure difference or deficit "...is the difference between saturant vapor pressure and current vapor pressure" (Cortés Enríquez, 1994)

provokes wider stomata openings, which accelerates the phenomena as well. Thereby, vegetative roofing enhances a better performance during sunny summer days in respect to sunny winter ones due to the intensified sun radiation input and the heat during that period (Tibbitts, 1979; Cascone, Coma, Gagliano, & Pérez, 2018). Other related factor of relevance are the hours of lighting exposition. Reports (Moore Kelaidis, 2012) cite that for the achievement of the right flowering and growing functions, most winter hardy succulents necessitate 8-12 h of midsummer sun exposure. The critical photoperiod to release from dormancy is about 15h during a 4 day-cycle which resulted in the same the same for flowering (Heide, 2008).

A conducted test (Secretary of Agriculture, Association of Land-grant Colleges and Universities, 1931) about flowering had yielded similar results. Sedums exposed to shorter day lengths [less than 10 h of sun] during 9 years had inhibited flower growth, whereas after a change in the regime [more than 12h and full summer day length] flowering was finally exhibited.

As in many places, sunshine length variation in Turin depends on the period of the year; the longest days found in the month of June 15 light hours. Indicating an ideal photoperiod, even for succulent's blossom and confirms a dormant-tendency in colder seasons. As it is shown in the stereographic sun path diagram in figure 30, in approximation, sun rises at 6:00 and sets at 21:00 during this season. By the contrary, winter days are short-length ones, of 6-8 hours. In this period sun hides at 17:00 and rises around 8:00.

Figure 30
Stereographic sun path diagram of Turin



The diagram shows the yearly variation, based on the solstices. The azimuth angles represent the horizontal path while the concentric circles represent the altitude.
Adapted by the author. Original retrieved 2020, from: www.gaisma.com

Figure 31.1
Example of shadow by sun altitude - December 21th

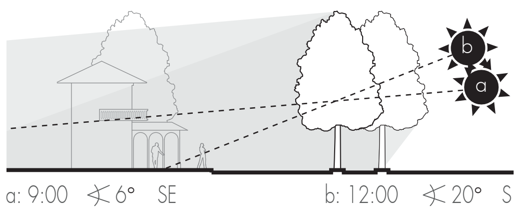
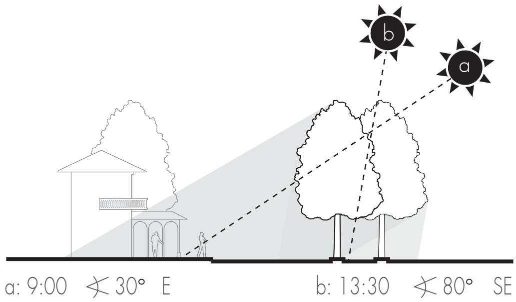


Figure 31.2
Example of shadow by sun altitude - June 21th



Scheme sections of a typical street of Turin, illustrating examples of sun inclination during the solstices in the morning and mid-day. Elaborated by the author.

The sun route varies seasonally too. The maximum reached vertical inclination during December's solstice is 20° [fig. 31.1] and in June's solstice 80° [fig. 31.2]. Variations of day light hours and sun path will determine the percentage of shadowing over horizontal and vertical surfaces; longer shodowing projections are presented in winter time, meaning that surrounding volumes could reduce light exposition even more. For this recomended to study the height and shadowing over a detailed context.

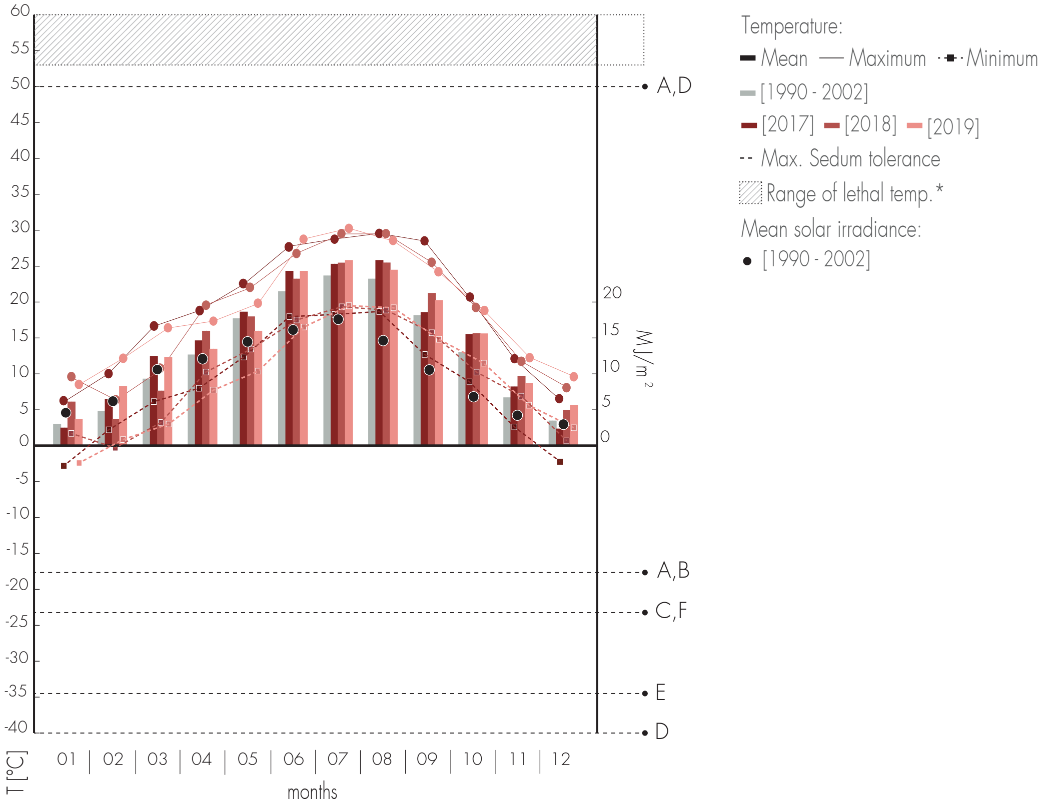
Temperature tolerance of plants depends on their species and type. By approximating to their maximum tolerance, vegetation may suffer injuries while surpassing it leads to their mortality. In spite of this, numerous species are able to develop certain frost and heat resistance. It has been proven that several species possess acclimatizing abilities, especially if exposition is gradual (Tooley & Sheail, 2019; Iles & Agnew, 1995). The amelioration of resistance adaptation can be induced too, for instance, after a constant exposure to low growth and regrowth temperatures and successively, a lower treatment over fall and winter (Precht, Christophersen, Hensel, & Larcher, 1973; Iles & Agnew, 1995). Hardy Sedums possess elevated resistance to extreme conditions and the capacity to acclimate. This ability functions in great measure due to specific plant organs that promote their regeneration like crowns, rhizomes or stolons (Iles & Agnew, 1995).

A study in Guangzhou area (Cfa in Köppen classification) by Tang, Guo and Kiu, revealed the mean heat lethal point of 7 sedum species[23] for green roofs. In this investigation, results provided a maximum of [53,05 - 60,90] °C as their lethality range (Tang, Guo, & Liu, 2013; Ruddle & Zhong, 1988). A second research (Zhao, Son, & Kang, 2012) about hot tolerance for Sedum extensive covers indicated that an increasing in substrate water content, intensifies the heat resistance property and plant water content reductions is correlated with an increment in frost tolerance for some plants (Iles & Agnew, 1995). Findings assert that resistance fluctuates in correspondence to the season. In specific, sedum montanum and Sedum spurium heat resistant exhibit a heat tolerance rising during summer and a cold resistance in winter (Precht, Christophersen, Hensel, & Larcher, 1973). Tests with the scope of define cold acclimation over two Sedum species tissues (Iles & Agnew, 1995) proved how frost resistance in September was limited to -3 °C. Nonetheless, through a gradual acclimatization treatment, each species reached their topmost tolerance in January, when killing temperatures for Sedum Autumn Joy was -27 °C and for Sedum spectabile Boreau. 'Brilliant' was -21 °C.

The bargraph in figure 32 shows the tolerance to extreme air temperatures of a variety of succulents. In the graph, the maximum heat resistance of the specific hardy Sedums is delimited under the following conditions: if the survivability rate was 100% and with a water soil content of 15%. On the other hand, frost tolerance is aligned to existing American standards, which identify the plants that are more likely

23 Including: *Murdannia loriformis, Tradescantia spathacea, Sedum lineare, Setcreasea purpurea, Sedum polytrichoides, Sedum emarginatum* & *Callisia repens.*

Figure 32
Turin air temperature in contrast to heat & frost tolerance of diverse Sedum species + solar irradiace



Particular species include [A]: *Sedum album*, [B]: *Sedum acre*, [C]: *Sedum sexangulare*, [D]: *Sedum reflexum*, [E]: *Sedum hybridum Czar's gold*, [F]: *Sedum dasyphyllum*. [*] See footnote 14. Note: Elaborated by the author, based on the USDA plant hardiness, climatic data from the city and additional sources about tolerance (Flora Italiana, 2020; United States Dipartment of Agriculture, 2020; Zhao, Son & Kang, 2012; Tang, Guo & Liu, 2013; McGourty, Harper, 1982; il meteo, 2020; Stazione Meteorologica di Fisica dell'Atmosfera, 2020, Provincia di Torino, 2003).

to thrive in locations with a certain temperature range. This standard serves as reference to determine the range of average minimum temperatures that the tissue can resist. For the graphic there were considered the minimum values instead of the ranges.

As expected by their correlation, the behavior among air temperature and sun irradiance patterns is consistent. The peak of either case is reached in mid-summer, and mean monthly temperature variations are gradual. For this reason and as expected, the greatest potential of the green cover transpiration cooling effect and photosynthesis will be achieved in that epoch, from month 5 to 9. Especially during midsummer. What is more, the survivability potential for hardy succulents will be elevated since observed temperature variations are modest and the gap between maximum/minimum temperatures and limit resistances surpassed in every case the ±15 °C. It can be hypothesized that since temperature changes are progressive, acclimation would be favored even for not local species.

2.3 Wind climatology:

The action of air in motion upon cultivated foliage is a topic of relevance. Especially for green roofs, which tend to receive a more direct wind force by their elevation[24]. A negative consequence of wind speed is that strong gusts could cause mechanical damages in cultivations (Cortés Enríquez, 1994). Heavy winds may originate broken roots, deformations or additional affections. If they are presented at extremely low temperatures -and mostly, over nonnative species,- strong gusts may lead to desiccation. Conversely, air motion at lower speeds could be advantageous. For example, breezes contribute to the vegetative enhancement and its spreading though pollen and seed's displacements. Also, winds provoke the dissipation of damaging pollutants (Whitehead, 1961; Cortés Enríquez, 1994).

Winds promote the development of cultivated plants by increasing the evaporation and regulating temperatures. The water vapor generated by greenery, requires constant air exchanges because the continuous vaporization (due to ET phenomenon) saturates the soil surface (Cascone, Coma, Gagliano, & Pérez, 2018). This vapor needs to be replaced by drier air, allowing the progression of the process. One experiment (Schweitzer & Erell, 2014) demonstrated that a variation of wind speed[25] from 0,1 $m \cdot s^{-1}$ to 1 $m \cdot s^{-1}$ heightened the ET rate from 10% to 30%. While a different investigation (Tabares-Velasco & Srebric, 2011) concluded that a higher wind speed [5 $m \cdot s^{-1}$] improved the ET over a 2$m \cdot s^{-1}$. Having stated that, various investigators have contrasted that the average weight and leaf area of plants is reduced at a greater wind pace, and water loss rises at the mentioned conditions as well (Withehead, 1961). The plants were tested at [0,5 $m \cdot s^{-1}$; 4 $m \cdot s^{-1}$; 8,5 $m \cdot s^{-1}$ and 14,8 $m \cdot s^{-1}$] speeds. The average leaf area at the lowest speed resulted many times higher and the dry weight of plants was also greater at lower speeds. As it was also mentioned, there were perceptible changes in the water balance. Plants exposed to major wind speed presented greater shoot water loss but a greater root production.

Two components (velocity and direction) were considered to make a general evaluation of winds in Turin. For this, speed data was collected and contrasted with the Beaufort wind scale[26] [table x]. The averages only showed oscillations from scale 1 [light air] to scale 2 [light breeze], which on land conditions implies: Barely visible motion through smoke and perceptible on exposed skin, respectively. Instead, the maximum gust peak during the three years was 16,3 $m \cdot s^{-1}$, registered the 22 of December 2019 at 14:15. This is classified as high-speed force in Beaufort scale but is not a constant value, either the strongest intensity degree in the scale. Additional records, from year 1990 to 2000, registered a greater number of days of weak winds [1 $m \cdot s^{-1}$ to 2,5 $m \cdot s^{-1}$] over stronger

24 Wind friction could be reduced at a major height because contact with surfaces is lesser, compared to ground floor.

25 $m \cdot s^{-1} = m/s$

26 Beaufort Scale is a wind force classification in respect to land and/or sea the cathegories range from zero to twelve. In $m \cdot s^{-1}$ scales are: 0 [<0,3]; 1 [0,3-1,5]; 2 [1,5-3,3]; 3 [3,3-5,5]; 4 [5,5-8]; 5 [8-11]; 6 [11-14]; 7 [14-17]; 8 [17-20]; 9 [21-24]; 10 [25-28]; 11 [29-32] & 12 [>33 or equal]. The lowest scale represents "calm" while the highest refers to "hurricane" (Horstmeyer, 2011)

intensities and the mean annual wind velocity, from 2006 to 2018, ranged from [1,3 to 2,0] m·s⁻¹ with a total average of 1,8 m·s⁻¹ (Comune di Torino, 2020) (Agenzia Regionale per la Protezione Ambientale, 2007).

The component direction is also illustrated [fig. x]. This graphic reveals the provenance of horizontal air masses in Turin and their frequency. The most frequent are breezes arriving from the east-northeast, with 24%-14%. This usually refers to continental dry air masses. Followed by air proceeding from the septentrional zone -which tend to be cold polar breezes- and winds from south-southwest -which is mainly humid warm air from Mediterranean- (Agenzia Regionale per la Protezione Ambientale, 2020).

To summarize, Turin's wind velocity can be described as constant presence of light air motion with eventual high-speed peaks. Calmness of air in the city is not weak enough to impede plant's enhancement and neither gusts are sufficiently strong to cause injures in hardy succulents. Instead, plant growing will be stimulated and the exchange of air will favor the ET, provoking an improved cooling effect. Since exposure to high speed gusts is less frequent and by considering the parameter temperature, it can be noted that chances of desiccation or further mechanical damages are excluded. As a conclusion, winds seem advantageous for roof greenery but their direction must be contrasted with the specific building location to study possible barriers.

Table 5

Wind velocity

month	2017 a	2017 b	2017 c	2018 a	2018 b	2018 c	2019 a	2019 b	2019 c
J	1,3	2,1	13,6	1,3	2,2	11,7	1,3	2,1	13,1
F	1,2	2,1	12,6	1,2	2,0	8,8	1,3	2,1	12,5
M	1,6	2,6	14,2	1,3	2,3	10,1	1,6	2,6	15,3
A	1,7	2,6	13,0	1,4	2,4	11,0	1,6	2,6	11,0
M	1,6	2,6	11,3	1,3	2,3	15,2	1,4	2,4	13,0
J	1,6	2,6	14,9	1,3	2,3	12,3	1,4	2,3	15,6
J	1,6	2,6	14,9	1,5	2,4	11,6	1,5	2,5	16,0
A	1,5	2,5	13,0	1,4	2,3	12,0	1,3	2,2	12,0
S	1,4	2,4	11,5	1,3	2,2	10,2	1,2	2,1	9,4
O	1,1	2,0	14,1	1,2	2,1	14,4	1,1	2,0	10,6
N	1,1	1,9	12,0	1,1	1,9	7,7	1,3	2,1	10,0
D	1,3	2,2	13,1	1,2	2,1	13,8	1,3	2,2	16,3
mean	1,4	2,4		1,3	2,2		1,4	2,3	

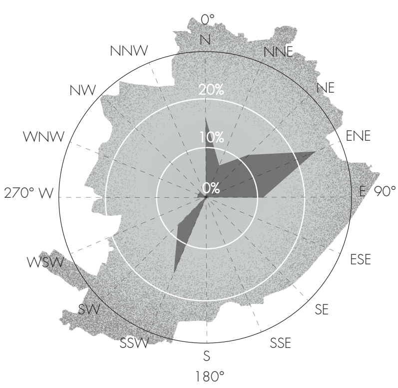
1 2 4 5 6 7 Beaufort scale

a mean wind speed
b mean gust speed
c max. gusts speed in month

Monthly wind velocity [m·s⁻¹] in Turin, focused in a 3-year period [2017-2019]. The table exhibits mean and maximum speeds in specific moments of the month. The table contrasts speeds w/ the Beaufort Scale.
Note: Author's elaboration. Based on climate data from the Meteorological Station of the Università degli Studi di Torino. (Stazione Meteorologica di Fisica dell'Atmosfera, 2020) and the Beaufort Wind Force Scale (Horstmeyer, 2011)

Figure 33

Frequency of wind direction



wind procedence

Turin's 16 - wind compass rose w/ percentage of frequency of the wind direction procedence (vertical axis).
Note: Adapted by the author. Based on wind rose from Arpa Piemonte (Agenzia Regionale per la Protezione Ambientale. Dipartamento Sistemi Previsionali)

3. Air pollution[27]:

Vegetative covers possess the capacity to remove air pollutants which are responsible of causing perturbations in the environment. It is widely spread how a constant exposure to high levels of this kind of contaminants is harmful to human health. Nevertheless, seeing that plants absorb air contamination, the phenomenon can become prejudicial to them as well if levels are critic. They may uptake aerial polluters either directly from air through stomata or from soil's moisture, through the roots.

Greenings can be especially affected by elevated levels of Sulphur Dioxide (SO_2) and Ozone (O_3), but Nitrogen Oxides[28] (NOx) and heavy metals as Cadmium can be also damaging, generating visible injuries[29] or growth suppression (Kumar, 1993). In particular, Kumar mentions that the SO_2 might cause affections in leaves and provoke their drop off, or interrupt blossom and shoot growing, leading eventually to dead after extreme exposures. On the other hand, O_3 destroys chlorophyll, reducing the rates of photosynthesis and consequently, respiration. Instead, the effect of Cadmium is limited to reduce growth.

The effects that nitrogen oxides exert on plants are much complex to enlist. Mainly because it is harmless if the specimen possess the capacity to metabolize it. Seeing that N is a macronutrient for greenings,

27 Units of air pollution are usually measured in micrograms (one-millionth of a gram) per cubic meter air or $\mu g/m^3$. In the case of Cadmium, the cited reports measured it in ng/m^3.
1 microgram (ug) = 0.000001 gram
1 nanogram (ng) = 0.000000001 gram
28 NOx is a generic term for the most commonly nitrogen oxides in air pollution: NO and NO_2
29 Such as leaf damages by loss of chlorophyll, necrosis, bleaching and glassening (Kumar, 1993)

Table 6.1

Air pollutants in Turin (2017-2019)

POLLUTER	UNIT	2017	2018	2019
SO_2	$\mu g/m^3$	7[y]	7[y]	7[y]
O_3	$\mu g/m^3$	7[z]	47[z]	18[z]
NO_2	$\mu g/m^3$	40[z]	35[y]	53[y]
Cadmium	ng/m^3	0,15[y]	0,10[y]	0,10[y]
PM_{10}	$\mu g/m^3$	43[y]	33[y]	28[y]
$PM_{2,5}$	$\mu g/m^3$	27[y]	21[y]	19[y]
NUMBER OF DAYS THE LIMIT VALUE WAS SUPARSSED				
PM_{10}	-	108[y]	55[y]	45[y]
		MEAN [2017-2019]		
O_3	-		49[z]	

The table reflects the mean annual air pollution values. Exceeded limits are shown in red. [y - z] Measurement stations. [y] Station of la Consolata. Via Consolata, 10 - TO. [z] Station of Lingotto. Via A. Monti, 21 - TO.
Note: Elaborated by the author, based on ARPA reports (Agenzia Regionale per la Protezione Ambientale, 2017-19), Italian Normative (Decreto Legislativo 155 [D. Lgs], 2010) and WHO standards (World Health Organization [WHO], 2005).

Table 6.2

Air pollution guideline

POLLUTER	GUIDELINE	UNIT	NUMBER OF TIMES LIMIT CAN BE SURPASSED
SO_2	20[bx]	$\mu g/m^3$	-
O_3	120[ax**]	$\mu g/m^3$	25**
NO_2	40[ax]	$\mu g/m^3$	-
NOx	30[bx]	$\mu g/m^3$	-
Cadmium	5[ax*]	ng/m^3	-
PM_{10}	20[ay]	$\mu g/m^3$	-
PM_{10}	40[ax]	$\mu g/m^3$	35[1]
$PM_{2,5}$	10[ay]	$\mu g/m^3$	-
$PM_{2,5}$	25[ax]	$\mu g/m^3$	-

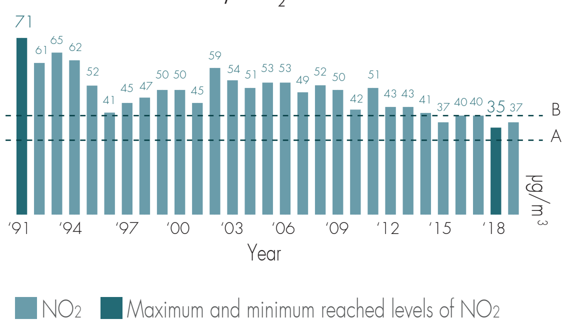
Complementary to table x.1. The table shows different standards of limit mean annual levels of air pollution. [**] Exception; in this case the evaluation is for a 3 year mean. It was suggested by normative that the limit 120 µg/m3 daily mean maximum measured in 8 hours should not be exceeded more than 25 days during 3 years. In fact, the yearly limit is 180 µg/m3. [1] Limit value 50 µg/m3. [*] objective value. [a] For vegetation protection. [b] For human protection [y - z] Entity. [y] WHO. [z] D. Lgs. 155 (2010).
Note: Elaborated by the author with information from Italian Normative (Decreto Legislativo 155 [D. Lgs], 2010) and WHO standards (World Health Organization [WHO], 2005).

a metabolizion process begins when the plant uptakes it. Firstly, metabolizing from nitrate to nitrite and later to ammonia, serving to proportionate amino acids to the organism. By these processes NO^- and NO_2^- are usually presented in plants, but levels of NO_2^- tend to remain lowered because its toxicity is recognized, which is why NO_2 could be harmless (Schneider & Grant, 1982). Yet, if toxicity levels rise, NO_2 causes similar effects than SO_2, affecting growth and depressing photosynthesis. However, is relevant to point out two facts: the toxicity becomes a real problem if it is presented in high exposure and in combination[30] and plants have been proven to be capable of developing resistance to NOx, SO_2 and O_3 if they grow under those conditions (Barnes, Bender, Lyons, & Anne, 1999).

In accordance to the municipality, the main cause of air pollution in Turin is traffic due to population's mobility. Secondary sources emerge from combustion, productive processes and waste treatment (Comune di Torino, n.d.). Measured levels of air contamination are reported yearly by the governmental regional entity (Comune di Torino, 2019) and by observing the results, it is important to note the tendency of aerial contamination to drop over the last years[31]. To address Turin's air quality situation, data from 2017-2019 about the mentioned air pollutants was collected and contrasted with safe limits from humans and/or plants according to the normative (Decreto Legislativo 155 [D. Lgs], 2010) and WHO standards (World Health Organization [WHO], 2005).

It is observable in tables 6.1 and 6.2 that yearly mean levels of SO_2, O_3 and Cadmium stood lowered to the limits. Even though O_3 and Cadmium limits are stated specifically for human protection, and according to U.S. Congress vegetation is more sensitive than humans to air pollution (United States Congress, 1967); the gap to reach the limits is significative and levels stood low. For example, the O_3 gap between the limit and the year with highest mean (2018) was of 73,89%, while in the case of Cadmium, the gap within the highest reached value (2017) was 97%. For this reason, we can presume the showed levels of O_3 and Cadmium as safe ones also for vegetation. However, Italian regulations contemplate a complementary factor to the annual mean, which is the number of times the levels were surpassed. In the case of O_3, it was stablished as objective that the maximum daily mean of 120 µg/m^3 should not be reached more than 25 times, in a 3-year evaluation. The mean of the 3 year was 49 days of surpassed values, exceeding the suggestions. Concentrations of NO_2 overpassed the mean yearly stipulated vegetation protection limits in the 3 years. Regarding vegetation, the level was 23 µg/m^3 over the norm, implying a possibility of reduction

Figure 34
Yearly NO_2 in Turin



[A] Limit NOx for plants according to the Italian Normative [B] Limit NO_2 for humans according to Italian normative

Note: Elaborated by the author with information from Italian Normative (Decreto Legislativo 155 [D. Lgs], 2010)

30 For example, if critical exposure of SO_2, O_3 and NOx are presented paralelly. It is proved that SO_2 and NO_2 together may cause injures from greater severity than acting separately.
31 Data from 1996 to today shows how all here mentioned polluted levels have drop, in the first years sharply.

in photosynthesis rates and plant size due to Ozono and Nitrogen Dioxide. In spite of this -and as it was mentioned-, a progressive reduction of most of the main air pollutants in Turin over the years is evident. For example, by revising the records of NO_2 of the last years, it is clear a gradual declining trend, shown in figure 34. Resulting logic to hypothesize that more favourable levels of nitrogen dioxide for plants will be reached in the next years.

Particulate matter (PM) standards were in every case exceeded, but unlike other aerial pollutants, PM effect over plants is limited. This is owing to the fact that particulate matter are extremely small masses in the air, while the other pollutants are completely gaseous. To be precise, PM is categorized by the diameter size[32] being $PM_{2.5}$ and PM_{10} fine particles (United States Environmental Protection Agency, 2017). These masses affect human because they can penetrate the respiratory track, generating different affections, while plants cannot absorb the majority of the particles (Kumar, 1993). By the contrary, leaves have the ability to capture many of them on their surface, mitigating their impact (Viecco, et al., 2018). Therefore, the addition of PM to the list is mainly linked to the fact that is one of the pollutants of major presence in the city and of wider consequences to human health, but is also a polluter with high potential of being removed by green canopies.

UNIVERSITY CENTER

The Polytechnic of Turin is one of the main universities of the city. It is considered a center of attraction with a dynamic daily flow of around 5000-15000[33] people. The facilities of the entity are distributed in different sites in the town. Transforming the institution into an integral component of city. This is in fact, a distinctive attribute of the educational center; it adapts to the local context. By doing so, it behaves as an articulated structure that belongs to the immediate environment instead of as a separated component (Politecnico di Torino, 2015).

The "sites" are comprised of:

- Corso Duca degli Abruzzi: The main administrative complex and base of the Engineering Department.
- Citadella Politecnica: Adjoined to the main campus for its expansion. Includes areas for research and technological services.
- Valentino's Castel: Representative image and historical body of the Polytechnic. Serve as the school of architecture.
- Design and Sustainable Mobility Citadel: the newest one devoted to Master Degree courses and Automotive.
- Lingotto: School of Masters

The targeted building is situated in the middle of two of the enlisted sites; the main place and the citadel, which is a late extension of the first, as shown in figure 35. Nowadays, either sites are active, but the citadel is still currently in development.

The evaluation of both sides is vital to reach an in-depth vision of the context which results fundamental for understanding the compatibility of the idea of greener rooftop gardens in relation to the physical place and its administrative structure. Seeking parallelly, the obtention of foundations

32 PM10: Diameter 10 micrometres (μm). PM2,5: Diameter of 2,5 micrometres (μm)

33 A 15% of the city's population is represented by the students of the two local universities of Turin. (Green Team Politecnico, 2016)

for the construction of a project concept.

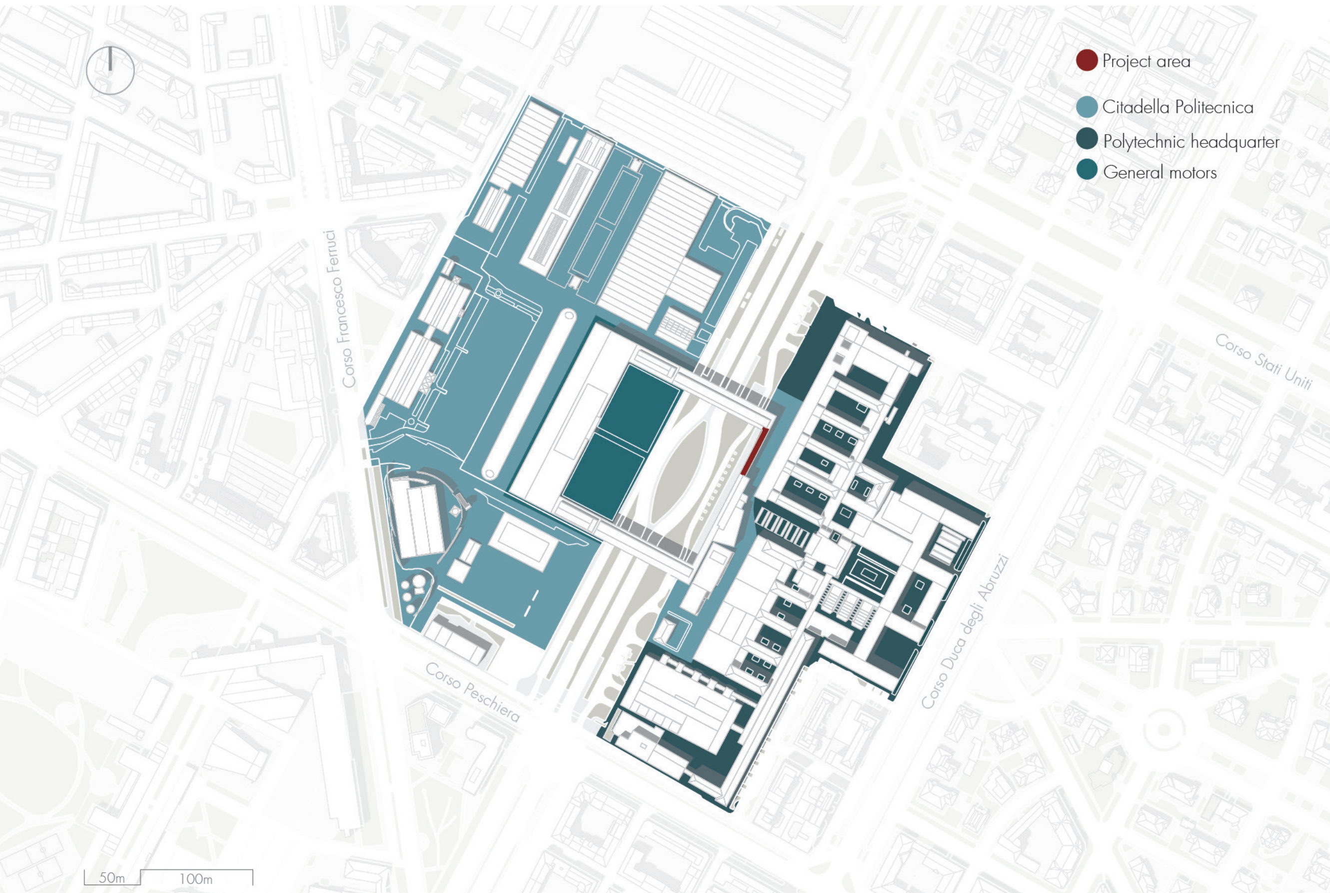
Area overview

In specific, the campus is situated at both sides of Corso Castelfidardo which is a street of primary hierarchy for the circulation of the city. At South, South East and South West the complex is delimited by more streets of comparable relevance. The streets are Corso Ferrucci, Corso Peschiera and Corso Duca degli Abruzzi. Being the last one the road that defines the main access and names the headquarter as well. Adding importance, Corso Duca d'Aosta which (in conjunction with its gardens and nodes) successfully highlights the significance of the entity.

The campus occupies vasts land areas. According to the administration of the institution, the citadel covers an extension of 122.000m^2 and the headquarter 170.000m^2 (Politecnico's corporate image office, 2018). In total, these two sites host the biggest number of students of the university.

In terms of building density, the is a strong contrast between both sides. The citadel is characterized by less constructed volumes and in spite of being composed of innumerable patios, the headquarter is denser.

Figure 35
Location



Note: Elaborated by the author

For the most, if it is compared to the surroundings.

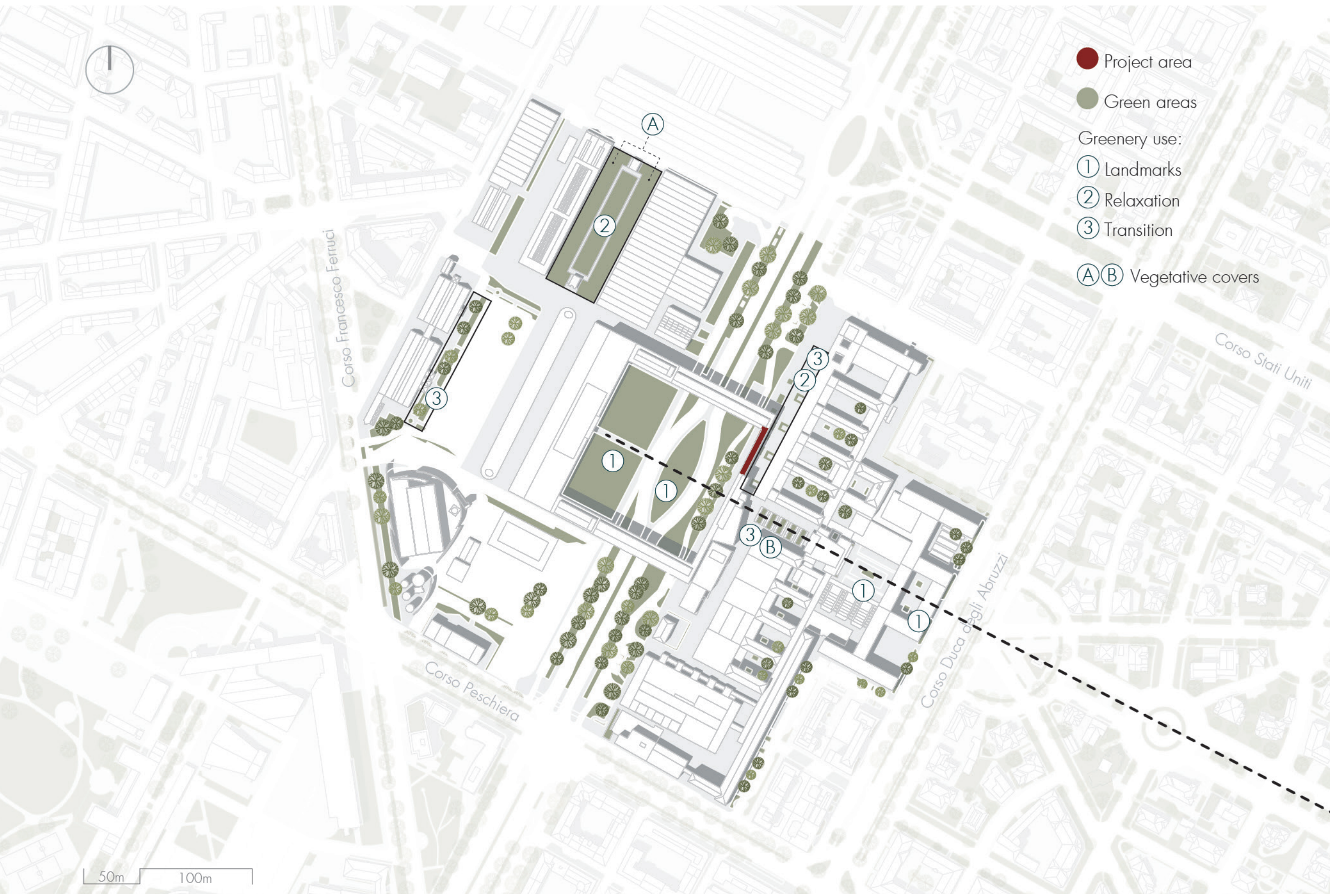
Vegetation & green areas

The evaluation of the vegetation is useful to understand the context, determine the current role of green spaces and design aspects. In general, the whole zone possess great amounts of vegetation, mostly concentrated at the east and in the tree line axes - which define streets of greater hierarchy and main walking paths-. In the case of the Polytechnic, it is observable the importance of one of these green lines which serve as the organizational central axis for the design of the campuses, visible in figure 36. In fact, this axis penetrates the complex, establishing the main entrance and by continuity, the position of some vegetative areas inside of the headquarter.

Greenery in the main campus covers about 6%[34] of the area on the ground floor and is predominantly distributed in green spots of minor scale and pedestrian paths in some of the delimitation borders. In the Citadel, vegetation encompasses in approximation 13% of the surface, focused on extensive

34 Measured in AutoCAD 2017©

Figure 36
Vegetation



Note: Elaborated by the author

green covers and their central space. To be more precise, the role the existing vegetative areas was recognized, concluding that their functions -besides aesthetics improvement and shadowing- are the following:

- Serve as landmarks to identify spaces of relevance, such as the main entrances and central spaces as the square that faces the Great Hall.
- As spaces of permanence for relaxation.
- As circulation passages for transition.

Both campuses present green covers on the ground level. In the citadel, an extensive grass rooftop destined to the repose, visible in figure 37. This roof is equipped with furniture for permanence and green shadowing systems. In the headquarter, a transitory space, essentially destined for circulation. The system of this cover consists in extensive blocks of shrubs and weeds.

Overall, is evident the variety of existing plant species, many of them as added furniture but the majority as part of the structure. Most repeated species are Acer trees (Acer platanoide L. and Acer neguno) while there is a wider diversity of shrubs and grasses. In fact, repetition of lower vegetation is not a constant and every

Figure 37
Vegetative roof A


Note: Photographed by the author

area seems to posseses a different shrubs and grass specie.

Building's heights

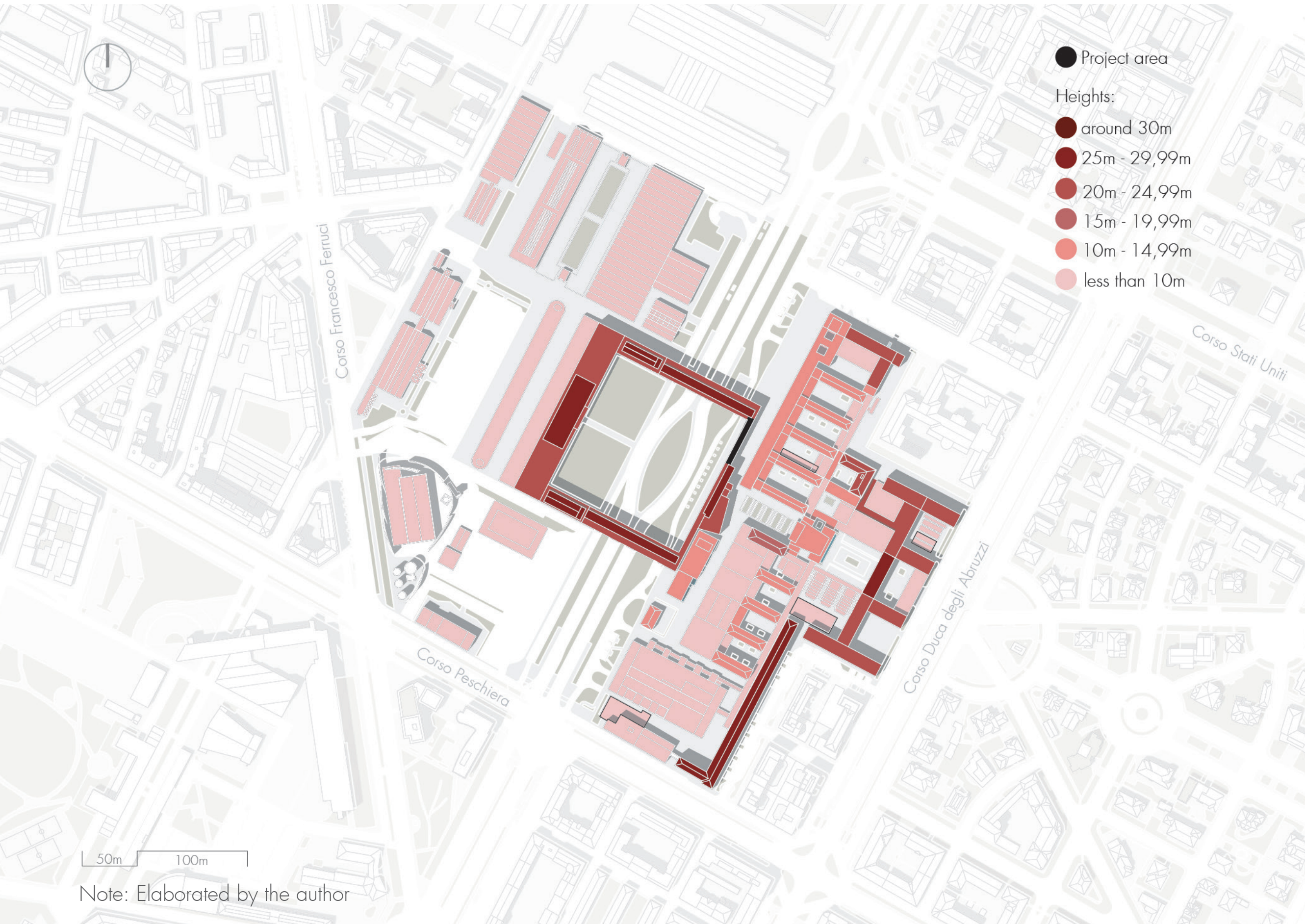
Building elevation has an associated role over the vegetated covers. Primarily, the height of edifice might influence to the internal cooling performance, as the chilling effect decreases at a major building altitude. In edifices over 60m height, the cooling effect could be seriously limited (Zhu et al., 2019). Indirect consequences of the building altitude over green covers are linked to the winds and shading. A major elevation might imply a stronger wind captation and depending on the near context, a higher sun irradiance by a minor variety of volumes to project shade.

For this reason, it's suggested to avoid the installation of roof gardens on rock bottom volumes (depending on the shading analysis) and on high constructions as a result of the presence of sturdy winds that would possibly destroy vegetation.

In the area, heights[35] range from low to medium as it is visible in figure 38. Seeing

35 Measured from ground floor surface to the maximum height reached by the roof. Not in the gross height [HL] of the Italian Building Regulations.

Figure 38
Building heights



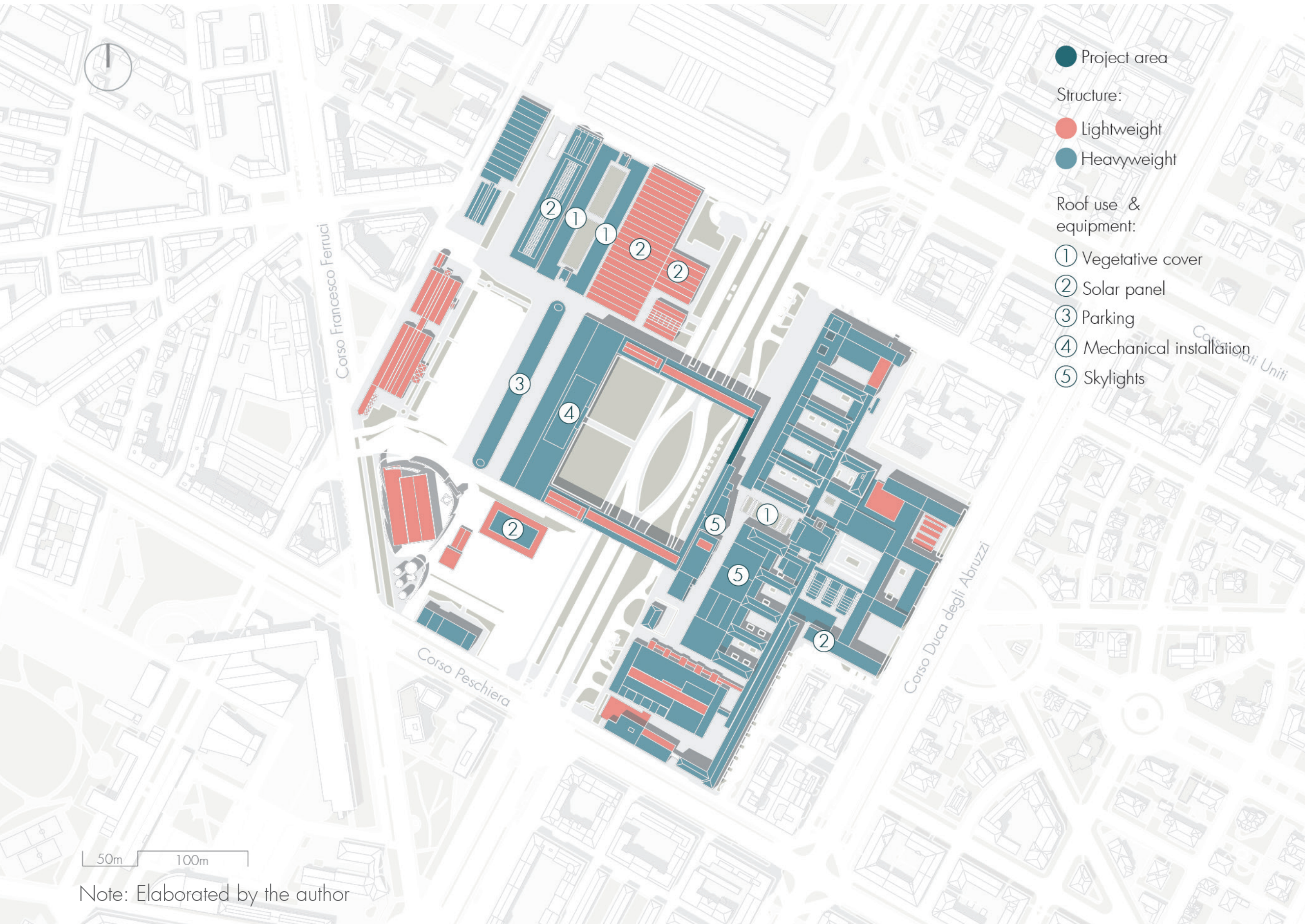
Note: Elaborated by the author

that the elevation of the highest volumes stands around 30m, buildings are exempt from a lack of cooling effect by a high altitude. On the basis of their heights and proximity, it is possible to discard also specific volumes of lower elevation for the GR installation, knowing that volumes of minor altitude and closest proximity will probably receive greater shadiness. However, it is necessary to check winds and shading impact in every individual case.

Roof weight capacity, use & equipment

Lightweight roof structures are not meant for holding additional loads. The FLL Guideline indicates that lightweight structure load-bearing safety margin is so low as to support a green cover emplacement. Owing to this, heavyweight and lightweight structures were identified in the figure 39, to easily discard structures in which greenings should not be applied unless further interventions and a major invernsement are implemented. In addition, roofs with pre-existent functions or elements are also identified. As it can be observed, there is a group of structures that are hypothesized to lack the needed holding capacity. Also, it can be seen that currently, specific rooftop surfaces are performing a role. In most cases, linked to sustainability (such as so-

Figure 39
Roof structure weight, use and equipment



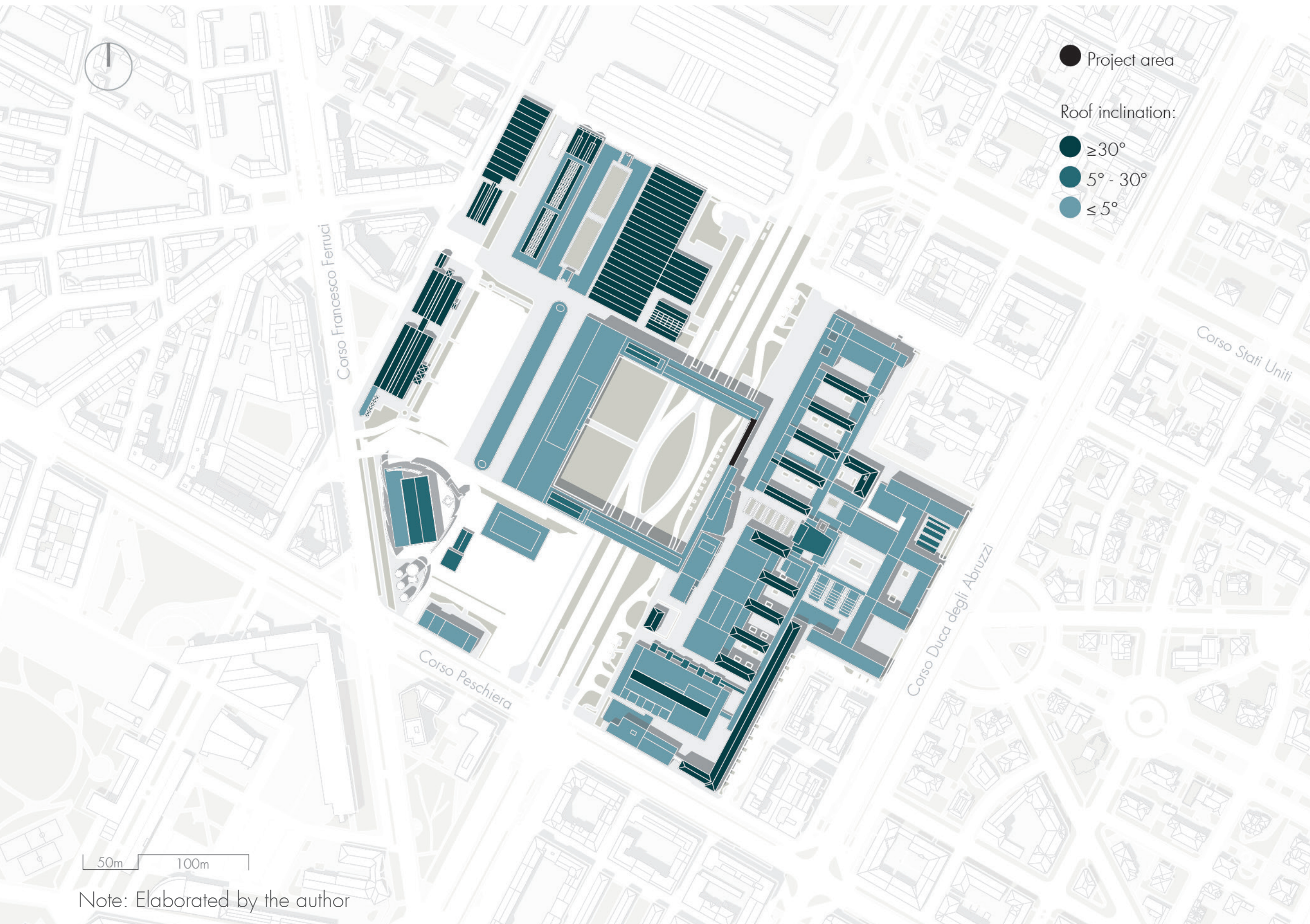
Note: Elaborated by the author

lar panels and green roofs). Lastly, objects over the building were pointed only if they embrace a reasonable area. Punctual elements were not taken into account. For instance, in the General Motors building side, there is a presence of a vast area occupied by a mechanical installation. Other buildings possess skylight all over the top. In this case that may difficult the roof garden establishment.

Roof inclination

The guidelines for GR stipulate specific measures and indicators about the angle at which cover slopes. As it was established in figure 7, there is a minimum required slope to avoid standing water and consequently, infiltrations or further structural damages. By normative, the slope should be at least 2% or 1,1. A minor slope will require special interventions. The regulations also indicate that as the gradient increases, runoff rates will rise as well, which is why additionals measures must be considered in such scenarios. This is why for slopes over 5% or 2,9, it is recommended the installation of a layered structure with high water storage capacity. With an angle of 20 or less, there is usually no need for additional interventions to avoid slipping and sharing while more than 20

Figure 40
Roofs inclination



Note: Elaborated by the author

will need anti-shear protection. If the slope exceeds 30, the roof will necessitate additional calculations and intervetions. Finally, for gradients in excess of 45, greenings should not be considered. Thereupon, for the ascertainment of the complexity of the installation, the slope of the covers in the area was pointed out.

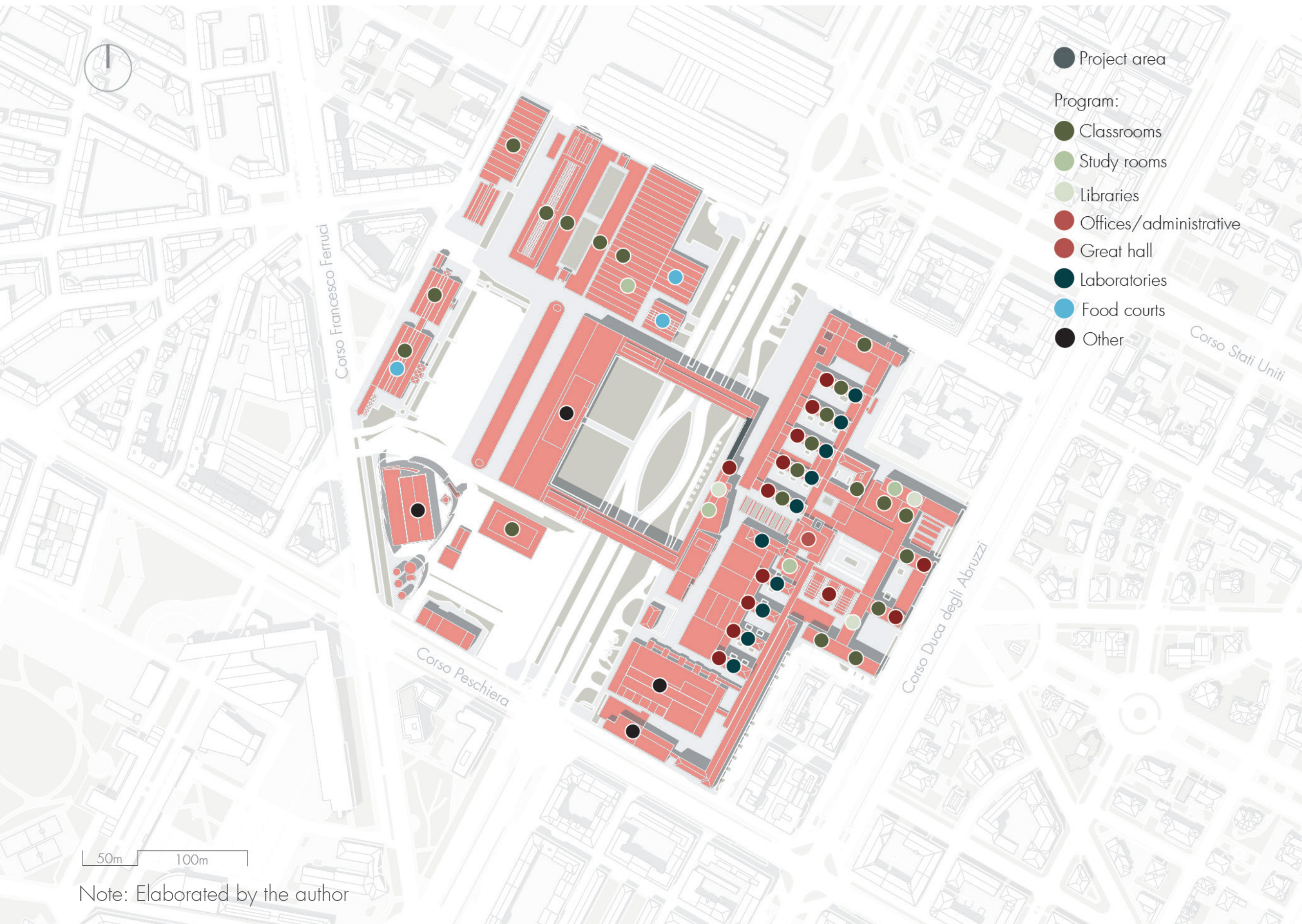
The studied place possesses either sloped and "flat" roof surfaces. Fortunately, surfaces angle do not surpass 45 in any case. On the contrary, as it is shown in the figure 40, at least half of the covers are characterized by their "flat" condition. Even so, a vast group of roofs possesses a top gradient of about 30, in which case, cost and difficulty[36] will increase.

General program

The familiarization with the developed activities in each volume will permit co-relate the mentioned ones with a project proposal in accordance to the dynamic of each building. Evidently, all these will be related to the education program because of the character of the institution. However, by being aware of more specific information, it is possible to generate more suitable green spaces. For example, the creation

36 Difficulty in terms of design and execution.

Figure 41
General program



Note: Elaborated by the author

of a green roof dedicated to the campus employees where office areas are focalized.

Undoubtedly, the majority of the volumes of the campus host classrooms [fig. 41] but several laboratories are also settled. Nonetheless, in view of the fact that one of the zones is the headquarter of the whole university, many offices and administrative areas are settled as well. More uses such are assocciated to companies and the thermal central of the unevisity pointed as "other" in the figure below.

Sustainability aim

For some time now, sustainability has been an issue of concern for the university. The environmental sustainability awareness and knowledge development have been consolidated and integrated as part of the university strategic plan 2018-2024. The promotion of those values, the orientation of the investigations to the field, and sharing the results are one of the aims of the Polytechnic. Also, seeing its potential, the university aims to cause an impact not only over its own facilities but over its city (Politecnico di Torino, 2015). What is more, one of the objectives of the strategic plan involves the enhancement to addressing the Sustainable Development Goals of the UN 2030 Agenda.

According to the ISCN-GULF Sustainable Campus Charter report and within the objective of the Polytechnic of sharing information. Activities related to sustainability were divided into five dimensions, being:

- Energy and building: Focused on the rehabilitation and utilization of pre-existing buildings of the urban area to improve energy efficiency, economy and sustainability.
- Urban Outreach: Looking forward to the integration with the city.
- Mobility and Metropolitan Area: Related to links of the university with the outside and, the paths that users embrace daily.
- People and Food: Focused on better life quality for the users with attentiveness to food, education and investigation.
- Purchasing and Waste: Centered on awareness of the life cycle of the used products in the campus and the spreading of recycle-reuse-decrease values.

Added to this, three principles are enlisted:

- *"To show respect for nature and society, sustainability consideration should be an integral part of the planning, construction, renovation and operation of buildings on campus"*
- *"To ensure long-term sustainable campus development…"*
- *"…Facilities, research, and education should be linked to create a "living laboratory" for sustainability."*

This demonstrates that the bases of sustainability are already a fundamental part of the goals of the university. Leading to compatibility between the ideals of the entity and the proposal of a more ecologic green roof.

Waste management

In order to determine if the implementation of waste produced in the polytechnic is affordable, it is imperative to comprehend its waste control procedures and numbers.

As it was stated in the dimensions of sustainability, the entity of the university aims to improve the efficiency of disposals and purchases, with particular attention on the entire life cycle of the products and seeking the approach of reusing-recycling-reducing.

In particular, for waste management and control, the polytechnic enabled over 435 trash cans. A group of them conforming waste ecologic islands of selective collection as shown in figure 43, with the purpose of classifying the discarded material. These islands are conformed by four types of containers for waste, paper, glass, and plastic, facilitating the recycle and reuse approaches. Other waste collectors include points for special waste Like WEEE (waste electrical and electronic equipment, goods, foliage, iron, etc.) Lastly, another system for waste management that is being introduced in the headquarter is the door-to-door collection service in collaboration with AMIAT.

According to the data, more 500Kg of plastic per week and approximately 1000Kg of organic matter are collected in the entity.
(Politecnico di Torino, 2019).

Figure 42
Cap collection spot

Potographed by the author (2019)

Figure 43
Waste islands

Potographed by the author (2019)

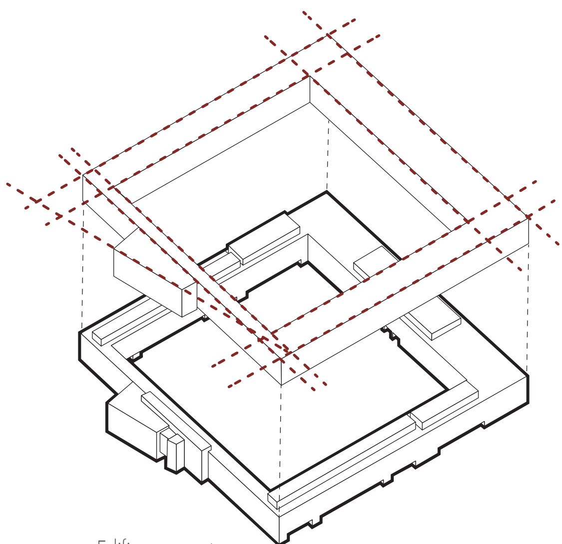
BUILDING & ROOF SITUATION

1. Building overview

1.1 Morphology & geometry

The edifice basic morphology, illustrated in figure 44, consists of a prisma with a central void. Interestingly, the void in the middle evokes to the configuration of central patio of many of the buildings of the Polytechnic's headquarter, but at a greater scale. This scale is generated by the importance of the posi-

Figure 44
Building geometry & abstracted shape



Elaborated by the author

tion of the building emplacement, which respects the relevance of the axes that pass through (Castelfidardo Street and the green axis of Duca d'Aosta Street). However, the configuration of the edifice gives the idea of linearity due to its geometry.

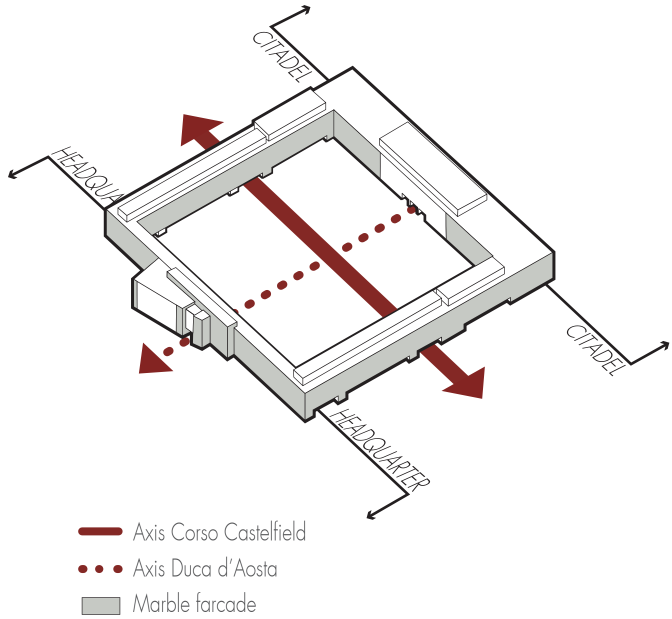
Overall, the building geometry is regular but the symmetry is broken by an angular piece in the East-side, which denotes the main access. At the top, a group of prismatic volumes is emplaced.

1.2 Design strength

The building is mainly characterized by its hierarchy [fig. 45]. Being a volume of great relevance due to (1) its position; because it is located in the interception of two important axes -acting as a node,- it is a centric piece and it is one of the main entrances to the headquarter, (2) dimension; its height and size, in general, is greater if it is compared to the near context and (3) texture by materiality (mainly purple marble panels) which differentiates it from the rest of the edifications.

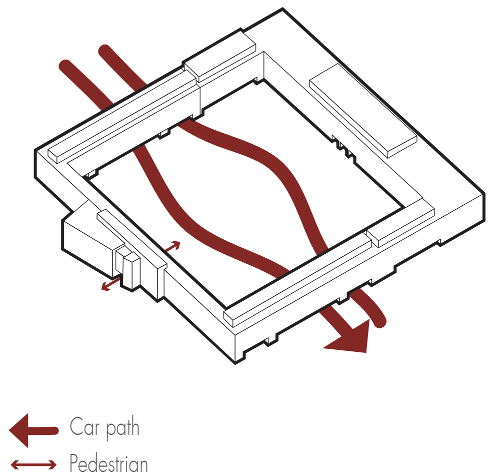
A second peculiarity of the edification is that it acts as a physical link between the campus and its extension, breaking the sensation of barrier that a street as Castelfidardo could generate. In addition, it is distinguished by its horizontal permeability at ground level [fig. 46] which contributes to the mentioned connectivity. On the main campus side, the building provides a temporary pedestrian permeability, adjusted to the schedule of the

Figure 45
Hierarchy elements



Elaborated by the author

Figure 46
Permeability



Elaborated by the author

institution. Whereas perpendicularly, a free transition of pedestrians, bicycles, and automobiles is permanently allowed.

1.3 Structural composition

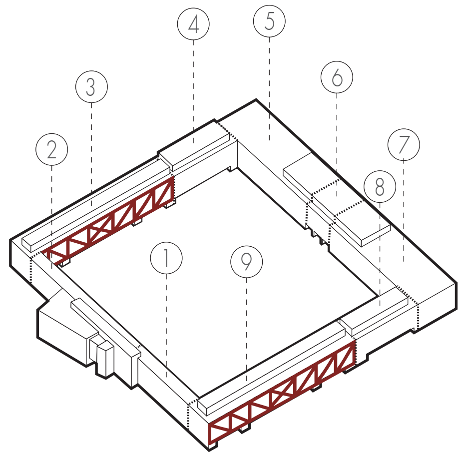
The volume is constituted by separated bodies which allow the implementation of a mixed structure. On one hand, suspended edifices [bodies 3 and 9] over Castelfidardo avenue function as a bridge due to the utilization of a metallic truss system resting on massive pillars of reinforced concrete, as it is illustrated in the figure 47. This configuration permits spans of around 40m, guaranteeing uninterrupted circulation in the avenue. On the other hand, a system of porticoes over a mat foundation supports the rest of the components, this second structural configuration is the result of the mixed of reinforced concrete and steel. Regarding the roof, it is an inverted flat structure. Every edifice was constructed in different phases of the project and linked by joints, giving the idea of a unique volume.

2. Roof overview

2.1 Area & accessibility

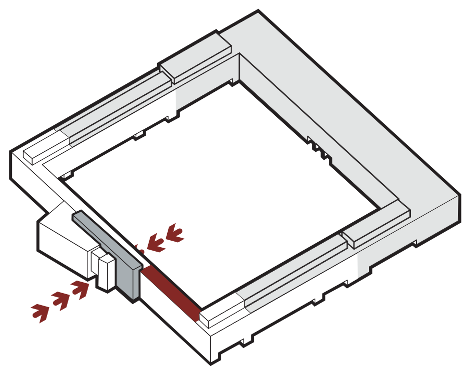
Regarding the property's partition, the East side corresponds to the Polytechnic while General Motor's company owns the West area, being of public and private domain respectively. In fact, the roof area from the private company is inaccessible for the users of the university and an alarm is activated if the limit is trespassed. The available proposed surface for the greenery

Figure 47
Structural composition



Elaborated by the author

Figure 48
Access and property's partition



Elaborated by the author

installation is situated in the Northeast. Covering an area of about 331m^2. This area is accessible for the students only by the concession of special permissions.

2.3 Roof elements

The area is elongated, delineated by walking paths in both longitudinal borders. The paths are accompanied by defined drainage channels in their inner side. The roof is integrated with protective devices to prevent falls, as stipulated by the Professional Garden Landscaper's Association. Essential during the installation, visits, and maintenance. In specific, the rooftop counts with concrete parapets in the edges finished with metallic handrails in the upper part.

Additional existing elements of the area include the ventilation system ducts shown in figure 49, which indicates the necessity of awareness in that specific spot in order to avoid mutual complications; the design should not interfere with the ventilation flow and a minimum distance should be maintained to elude the direct contact with the removed air if it is the case. Other elements outside the limits of the selected area include the electrical installation panels, in the approximation of the pipelines and an antenna. The last object is located on the top of a different volume, impacting exclusively over the visuals.

2.2 Winds & shadiness

By the evidenced wind direction and height of the immediate context, it is feasible to hypothesize the wind flows affecting the specific roof surface area. Since proximal edifices are shorter in height, they probably do not affect air masses' movement on the surface, allowing the flow of east-northeast breezes. In view of the central open space, flows from the south-southwest are

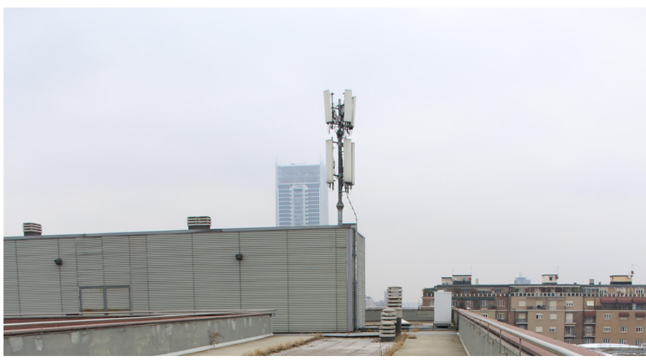
Figure 49
Ventilation pipeline

Photographed by the author

Figure 50
Electrical installation

Photographed by the author

Figure 51
Antenna - North view



Photographed by the author

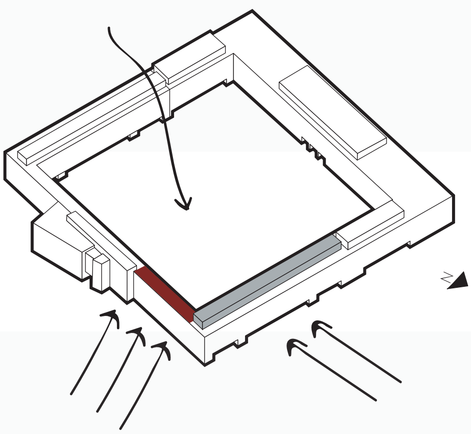
not either obstructed. Only parapets in the specific roof zone could mitigate winds from the mentioned direction. Yet, the volume in the north will possibly block the freezing northern flows.

Even though the day length in the city was previously mentioned, it is also important to pinpoint the hours of direct sun that the roof area actually receives. The elements that might project shadow over the specific roof surface (by height and proximity) include the parapets and the access volume. Nonetheless, in order to verify the shading in the sector during the vegetative period[37], the 3D model was firstly geo-located and oriented. Subsequently, the tools Curic Sun © 2017 - 2020 and Solar North Tool © 2013 were executed in the model.

Variations of shading during specific times and days of the vegetative period and the winter were evaluated in table 7. To understand variations during the whole vegetative period, days of the first mid and last months of the season were evaluated. For

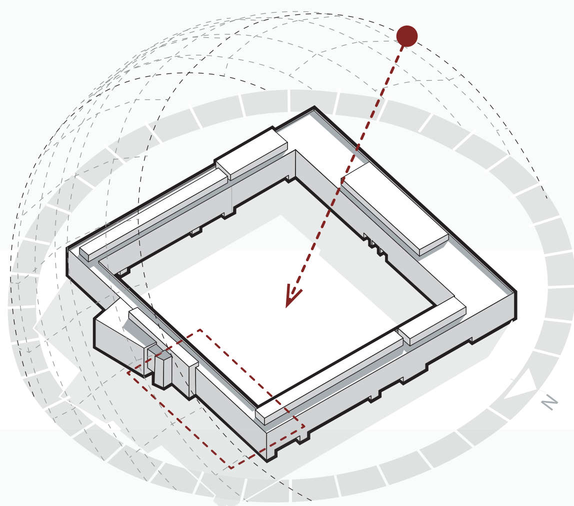
37 As already noted, vegetative period is the period of greater relevance for Sedums development, time in which a complete nutrient absotion is vital

Figure 52
Winds over roof



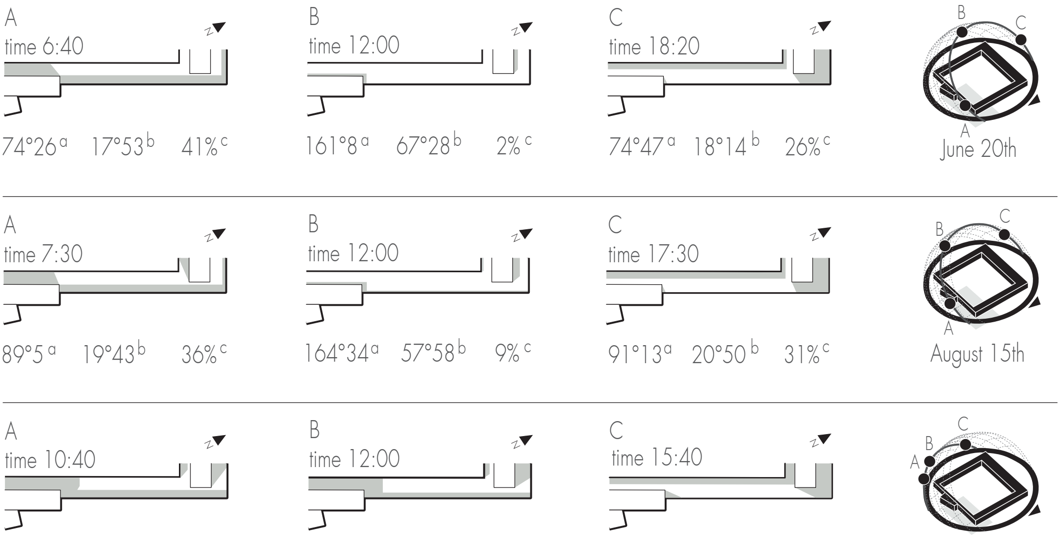
Elaborated by the author

Figure 52
Shade over the roof



Elaborated by the author

Table 7
Percentage of shade over the specific roof area during Sedum vegetative and winter seasons



Morning	Noon	Afternoon	Navigator
A time 6:40 — 74°26 [a] 17°53 [b] 41% [c]	B time 12:00 — 161°8 [a] 67°28 [b] 2% [c]	C time 18:20 — 74°47 [a] 18°14 [b] 26% [c]	June 20th
A time 7:30 — 89°5 [a] 19°43 [b] 36% [c]	B time 12:00 — 164°34 [a] 57°58 [b] 9% [c]	C time 17:30 — 91°13 [a] 20°50 [b] 31% [c]	August 15th
A time 10:40 — 154°2 [a] 16°3 [b] 46% [c]	B time 12:00 — 173°2 [a] 21°13 [b] 35% [c]	C time 15:40 — 136°10 [a] 8°37 [b] 38% [c]	December 21th

[a] Sun Azimuth angle [b] Sun altitude angle [c] Percentage of shaded surface in the specific roof area.
The table shows plan schemes of the variations during the vegetative period and december solstice in the specific roof area. The shown roof section is indicated in the shading axonometry of figure x. Since variations between august 15th and april 15th are almost imperceptible, it was decided to synthesized the scheme by representing solely the shade in Ausgust. Note: Elaborated by the author

the "mid-month", the selected day was the longest one while for the limit months of the season were picked intermediate days. In order to contrast the shade of the vegetative period and winter, the shortest day of the year was also evaluated. In addition, variations during the morning, mid-day[38] and afternoon were considered, focusing on hours of total direct solar lighting[39].

As shown in the table, the maximum reached hours of direct solar lighting are close to 12h during June's solstice whilst the maximum variation of the vegetative period is -2h either in April and August. This is a sufficient light duration to allow Sedum's flowering and enhancement, moreover by summing these to the hours of caught indirect solar lightning. Already from September, the day length is shortened but the minimum day length occurs in December when the changes on shading are clear. The shortest day has a duration of at least 5h which matches the dormancy period.

2.2 Current situation

Is of utmost importance to evaluate the current state of the construction area in terms of degradation. By doing so, it is expected to understand if actions are necessary to elude structural damages or just to favour aesthetics. Since the construction

38 In order to visualuze the variations between winter and the vegetative period, it was selected a specific time of mid-day (12;00). Serving as a "control column
39 For this report it is considered as "hours of total direct solar lighting" the periods in which more than 50% percent of the specific area receives direct sun light.

is relatively new[40], the roof is currently in optimal structural conditions. The top of the edifice presents fewer minor defects that might reduce its attractive physical quality, in most cases, insignificantly. The visible pathologies are superficial, the most relevant, based on the Italian Normative (UNI 11182, 2006) are the following:

- Cracks: A group of superficial fissures is notorious along with the parapet's plaster, shown in figures 53 and 55. Many of them of minor importance (mainly hair cracks). However, some cracks caused the loosening (partial detachment) of plaster in various sectors of the surface. Fewer cracks of major depth are also visible through the walking path.
- Discoloration: Chromatic alterations occur in various sectors of the roof; parapets [fig. 53] and pavement [fig. 54]. In specific, staining and moist areas. The first ones occur by the discoloration of limited extensions while the second ones correspond to the darkening of damped areas.
- Biological colonization: Owing to natural causes of prolonged action, a few areas of the roof present living macro-organisms. Affected zones include the drainage rails and specific spots along the area. Regarding the drainage rail, the formation of moss, spontaneous growing of weeds and of higher plants by humidity is clearly visible in figure 54. The situation of unplanned weed establishment is repeated in some cavities between tilses, and in a few walking path cracks. In addition, a growing of one young shrub in a specific point of the base of the parapet results evident in figure 55.

40 The building was onstructed between 2001 and 2006

Figure 53
Superficial crack & decoloration

Photographed by the author

Figure 54
Biological pathology - moss and weed formation

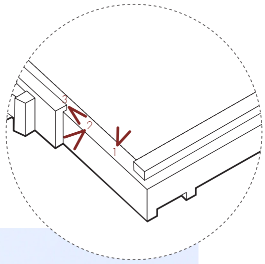
Photographed by the author

Figure 55
Biological pathology - plant growth

Photographed by the author

Figure 56. View 1. Facing to General Motors
Photography by the author

Figure 57. View 2. Facing to the Polytechnic headquarter.
Photography by the author



Views

Figure 58. View 3. Over the roof area
Photography by the author

CHAPTER IV
PROPOSAL & VIABILITY

PROPOSAL & VIABILITY

PROPOSAL PREMISES

Itemizing the basic project requisites results useful to assembly a coherent proposal, serving as the "foundation" for projectual decisions. The following is a presentation of the initial considerations for the design of the particular case study green roof. Each of the next points which are based on highlighted aspecs of the Italian Normative, German Standards, university prerequisites and achieving greener roof goal are inter-dependand factors:

Typology:

The selecion of the green roof typology is a primiry decision for the proposal. The chosen typology affects the majority of the aspects of the system, including its weight, required economical inverstment, manteinance frequency and more indirectly, potential use. By understanding the rooftop garden systems, it is possible to select the aptest option for the target area. In this instance, the use of an intensive or simple intensive covers are least feasible either in an economical point of view and structural one, mainly because the building consist in a settled structure. Thus, the implemention of an extensive cover is more practical solution in view of its lower weight, maintenance and needed financiation. This also suits the commissioned rooftop use.

Installation method:

The installation method is strongly linked to the green cover typology. By selecting an extensive cover, any known form of emplacement is conceivable as the named system is compatible to all of the installation methods. Regarding simplicity, it was previously evidenced that the simplest installation methods for a roof greening are mats and modules. However, both methods consist in commercial prefabricated ones, restricting the selection of materials.

In view of the importance of the layering flexibility for the proposal of a greener roof, the most suitable option is a builded in place installation. In doing so, it is possible to select specific reused and recycliced materials. In addition, even though the implementation of modules allow a wider design layout in contrast to the mats, building in site enables a major versatility.

Lightness:

Even though structural calculations consider in every case addional loads, the prevention of a supplementary support for future extensions or upgrades is rarely contemplated. Furthermore, roofs are generally designed to stand maintenance visitations rather than larger and regular influxes, increasing the importance of the "lightness factor". Bearing that in mind, it is crucial to corroborate the roof load capacity in order to ensure the feasability of the application of a green roof system. It is also assumed that by resulting positive, the installed system and its components should be as lighter as possible being the main reason why an extensive application is preferred. Installing a heavier system could lead to the necessity of reinforce the edifice's structure, involving addiotional interventions and expenses.

So as to achieve the lightened of the system, it is proposed to implement the minimum quantity of elements whist enabling its proper functioning. These include essential primary components for the green roof constitution (the waterproofing, root barrier, drainage complex, filtration mat, growth media and vegetation) and imperative elements to permit the cover subsistence and autonomy (like the water storage element). In addition, the waterproof and root barrier layers can be resolved as a single piece, instead of separated elements and the growing media depth reduced to the minimal with a lighter mix.

Purpose:

The purpose of the green area is strongly attached to the living roof type, the building structural capacity, the place accessibility and the general design. Regarding the finality of the specific area, its commissionated utilization is to serve as a research material for the university. This is in fact aligned to the aim of the Polytechnic of perform the job of a living laboratory integrating in paralel the sustainability. In this instance, characteristics of an extensive surface satisfy the demand while improving the edifice in diverse aspects (energy saving, temperature regulation, sound mitigation, runoff absortion and aesthetics).

The building roof is currently accessible to selected people, condition that must remain invariable because of its main purpose. In order to enhace the execution of investigations of concern and the roof maintenance, a short term permanency for specific users will be allowed, including reduced groups of studens, professors, researches and technicians. By doing so, the impact over the structure by the roof use will be minimal.

Respecting the design and in spite of the reduced number of users, it is vital to ensure the adequate conditions not forgetting the aesthetics. On one hand, by guaranteeing a proper circulation, taking into consideration that the transporation of devices for the diverse investigations will be necessary. On the other hand, by adding the appropiate furniture for the purpose task and the researcher's comfort.

Economy:

Expenses related to a vegetative cover are distributed among the installation and maintenance costs. In general, it is expected for this project to diminish the demanded inversment during the installation by reducing the amount of intervertions, mainly by avoiding modifications in the structure and building's elements. For example, conceiving a lightweight system. Further aspects during the initial stage involve employed materials and their procedence. In these terms, it is expected to generate savings by exploring greener solutions of lower cost for the living rooftop composition. Especially by the utilization of reused and recycled materials from the managed waste of the campus. In addition, encouraging the users to participate in every phase of the proccess (collection of materials, installation of the system and after its finalization).

The selected system will repercute over the economy in both stages. The chosen typology is an extensive one which is the cheapest due to their lesser material and preservation care. This implies that the inversment for the maintenance stage will be reduced. Nevertheless, by employing waste materials results necessary to investigate in depth the duration of the selected components.

Autonomy:

Referred to the capability of development and surviability of the vegetative cover by lacking of additional interventions. In fact, extensive covers are allegedly autonomal since require fewer maintenance visits per year and tend to count to their own water storage component, reducing the irrigation frequency need. However, for the specific proposal, it is a goal to seek the autonomy regardig the two mentioned aspects (irrigation and maintenance) but also regarding the used resources, being supplied exclusively by rain water through diverse components and feeded with its own energy if this is required.

Adaptability:

In this escerario the term is intended as the qualitity of the project to adajust to the context and the green roof use. Principally, in reference to the design; spatiality, permeability, materiality and fexibility. Aligning the same to the principle of the university of reaching a more sustainable campus and taking advantage of its current phylosophy and administrative management.

- Spatiality: By harmonazing to the given space quality, dictated by the morphology of the edifice.
- Permiability: By allowing a proper circulationg
- Materiality: By appliying local materials and local vegetation especies.
- Flexibility: By creating adaptable furniture to guarantee their compatibily to the possible kind of research.

PROJECT DESIGN

The project design is based on the previous treated aspects, considering the living roof not as an individual green area but as an integrated part of the building and campus. Taking into account the existent potential of improving the current local conditions. It is also of concern the need of the creation of a functional landscape and not solely an aestethic roof.

In general, the landscape design process consist in a theoretical phase and a practical one (Rico, 2004). The first is constituted by the planification, involving: (a) the evaluation of the area (site analysis) and current place situation[1], and (b) the site plan. The site plan includes the determination of preliminar requirements (objectives) and the general action plan (timeline), identifying the appropriate timing for planting the vegetation. On the other hand, the practical phase consists in the design of the physical space, taking into consideration basic concepts of composition and all the collected information. At this point is vital incorporate the feasibility studies (structural, economical and further variables)

1. Site planning

In order to generate a logical structure, the timeline plan in figure 59 is diveded in two stages; the preliminar stage and the system stablishment.

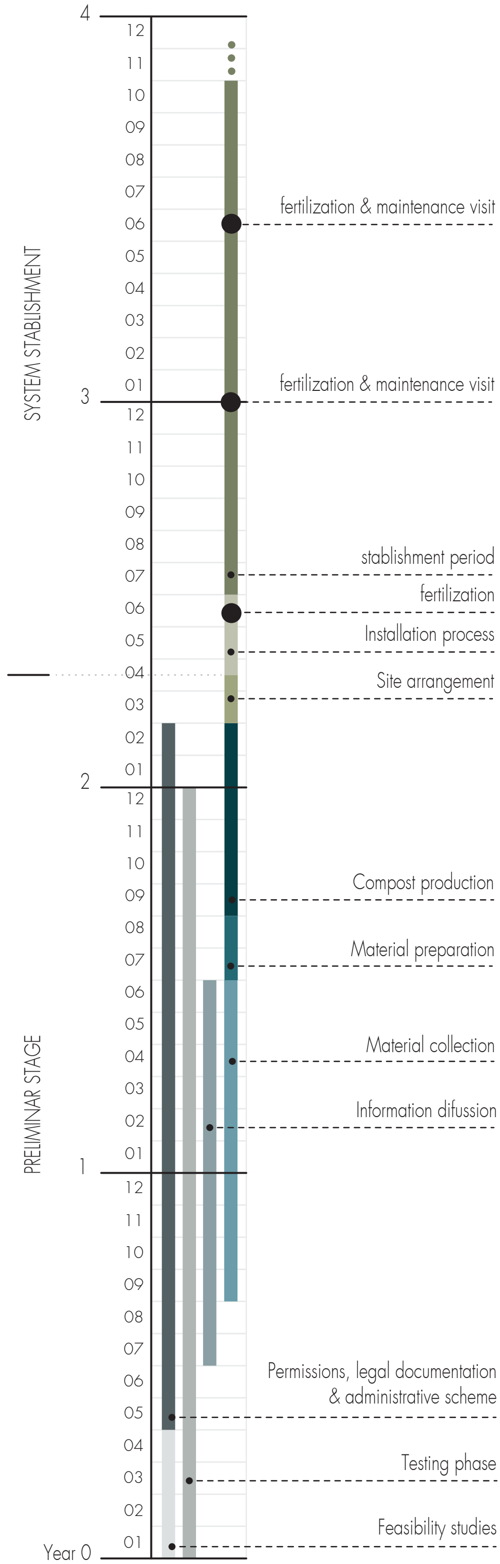
Addressing a time gap prior to the system's installation results as indispensable as the system settlement. Aside of the design process and study of the area, this period is essential to determine the feasibility of the project[2], to complete bureaucratic proce-

1 Developed in chapter 3 [study case] on the basis of the established by the Italian Normative and German Standards.
2 Including structural and economical feasibility

dures and to perform a variety of tests. As it is proposed the utilization of unconventional materials in this particular case, the mentioned testing phase is vital to prove the functionality of the entire system at supporting vegetation and prove each layer individually. It is suggested a lapse of around 2 years[3]. Furthermore, diverse points for this project require a certain anticipation. These points involve diffusion, colletion, preparation and site arragement.

- Information diffusion: In order to notify the campus community through flyers, posters, mail, web site and the mobile app, relative data to the project. The goal is to educate and increase the familiarization of the users to the green roofs and the specific project, emphasizing the importance of a correct waste disposal and encouraging them to participate either in the material collection or installation process.
- Material collection[4]: In the first place, by taking advantange of the existent waste management system of the university, which allows a greater selectivity. Secondly, by incentivate the users of the campus to contribute with the collection of specific waste materials of simple transportation for the green roof system layering. These materials, can be collected primirily in the university by the daily discarted materials but also externally, though a pyramidal system of collection[5].

Figure 59
General timeline planning



Elaborated by the author

3 The German Standards specify a 2 year evaluation period to test the root barier because is the period of fully development of specific plants, being suitable for this kind of evaluations (F.L.L, 2002). Since this project proposes waste materials for the composition of the green roof, the two year period was taken as reference to test the total system functionality with a real subject.
4 Regarding collection time, if we consider that 10% of the minimum daily people flow of the university consumes 1 bottled water per day, there are needed only 250 days to collect the minimum water caps required by the proposal
5 The user might collect their items and encourage aqcuaintances to do the same.

- Material preparation: To clean and if it is the case, intervene the elements that will be employed in the various layers of the garden rooftop and the immediate surroundings. This point includes the production of compost, which must be utilized in a short term after the manuring and its production requires 3 to 6 months (Rosales & Woo, 1982).
- Site arrangement: Prior to the installation of the green cover system, it is necessary to prepare the area. In first place, by the extraction of the existent tiles to reduce the extra weight load on the roof. Instead of discard the material, the mentioned tiles can be employed as aggregates for the green roof. Afterwards, the correction of the slope is necessary at this point to guarantee a correct drainage flow. It is also recommended the intervention of specific degrades including the replacement of the plaster at the internal faces of the parapets, in order to improve the visual quality. More importantly, the removal of biological colonizators, by extracting and employing detergent and focusing in weeds and shurbs to avoid structural damages.

Subsequently, the system stablishment, which was defined as the period that goes from the installation process to the vegetation's settlement. Regarding the vegetation, it is highly recommended to plant Sedums in late spring, when the air temperature increases and in time for the growing period (National Gardening Association, 2019). It is suggested as well to fertilize each 6-8 months, incorporing slow release fertilizators (F.L.L, 2002), specially from April to June (Uhlig, 2005). Maintenance visits are required with major rigurosity the first years, until the roof is completely settled.

2. Design parameters

2.1 Use: Seeing that there is an implicit educational purpose, it is proposed to involve education during the different phases of the project; in the preliminar phase by informing people data of interest about green roofs, during the stablishment by allowing students to participate in the installation process as a practical work under supervision and finally, by allowing the use of the area as test subject for the reasearch. The place is condicionated to serve to this purpose by the incoporation of two spots that can be used for the emplacement of equipement to test and measure the different variables of a green roof. In addition, these spots count with forniture to increase the comfort sensation of researchers and students during the waiting time, allowing them to have a support for the realization of annotations, drawings, etc.

Even though the pathways remain untouched, the drainage configuration allows their extension, permiting to generate an informative pathway. This consist in the addition of relevant stamped data in the drainage area of the sidewalk, enabling the adquisition of information during the circulation. For instance, the name of each plant specie and the measures of the green area, in order to facilitate process of investigation.

2.2 Morphology: The propose seeks to respect the existent linear morphology, determined by the elongation of area and the disposition of the circulation paths. This characteristic provides the linearity concept employed in the propose. The green area is organized through a linear element, breaking however, the ortogonality by the integration of curves. In specific, the main organizational line is generated by curves, disposed in the central axis of the area and defined by the use of diverse vegetation species. Additional curves are integrated in base on the mentioned central line.

The "linearity" is also present in the elements that complement the green roof. Pergolas and furniture are constituited by linear elements, integrating to the morphology concept. These elements are pararel to the central axis in order to conceive their integration.

2.3 Geometry: The geometry was stablished in base on the shape of the area, serving as organizer for the generation of a rhythmic composition. The geometry is constructed from a central axis in the longitudinal sense while a modular partition organizes the transversal one. This partition is determined by a distance "A" and its subdivisions: "A/2" and "A/6". From this network, it was possible to construct a linear scheme of curves.

2.4 Circulation: The pre-existing walking paths at the longitudinal borders remain unalterable. This decision was essentially subjected to the fact that by the utilization of the current paths, it is avoided the execution of additional unnecessary interventions. Furthermore, by maintaining the existent distribution, the remaining surface for the installation of the green system is the area receiving a larger number of hours of direct daily natural solar light. All this seeing that -as it was shown at the shade study- the elements generating a wider shading surface over the selected roof area are the parapets.

Taking advantage of the pre-existing configuration of pathways, which virtually frame the space between them, it was proposed to employ this zone (originally walkable) for the installation of the green roof. Subcequently, a few links running transversally from the semi permanence spots are integrated in order to maintain a proper circulation flow in the mentioned sense. These links are complementary to the circulation. The mentioned ones are conformed by discontinuos concrete panels, allowing the displacement of the users without interrupting the concept of linearity.

2.5 Permeability: The permeability is present in the pergolas, at the semipermance spots. The incorporation of the mentioned elements serves for protection, by mitigating the effects of sun over the users and even the forniture. These pergolas are composed by interleaved linear elements which permit the penetration of solar light and consequently, promote the development of the vegetation. On the contrary, if a continuous element is employed, this would maximise the surface of projected shade, prejudicing the development of plants at major proximity.

The permeability is also found in the circulation, by allowing the transversal flow through the green area. This gesture seeks to create an echo of the situation of the building at ground floor but in a minor scale. Making the design object penetrable.

2.6 Permanence: The stipulated use of the roof area contemplates the short term pemanence of fewer users. In order to achieve a degree of comfort, spots equipped with flexible forniture are placed in each side of the main walking paths. The generation of these stations permits the uninterrupted circulation in the mentioned paths.

Each semi-permanence station possess protection for the mitigation of sun and rain. The stations count with forniture to improve the comfort during brief periods, including benches and desks. Placed to improve the quality of the waiting time and proceed with the investigations.

2.7 Flexibility: The semi-permanence spots of the green roof area possess vertical elements fixed to the pavement. These have the capacity of being transformed into a simple desk or stand 'closed', adjusting to the necessity. For instance, these can be used as an extention of the walking path, allowing a free transversal circulation. By the contrary, as a desk for a few users. The station can be employed as a combination of platform and desk as well, in order to place the required equipment needed for the different investigations while in the meantime, the user proceeds with the written investigation or relaxation.

2.8 Biodiversity: The project incorporates diverse Sedum species. Fundamentally, seeking the improvement of the funcionality of the green roof system. Seeing that the implementation of various species may increase the system's performance results (Patton & Bauerle, 2012). In fact, findings demonstrate that mixing diverse species improves the surviability rates during drought periods (Nagase & Dunnett, 2010). Secondly, to be able to create a composition by the integration of diverse colors and textures, transforming a flat surface into a landscape with an additional interest. Being also able as well to generate a dynamic landscape by the seasonal color variations of selected species.

The integration of different plant species is congruent with the campus green landscapes, since the greenings are composed by a combination of several plant species and repetition is not often applied.

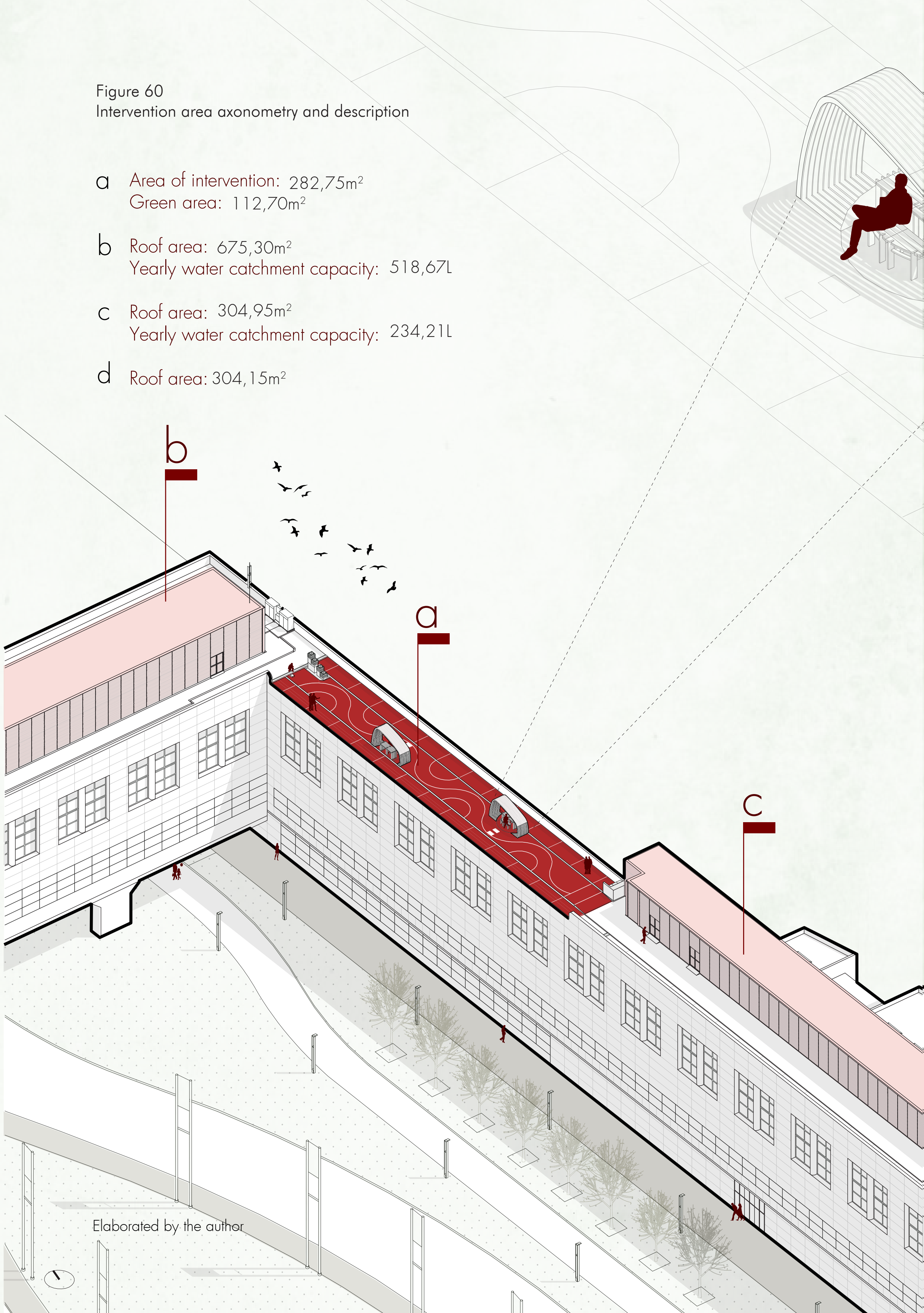
Figure 60
Intervention area axonometry and description

a Area of intervention: 282,75m^2
Green area: 112,70m^2

b Roof area: 675,30m^2
Yearly water catchment capacity: 518,67L

c Roof area: 304,95m^2
Yearly water catchment capacity: 234,21L

d Roof area: 304,15m^2



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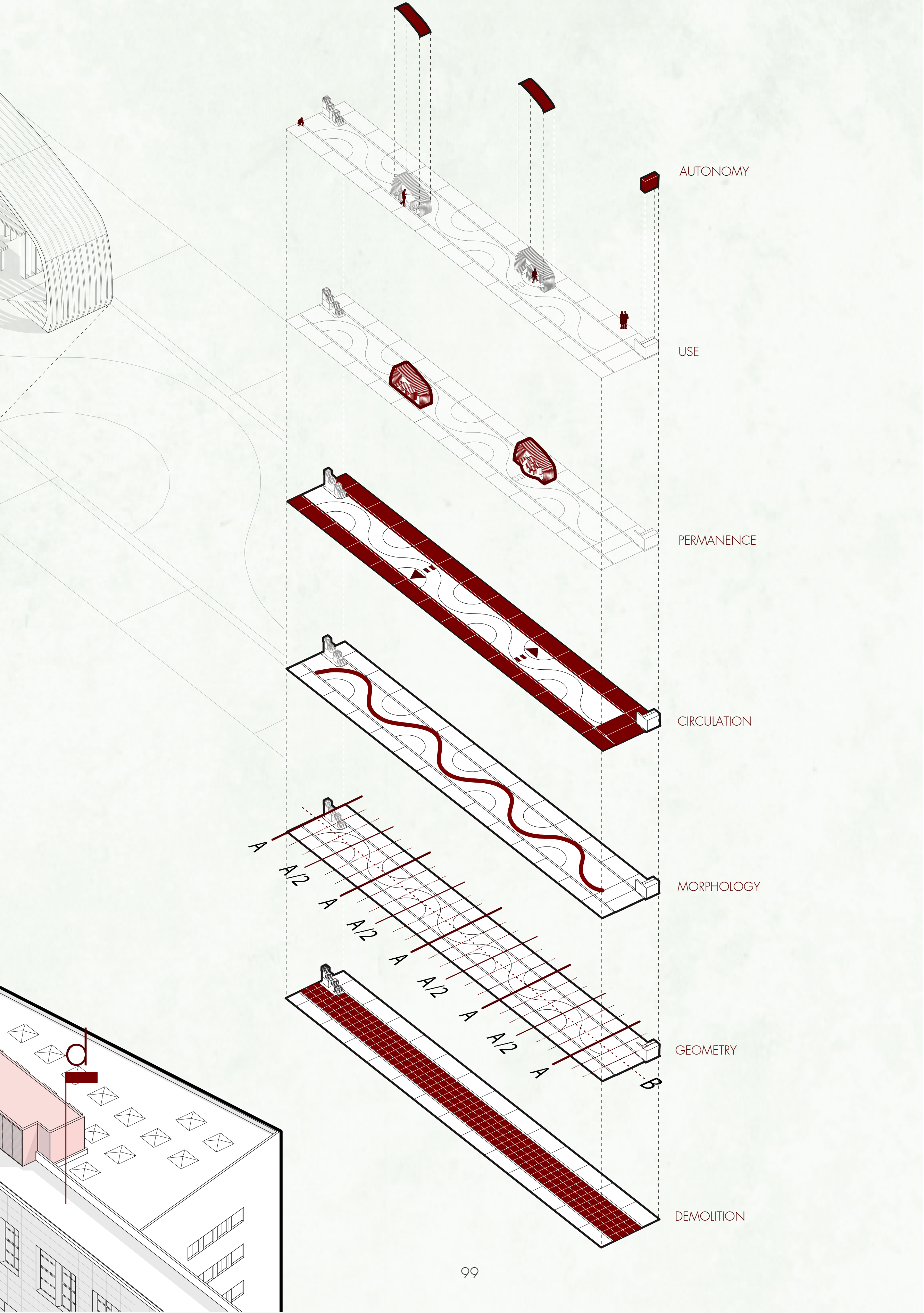
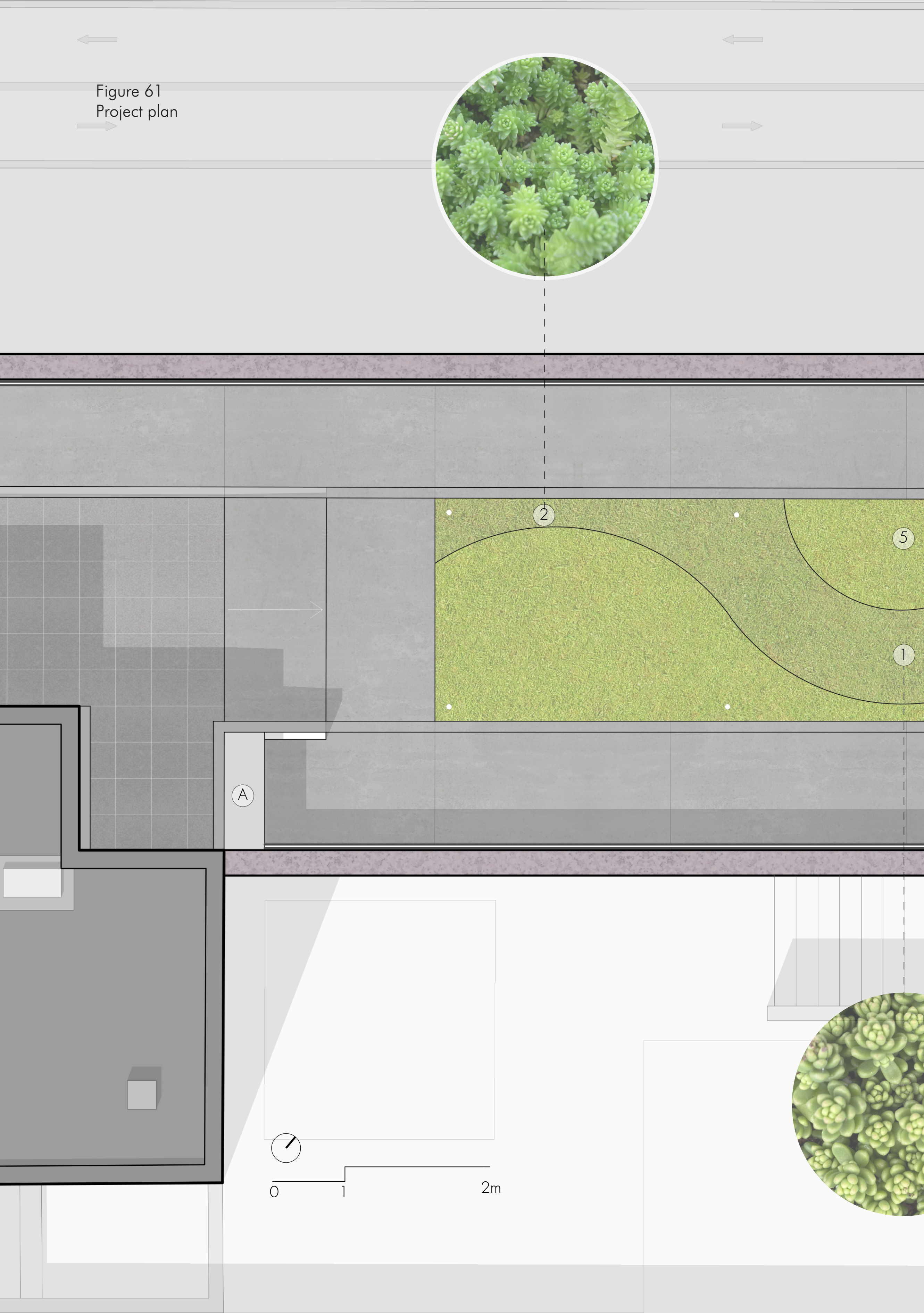
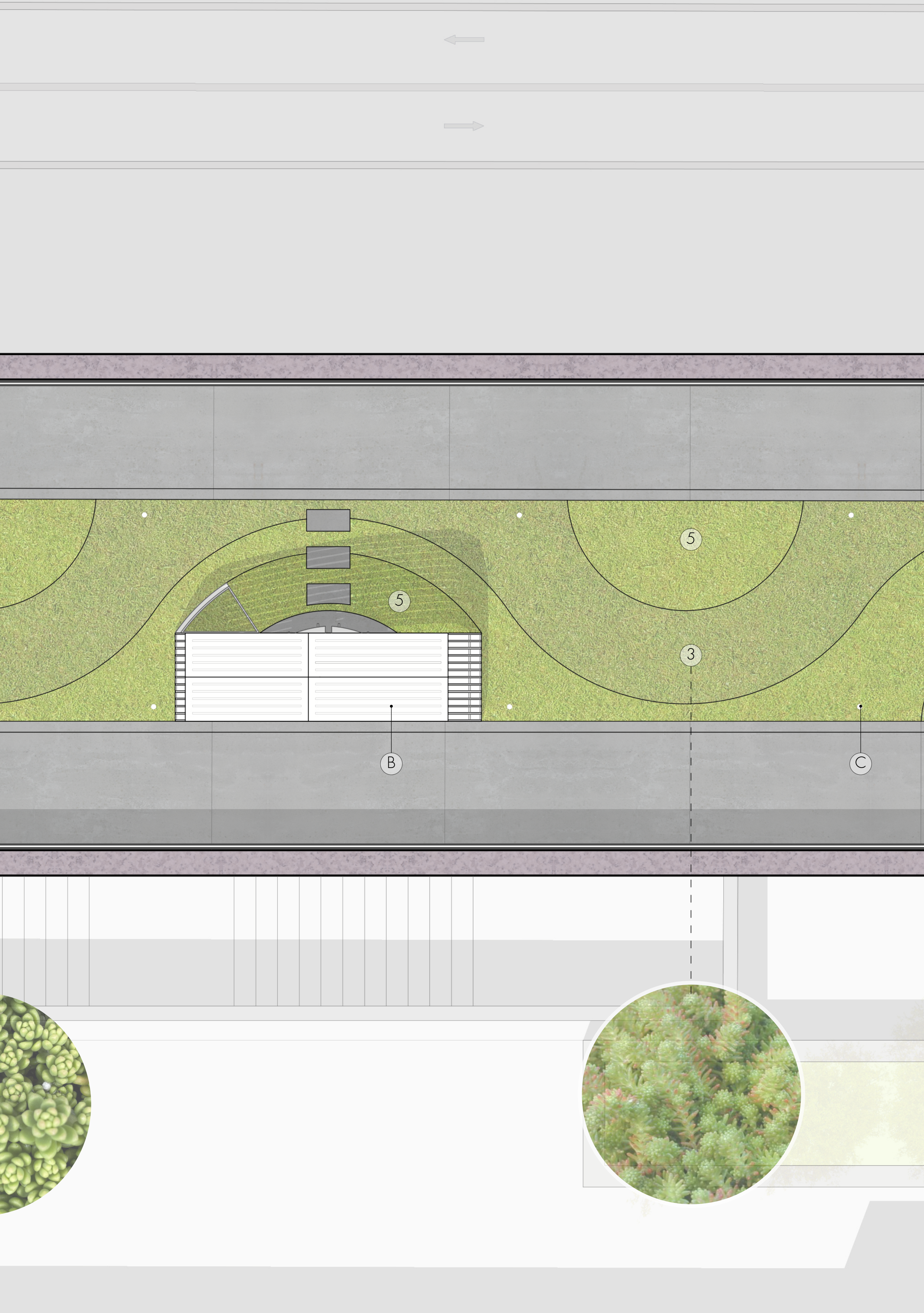
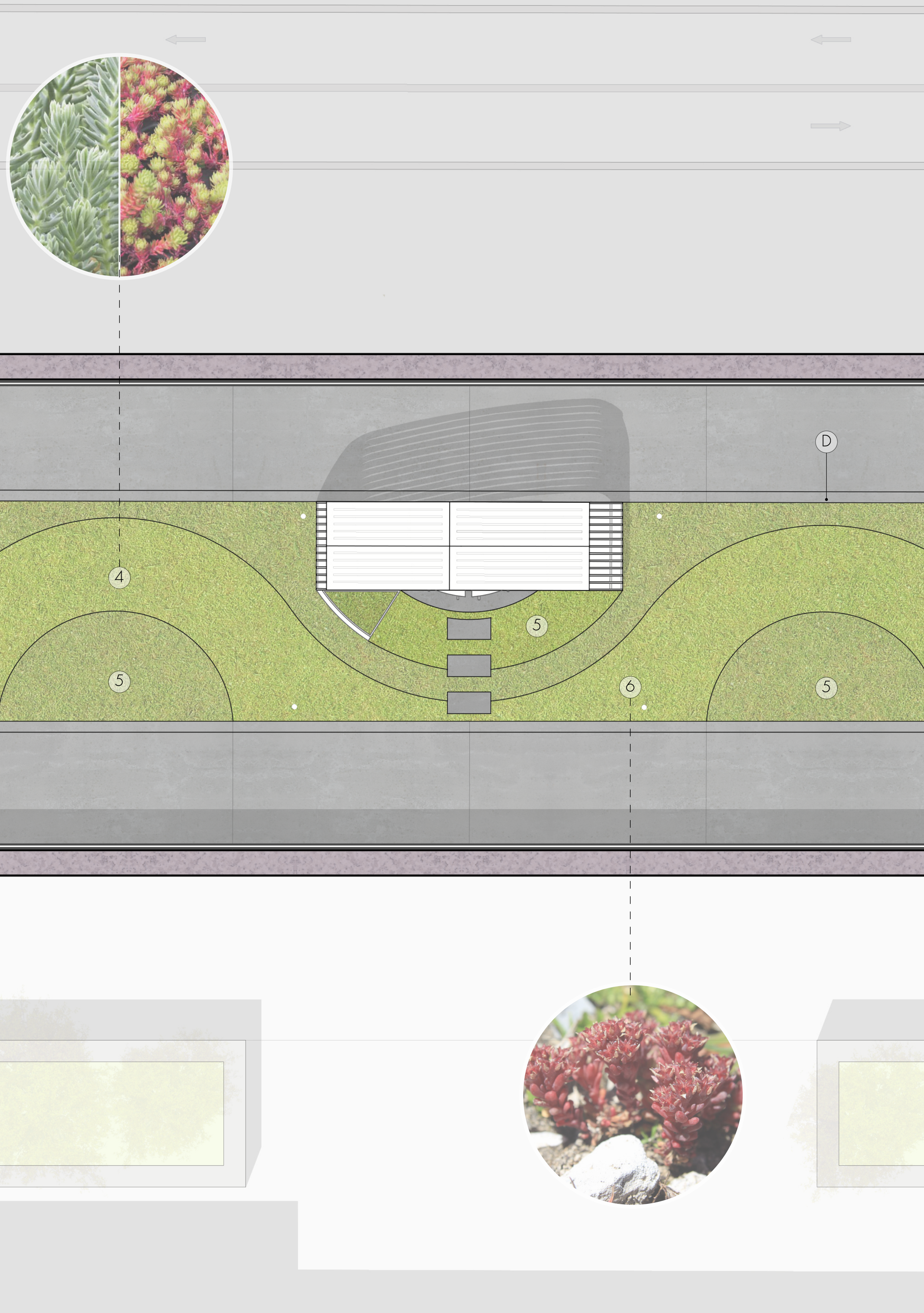

AUTONOMY
USE
PERMANENCE
CIRCULATION
MORPHOLOGY
A
A/2
A
A/2
A
A/2
A
A/2
A
B
GEOMETRY
DEMOLITION
d

Figure 61
Project plan




5
5
3
B
C


D
4
5
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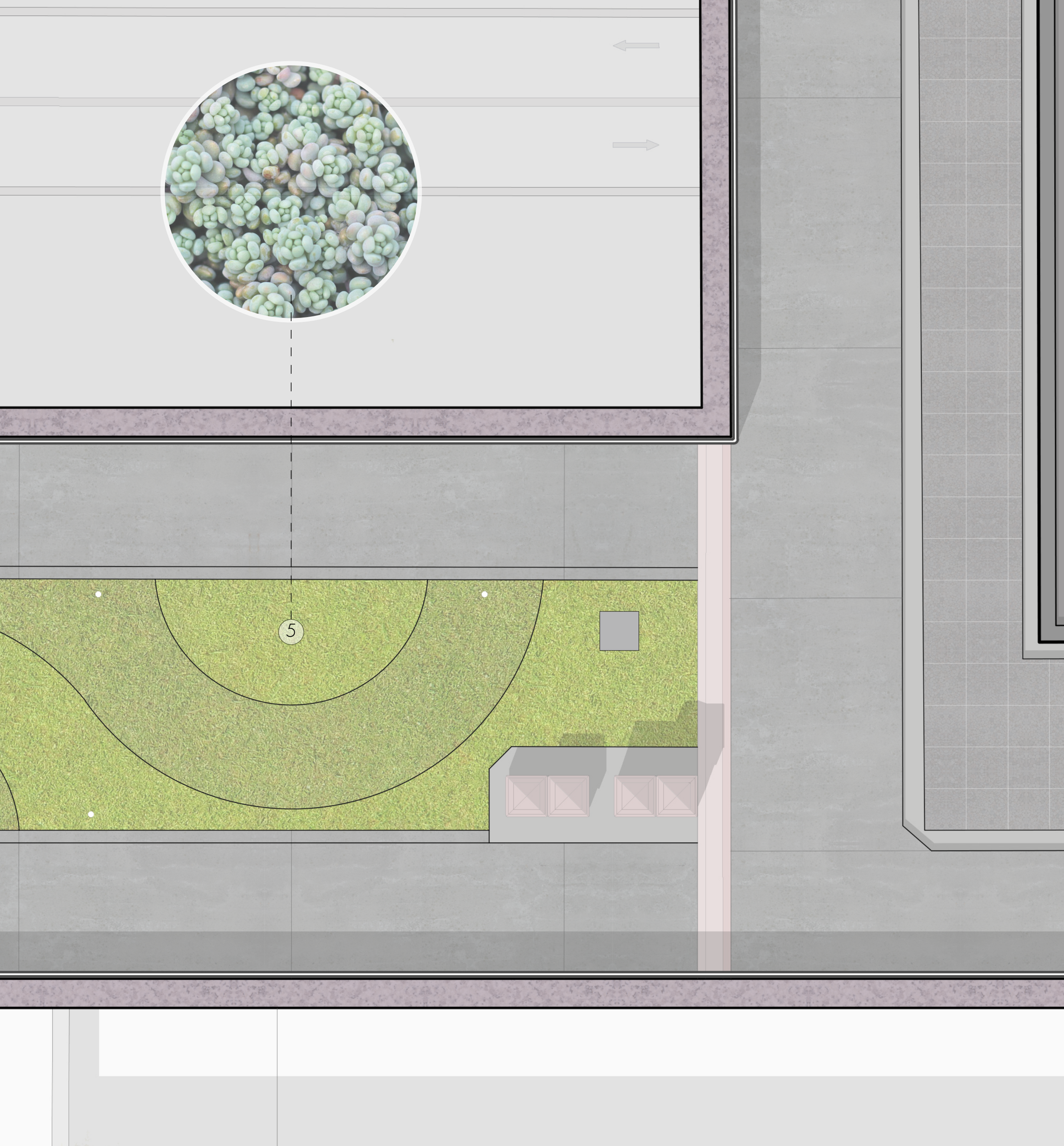
6
5



LEGEND

VEGETATION

1. Sedum Album
2. Sedum Acre
3. Sedum Sexangulare
4. Sedum Reflexum
5. Sedum Dasyphyllum
6. Sedum Atratum

ELEMENTS

- A Water tank
- B Flexible solar panel
- C Solar cells lighting
- D Concrete tile - Plant ID

Figure 62
View of Green Roof Proposal

Elaborated by the author

Figure 63
View of Green Roof Proposal

Elaborated by the author

STRATIFICATION & COMPONENTS

At this point, the layers and components are shown in detail. Their configuration and composition selection are referenced by the commercial version of the Sedum extensive cover from the brand Zinco ®, which will serve as a guideline, reason why some of the layers present a brief review of the mentioned product. The totality of the stratums composition and selection are supported on the *Italian Normative UNI 11235*[6] and *F.L.L. Guideline*[7] as well.

The anatomy of the green covers and their vulnerability was considered for the selection of the stratification, seeking the implementation of a minor number of stratums, but selecting the basics to allow a correct performance. The selected layers to compose the green cover include waterproof barrier, root barrier, water drainage, water storage, mechanical protection, growing media and vegetation support, form which specific layers with compatibility were sythesized in one. In this case, the waterproof and root barrier were summarized in one element, as well as the dainage and storage layers. After this, it was determined how critical specific elements could result for the green cover survivability, concluding that the protection membrain results the point of major vulnerability for the green cover and roof structure. It was decided then, to mantain the commercial version of the mentioned layer and propose alternatives for the remaining ones.

The selection of alternative materials for the green cover composition is based on the context situation. For instance, Italy holds a record of the major consumer of bottled water, intaking around 220 liters per year per inhabitant (Città Metropolitana di Torino, 2021). Statistics has shown a growth in the matter the last years (Statista, 2021). Reports of the private company COOP, shown a slight reduction in plastic water bottles sales only during Covid pandemic, between June and August 2020 (Città Metropolitana di Torino, 2021).

The fashion industry have also had a massive impact in the waste generation by the popularization and spreading of fast fashion[8]. Even though in recent years the European Union has taken iniciatives[9] to improve this situation, several great scale brands[10] still produce sheer volumes of clothing from virgin polymeric materials. All that, excluding the fact that many of these are produced in Asia[11]. Summing to the equation the increasement of pollution levels by transportation emmisions and packaging production. In accordance to the data of the European Parlament from 2004 to 2016 Italy was on the top of the ranking of textile waste production in the continent, reaching 465.925 Tonnes in 2016 from which 81,8% was diposed on landfill or insinerated (Eurostat, 2021) and until 2019 textile waste in Europe was still rising (The European Apparel and Textile Confederation, 2020). As these examples, there are several potential waste materials that can be implemented as main elements for the composition of architectonic elements as the green roof systems.

6 (Commissione Centrale Tecnica, 2006)
7 (FLL Guideline, 2002)

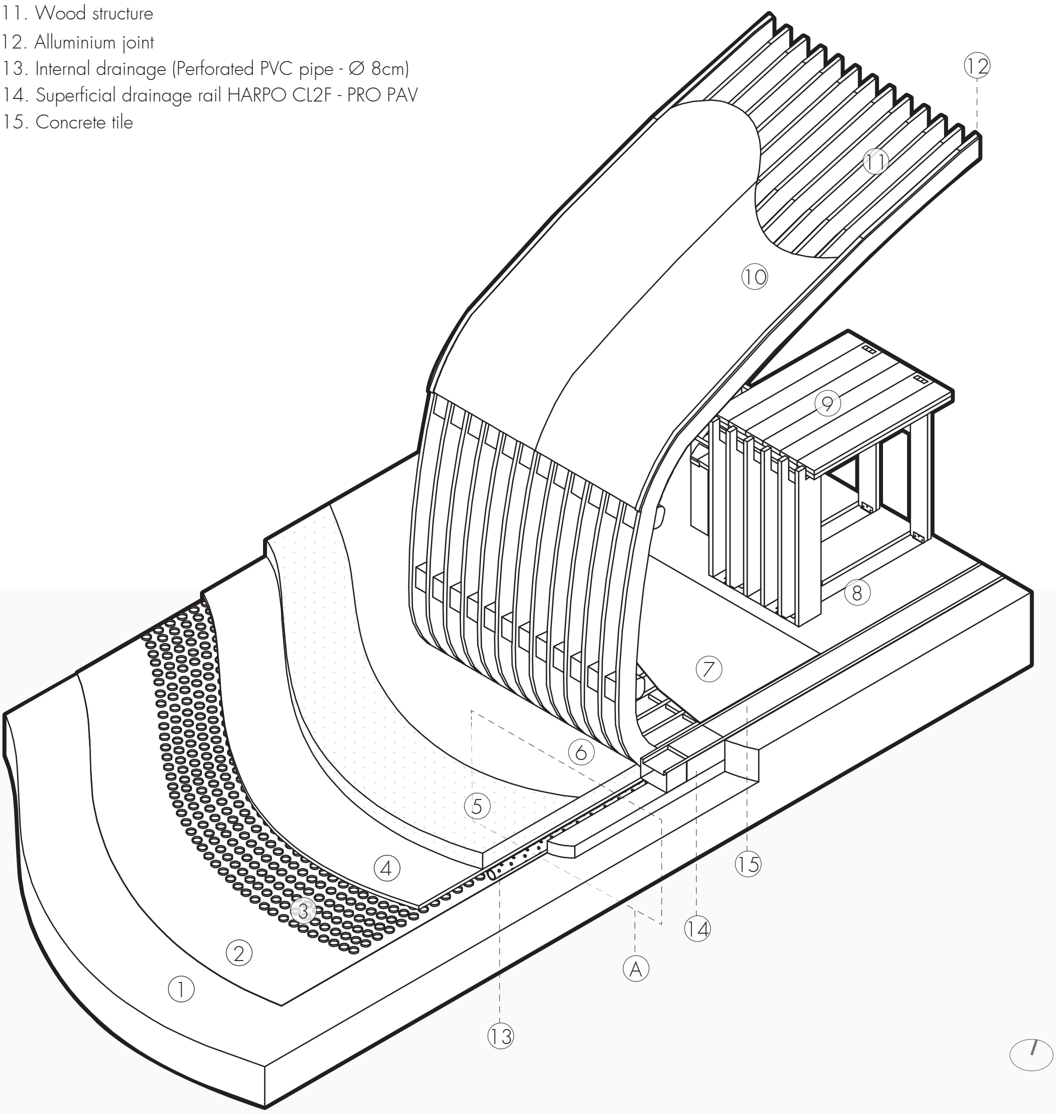
8 Fast fashion: Rapidly mass produced inexpensive clothing by large retailers, in order to satify latest trends demands.(Oxford Languages, 2021)
9 One main initiative in the topic is ReHubs, which seeks upcycling of textile waste (The European Apparel and Textile Confederation, 2020).
10 Brands like Bohoo, Pretty Little Things, Missguided, etc.
11 Such as SheIn, Aliexpress and Wish

Figure 64
Green roof stratification anatomy

0 0,5m 1,0m

Leyend

1. Pre-existent structure and cement morter 1-2% slope
2. Protective layer (waterproof antiroot barrier Harpo ZD UV membrain 0,15cm)
3. Hydric accumulation and drainage (HDPE caps)
4. Mechanical protection (polyester mat)
5. Vegetation support course (crushed gravel tiles - 8cm)
6. Vegetation layer (local Sedum mix)
7. Colored alluminium panel
8. Wood structure
9. Recycled wood pallet (European norm ISPM)
10. Flexible translucent silice solar panel mat ASCA
11. Wood structure
12. Alluminium joint
13. Internal drainage (Perforated PVC pipe - Ø 8cm)
14. Superficial drainage rail HARPO CL2F - PRO PAV
15. Concrete tile



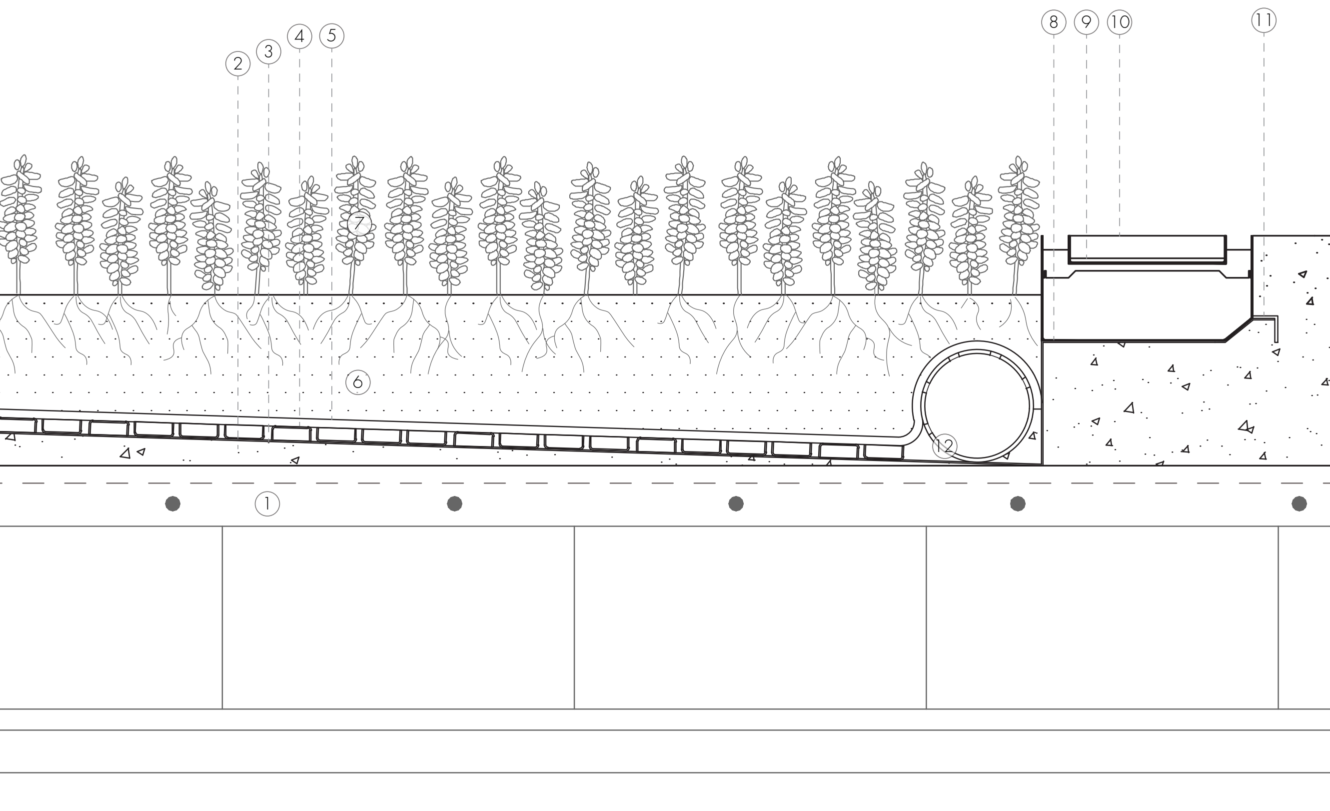
Elaborated by the author

Figure 65
Green roof detail. Section A

0m 0,25m 0,50m

Leyend

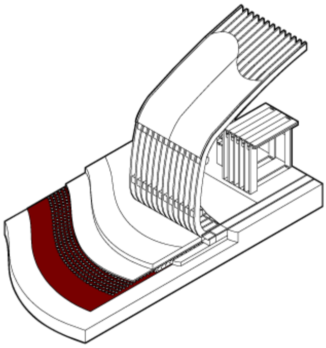
1. Pre-existent structure
2. Cement mortar (slope 1-2 %)
3. Protection layer (waterproof antiroot barrier Harpo ZD UV membrain 0,15cm)
4. Hydric accumulation and drainage (HDPE caps)
5. Mechanical protection (polyester mat)
6. Vegetation support course (crushed gravel tiles - 8cm)
7. Vegetation layer (local Sedum mix)
8. Superficial drainage (Harpo PRO-PAV channel)
9. Mortar coat
10. Cement tile (1,6cm)
11. Zinc element
12. Internal drainage (Perforated PVC tube - Ø 8cm)



Elaborated by the author

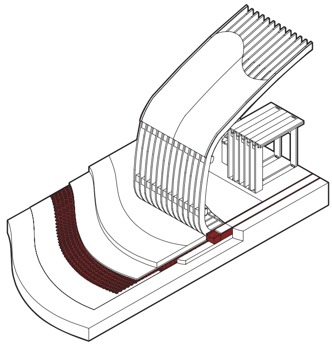
1. *Stratification structure*

1.1 Protective layer (antiroot & waterproof)



The general requisite for the mentioned layers is the resistance against water and root action. Both layers can be integrated as one single element and being also compatible, resist the permanent loads of the upper layers and resist the presence of microorganoisms. The Zinco's company proposes to implement two stratums; the Protection Mat SSM 45 [appendix 2] and the Antiroot WSF40 [appendix 1]. However, other companies propose a single sheet with both functions

In view of the fact that the protective layer is the most critic for the surviability of the building structure, it is highly suggested to avoid the use of recycled or reused alternatives that were not created with the primary purpose of serving as as a protective layer because of the risks that it could carry for the building structure and the green system functioning. It is instead suggested to employ a commercial protection mat that sythesizes the two functions in a single element. In this case, the Harpo ZD UV sheet, which is also lighter and thinner as it is shown in the appendix 6.



1.2 Hydric accumulation & drainage

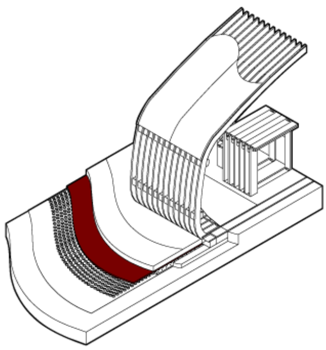
The water supply is one of the major limitants for the enhacement of plants. Even though, water might be stored in different components of the system, it is recommended water reservoir layer to elude the need of additional irrigation. Excess of water must be removed though a drainage system which is composed by the drainage stratum, a superficial drainage line and an internal PVC pipe. The superficial rail will catch the exceded water of pathways and the green cover while the internal elements will avoid the green roof waterlogging.

The Zinco Floradrain ® FD 25-E storage drainage consists in a highly optimazed piece. Its morphology permits compression resistance and the accumulation and drainage of water. The mat component is the result of thermoformed recycled polyolefin, a synthetic plastic from diverse polymers must likely including LDPE, LLDPE, HDPE and PP.

The outlined commercial drainage configuration is essentially composed by holder elements for the water retention and drainage gaps, to allow the circulation of the excess of liquid [appendix]. In this case is proposed the use of plastic water caps. The caps would be randomly disposed allowing the accumulation of water and its drainage through the gaps. The effectivity of must be tested in deep.

Overall, the benefit of the plastic caps is that its collection can be easily excecuted in the campus area by the university users, reducing landfill waste and emissions by transportation. In addition, these elements would gain a second life without any treatment and they can be directly used (after a cleaning process).

1.3 Mechanical protection



The reference filtrating sheet consists in a 0,60mm surface made of thermally treated polypropylene. This material allows a variety of applications due to its flexibility and its resistance to acid substances. In addition, its installation is simple and it allows a high water flux. According to the standards (F.L.L, 2002), the main function of this layer is to protect the downward stratums during the installation and the whole system's lifetime, while allowing a correct permiability and root penetration. As the referent, the layer requires a certain resistance and flexibility, in order to adapt to the other layers.

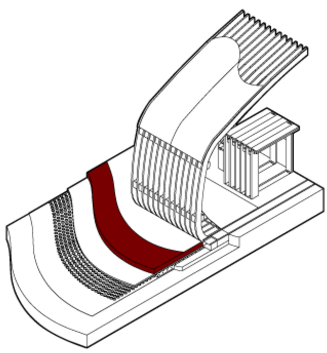
For the project's filter it is proposed the collection of tissue from clothing through the population of the university; the users would be informed and encouraged to collect their old used clothing instead of discard them. The selection of items would be dependent on the item composition. As several geotextiles[12], many sportive clothes and winter jackes of common brands are composed of polyester fabric. In fact, diverse of these popular brands seek to reduce costs not just by the implementation of synthetic materials but by reducing elaboration timing and quality of finishings elements (zippers, seams and buttons). As a consequence, the lifetime of items is shortenen, increasing the waste volume in landfill. Of special interest is the fiberfill of winter equipments, which is similarly disposed to geotextiles but differentiated by a greater volume.

It is expected to substract the fiberfill material form the equipment and compacting them through mechanical compression until it reaches a thickness of around 1mm. In doing so, the material can be implemented for a second life instead of being discarted or passing through complicated recycle processes which involve elevated energetic consumption and gas emissions. Nevertheless, the hydraulic velocity flow must be evaluated and if it is necessary, the material must be manually neddle-punched to increase the permeability.

12 Some commercial brands use the geotextile polyester fabric for the filter and drainage layers of green covers.

Due the their characteristic production process and involved additives, polyester resistance is elevated. For instance, the use of phosphatic compounds increases their thermal resistance and the application of ageing inhibitors augment the UV resistance (Wojtasik, 2018).

1.4 Vegetation support course:



The referential Zinco ® substrate consists in an allegedly ecological mix, since is produced from recycled materials. Essentially, composed by treated bricks based-on minerals and fiber matter compost. The brand offered mix depth of "Zincoterra" variates from 80mm to 90mm.

Ideally, the growth substrate must serve to aerate, drain, nourish and stabilize the supported vegetation. All the mentioned functions can be achieved by applying a correct mix of organic and inorganic elements. However, particular physical and chemical properties and characteristics must be considered.

Similarly to the reference, for this project it is proposed the utilization of debris (tiles, concrete and bricks) and compost, serving respectively as the granular components and the organic matter. Seeing that the proportion of the mix influences the roof enhancement, it is suggested to amend the inorganic material with a 10% in volume of organic matter (Ente Italiano di Normazione, 2015). This proportion allows an stable development of plants during dry and wet regimes. In order to reach the substrate stability, the granolumetric distribution of the aggregates must be taken into consideration and match the standads, with a maximum diameter of 100mm and a minimum of 0,075mm (F.L.L, 2002).

The inert debris material would derivate in first place from the removed tiles of the roof area. These tiles content gravel, typically used in green roofs for their compatibity with other elements and propierties. In second place, debris from the current construction works in the citadel. The totality of these elements must be crushed, in order to achieve the desired diameter range and subsequently sieved. In the same way, the employ of composted organic matter from the campus waste is suggested. This compost would be produced in the place by taking advantage of specific green[13] and brown[14] waste (from the food court, green areas among others). Green items might include vegetable scraps and grass clippings while brown ones include leaves, newspaper and paper. For the selection of raw materials, the carbon to nitrogen ratio [C/N] must range between 25:1 and 30:1 (Sidder, 2016; Rosales & Woo, 1982).

The decision of utilizing the mentioned

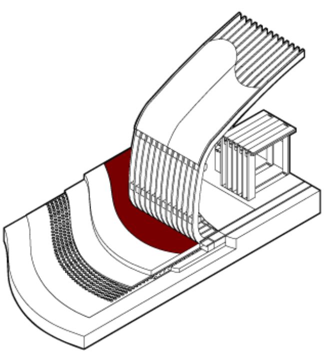
13 Defined as "waste that decays naturally and in a way that is not harmful to the environment" (Cambridge dictionary, 2020), essentially wet material from plants which are rich in Nitrogen.
14 Similar to the green waste but referring to the dry plant material instead of the wet one. The brown waste is the source of Carbon.

materials is led by the fact that those are a greener solution, analogous to the commercial version and found in the campus radio. Laboratory tests (Mickovski, Buss, McKenzie, & Sökmener, 2013) have concluded the suitability of recycled construction waste materials in supporting the vegetation. These aggregates resist erotion while possesing an adequate drainage property.

A life cycle assessment of greener living rooftops states that applying compost is a more suitable option if compared to the scenario of using this organic waste in landfill (Bozorg, Lehvävirta, & Häkkinenc, 2015). Added to this, it is proven that composted green wasted ameliorates the water holding capacity of the substrate and plant's property and surviability (Graceson, Hare, Hall, & Monaghan, 2014).

Regarding the required substrate depth, it is dependant of the greening type and vegetation used. The Italian standard (Ente Italiano di Normazione, 2015) suggest 80 mm depth for Sedums on extensive covers, while the F.L.L suggests a range between the 20mm to the 150mm (F.L.L, 2002). The proposed depth for the project is a 80mm, matching the commercial and fitting the standards.

1.5 Vegetative stratum



The vegetation for the system is defined by considering the climatic and territorial context in order to reach a better optimization as indicated by local regulations (Ente Italiano di Normazione, 2015). Local vegetation is prefereable[15] because is naturally adapted to the area conditions. Especially plants with a higher resistance to harsh conditions. Plants from the genus Sedum are suitable to this purpose and often utilized in green covers over other types because of their high resistance capabilities (Boivin et al., 2001, as cited in VanWoert N, Rowe, Andresen, Rugh, & Xiao, 2005).

Sedum present a greater drought tolerance than forbs and grasses (Dunnett, & Nagase, 2010) in view of their photosynthetic carbon metabolism and capacity to store water. These species are cathegorized as Crassulacean Acid Methabolism (CAM), meaning that they posses the ability to adapt to dry coditions (VanWoert N, Rowe, Andresen, Rugh, & Xiao, 2005). For this reason, they require a minor frequency of irrigation and lower maintence in comparison to other species. Sedums withstand heat and frost while maintaining an optimal performance (Purwadaria, Seminar, Suroso, Tjokronegoro, & J, 2002). In addition, succulents are distinguished by their shallow roots and the variety of shapes and colors of their shoots and leaves, fact that might improve the aesthetics aspect of the target area.

This investigation enlists a selection of

15 Regulations of public and private greens for the city of Turin (Consiglio Comunale di Torino, 2014), article 56, encourage the utilization of autochthonous species for the creation of green areas as well, seeking the improvement of the local place value.

the most suitable sedum species for a green cover in Turin. Including: Sedum Album, Sedum reflexum, Sedum Acre, Sedum Sexangulare, Sedum Dasyphyllum and Atratum. All of the mentioned species are native and found in the nature in the area of the intervention. Besides of being adapted to the local conditions, they are selected in order to promote the place values, as suggested in the Normative of Public and Private Green on the city of Turin; in which it is explicit, in the title II article 56, that "in the selection of the species to implant in the green areas they must be privileged the autochthonous species"

2. Compulsory accessories

Referred to the components excluded from the stratigraphy but necessary to reach the correct system's functionality and maintenance. The selected accesories are commercial. These products involve:

2.1 Drainage rails

As an integral part of the drainage system, the drainage channels consist in linear permeable elements, necessary to permit the water flow and drainage. In particular, it is proposed the utilization of a lineal stainless steel drainage trail with double slit by Harpo ®. In specific, the CL2F - PRO PAV (Harpo Group, 2020). The particularity of the mentioned element is that it 'camouflages' to the architectural context. Effect that occurs due to its configuration of thinner grooves and free central space for the emplacement of tiles. Tiles that in this case consist in concrete pieces. On the other hand, it is proposed an internal PVC pipe avoid the water accumulation in the deepest part of the system.

SPECIE	LOCATION
SEDUM ALBUM (white stonecrop) (borracina bianca)	
SEDUM ACRE (goldmoss stonecrop) (Borracina acre)	
SEDUM SEXANGULARE (Tasteless stonecrop) (Borracina insipida)	
SEDUM REFLEXUM (Sedum rupestre) (Borracina rupestre)	
SEDUM DASYPHYLLUM L (Thick leaved stonecrop) (Erba della principessa)	

Table 8
Vegetation

CHARACTERISTICS | PROFILE VIEW

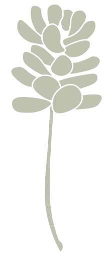
MAXIMUM HEIGHT 10cm

SPREADING RANGE 46cm

FLOWERING PERIOD

J	F	M	A	M	J	J	A	S	O	N	D

- Cromatology: Green lime,red burgundy
- Bloom: White
- Root depth: Shallow
- Maintanance requirement: Low
- Irrigation need: Medium
- Sun requirement: Full sun
- Tolerace: Drought, shallow rocky soil, air pollution, light shadow
- Attracts: Butterflies
- Other characteristics: Fast grow, easy to propagate, perennial, evergreen.



MAXIMUM HEIGHT 7cm

SPREADING RANGE 61cm

FLOWERING PERIOD

J	F	M	A	M	J	J	A	S	O	N	D

- Cromatology: Green
- Bloom: Yellow
- Maintanance requirements: Low
- Irrigation need: Dry, medium
- Sun requirement: Full sun
- Ground coverage: Good
- Tolerace: Drought, dry soil, shallow rocky soil, air pollution, light shadow
- Other characteristics: Perennial plant, evergreen.

MAXIMUM HEIGHT 10cm

SPREADING RANGE 61cm

FLOWERING PERIOD

J	F	M	A	M	J	J	A	S	O	N	D

- Cromatology: Green, coral-reddish
- Bloom: Yellow
- Maintanance requirement: Low
- Irrigation needs: Dry, medium
- Sun requirement: Full sun
- Ground coverage: Excellent
- Tolerace: Drought, dry soil, shallow-rocky soil, air pollution, light shadow

MAXIMUM HEIGHT 10cm

SPREADING RANGE 61cm

FLOWERING PERIOD

J	F	M	A	M	J	J	A	S	O	N	D

- Cromatology: Green, coral-reddish
- Bloom: Yellow
- Maintanance requirement: Low
- Fertility: Low, moderate
- Irrigation need: Dry, medium
- Sun requirement: Full sun
- Ground coverage: Excellent
- Tolerace: Drought, dry soil, shallow-rocky soil, air pollution, light shadow
- Other characteristics: Mat forming perennial plant, evergreen.

MAXIMUM HEIGHT 8-12cm

SPREADING RANGE 38cm

FLOWERING PERIOD

J	F	M	A	M	J	J	A	S	O	N	D

- Cromatology: Grey green, turquoise grey
- Bloom: White, pink
- Maintanance requirements: Low
- Water needs: Moderate
- Sun requirements: Full sun or slight shadow
- Ground coverage: Excellent
- Tolerace: Drought, dry soil, shallow-rocky soil, air pollution, shadow
- Other characteristics: Low mat forming perennial plant, evergreen.

2.2 Inspection chamber

The selected control spots are the offered by Harpo ®. The PK 5 control chambers consists in a thermo-insulated metallic piece. This piece is resistant to compression and posses vertical perforations in the lateral faces and superficial perforations in the top area to allow the water flow (Harpo Group, 2020). Their purpose is serving as spots to execute pretinent maintenance inspections.

2.3 Irrigation system

The proposed method is drip system. Consisting in a network of thin hoses installed over the growing media, for the slow release of water.

3. Additional accessories

Referred to the non compulsory accessories that could improve the performance of the system

3.1 Hydric measurement device:

Since additional irrigation might be required during dry seasons, it is recommended the incorporation of a tool for the automatization of the vegetation water supply. The mentioned device is the Medi WaterSafe of Harpo ® and it measures the hydric potential through electromagnetic probes, activating the water flow if lectures show a drop of relevance (Harpo Group, 2020). This allows the maximum performance of the vegetation, at maximum saving of resources.

4. Surroundings

Referred to the architectonical elements which form an integral part of the roof top garden regarding design and functionality at user dimension. In other words, elements constructed around the green roof system itself.

4.1 Trafficking areas:

As it is illustratated in figure 60, the project counts with defined circulation areas. The main ones consiting in the

SEDUM ATRATUM
(Dark stonecrop)
(Borracina verde-scura)

Figure 66
Superficial view of CL2F - PRO PAV drainage

Note: Harpo verdepensile. (n.d.). [Pothography of example of application of PRO PAV drainage in real life]. Retrieved 2021, from: https://www.harpogroup.it/

MAXIMUM HEIGHT 8cm

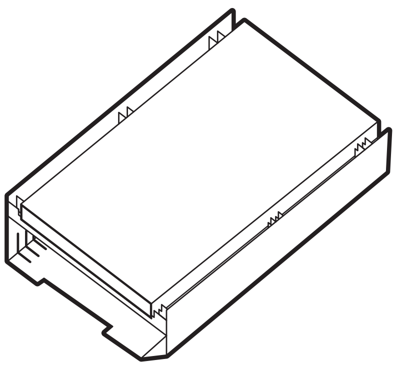
FLOWERING PERIOD

J	F	M	A	M	J	J	A	S	O	N	D

- Cromatology: Green, reddish.
- Bloom: white
- Maintanance requirements: Low
- Water needs: Dry, moderate
- Sun requirements: Full sun
- Tolerace: Drought, dry soil, shallow-rocky soil, shadow

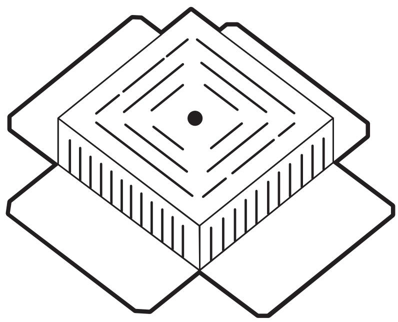
Illustrated table of proposed Sedum species and their characteristics. Including: Location, flowering time, spreading, height, description and an schematic view. Elaborated by the author. Based on information retrieved June, 2021, from https://www.floraitaliae.actaplantarum.org/

Figure 67
Illustration of CL2F - PRO PAV drainage rail detail



Note: Adapted by the author from Harpo verdepensile. (2021). Canalette lineari a fessura. Retrieved June, 2021, from: https://www.harpogroup.it/

Figure 68
Harpo PK 5 inspection chamber illustration



Note: Adapted by the author from Harpo verdepensile. (2021). Pozzetti di controllo per scarichi in copertura. Retrieved June, 2021, from: https://www.harpogroup.it/

pre-existent paved paths, aligned to the logitudinal axes of the greening emplacement. Concrete tiles inserted in the drainage rails complement the mentioned path. The transversal link is allowed by concrete panels.

4.2 Furnishing:

Pergolas are settle for the semi permanence, incorporing tables and stools.

FEASIBILITY

1. Technical viability

1.1 Structural capacity[16]

In order to perform a complete analysis, the loads that gravitate on the roof

16 Tables in appendixes 11 to 17

of the building are studied in this section. An evaluation of the most unfavorable combination is taken into account to ensure that the building resists the installation of the chosen green roof. The required mathematical process is performed following the official norm "Norme tecniche per le costruzioni".

1.1.1 Combination of loads:

The norm defines the combination used for the Ultimate Limit State (ULS) as:

$$\gamma_{G_1} \cdot G_1 + \gamma_{G_2} \cdot G_2 + \gamma_P \cdot P + \gamma_{Q_1} \cdot Q_{k_1} + $$
$$+ \gamma_{Q_2} \cdot \Psi_{02} \cdot Q_{k_2} + \gamma_{Q_3} \cdot \Psi_{03} \cdot Q_{k_3} + \cdots$$

Adapting the expression on the particular case of this project, the new definition becomes:

$$\gamma_{G_1} \cdot G_1 + \gamma_{G_2} \cdot G_2 + \gamma_{QU} \cdot Q_U + \gamma_{QS} \cdot \Psi_{02} \cdot Q_S$$

Where is the structural and non-structural own weight as permanent loads, the use overload as the principal variable load and finally the snow as the secondary one, applied with a combination factor. This is the chosen combination due to the high probability of using the roof as a walkable zone. Wind load, which is horizontal, is not considered as the roof is the only part of the building that is being studied in this project.

- Own weight of structural materials (G_1):

Considering that in our building reinforced concrete is used, we multiply the specific weight [appendix 12] by the vertical dimension, which is around 0,5 m, and we obtain the load in [kN/m^2]

G_1= 25 kN/m^2 * 0,5m
G_1 = 12,5 kN/m^2

- Own weight non-structural materials (G_2):

The materials of the green roof can be considered inside this category as this component does not contribute to the resistance of the structure [table 9].

G_2= 92,1 Kg/m^2 * 9,81m/s^2
G_2= 0,90kN/m^2

Table 9
Stratigraphy Loads

LAYER	DEPTH (cm)	MATERIAL	PERCENT (%)	WEIGHT* (Kg/m^2)	WEIGHT** (Kg/m^2)
Waterproof antiroot	0,15	PVC membrain		2,20	
Drainage [b]	1,00	Bottle caps		4,90	
Filter	1,00	Polyester		0,20	
Growing media	8,00	Compost	10	2,80	59,8 [a]
		Gravel and cement	75	50,0	
		Air	15	0,00	

[*] Weight per square meter, [**] Weight per square meter at maximum saturation, [a] Since is propose to use the tiles located in place as aggregate component, the total weight of the tiles that currently occupy 1m^2 was sustracted because the building resistance data was already considering that weight. [b] Summatory of layers weights, considering a 70% of the water caps facing up and fully saturated. Maximum capacity of 7L. Elaborated by the author

- Overload due to use: A uniformly distributed load is considered as the use of the roof. The category I type B1 was chosen [appendixes 13, 14] as the space is designed to be a workplace.

Therefore, the variable load due to use would be:

$Qu = 2kN/m^2$

- Snow load:

The load due to the weight of the snow is computed following the norm with the expression:

$q_s = q_{sk} * \mu_i * C_E * Ct$

Where qsk is the reference value of the snow load, μi[17] is the shape coefficient, C_E[18] is the exposition coefficient and Ct[19] is the thermic coefficient.

For all these values tables and graphics can be found on the norm, in the appendixes 15,16,17.

Finally, we get the snow load:

$q_s = q_{sk} * \mu_i * C_E * Ct$
$q_s = 1{,}5\ kN/m^2 * 0{,}8 * 1 * 1$
$q_s = 1{,}2\ kN/m^2$

After the computation of all values, we can finally complete the expression previously explained, which represent the combination of loads required to be studied under the Ultimate Limit State (ULS) criterion[20].

$Ed = 1{,}1*12{,}5kN/m^2 + 1{,}1*0{,}90kN/m^2 + 1{,}5*2kN/m^2 + 1{,}5 * 0{,}5 * 1{,}2kN/m^2$

$Ed = 13{,}75kN/m^2 + 0{,}99kN/m^2 + 3kN/m^2 + 0{,}9kN/m^2$

$Ed = 18{,}64kN/m^2$

Importance and combination factors were chosen the tables in appendix 26 and criteria showed previously.

1.1.2 Roof resistance:

The obtained load demand is compared to the design resistance of the roof, obtaining that:

$Rd \geq Ed$
$20kN/m^2 \geq 18{,}64kN/m^2$

The building is clearly suitable for the chosen green roof to be installed. Extensive greening solutions are lighter in comparison with the other alternatives and this one in particular should not represent a structural problem if a correct periodic maintenance is performed. However, it must be noticed that the combination of loads of a commercial proposal such as the Zinco extensive system [loads in appendix 16] is more favorable, with a result of $18{,}1kN/m^2$.

1.2 System's autonomy

Regarding to the capacity of the roof garden system to self sustain. Factors as irrigation and energy requirements are considered.

17 Depends on the shape and inclination of the roof surface with respect to the ground. In the case of this project, the roof is lightly inclined and therefore the value can be read on the table, where μi = 0.8
18 The exposition coefficient (CE) depends on the specific characteristics of the zone where the building was constructed. As this building is located on a city, a normal exposition can be considered. Due to this, the value is CE = 1
19 This factor considers a reduction of the snow load due to its melting when a thermal insulation material is present. In this case, in absence of one, Ct = 1
20 The ULS condition is a commonly used criteria to check the behaviour of a structural scheme. The limit is located at the upper part of the elastic zone, approximately 15% lower than the elastic limit. The reason of choosing this limit, far from the real ultimate point which is on the plastic zone, is the security we get about the capacity of the structure under repetitive loadings. The ULS is purely an elastic condition, and the level of safety and reliability assumed on the design phase is satisfied as long as the mathematical condition is fulfilled.

1.2.1 Irrigation system

A consideration of interest to deliniate the autonomy of the green cover are all elements intervening in the irrigation process. In accordance to the *Italian Normative UNI 11235*, each component in degree of holding water must be included. The irrigation system them is composed by the growth medium, storage devices and drainage elements.

Even though it was stablished that Sedum can withstand 88 days drought and the record of days lacking of precipitation in Turin is minor, water storaging must be considered to permit their best performance. It is proposed for the project the natural precipitation as unique source of water for irrigation. The water uptaking will be divided in three different levels: the vegetative support course, the storage reseivour and a backup tank.

1.2.1.1 Vegetation support course:

As a reference, the guideline (F.L.L, 2002) states that a *Sedum* extensive growing media of 80mm depth will retain a maximum annual average of 50% liquid, which in this instance could be slighly lower by the yearly precipitation in Turin. The monitoring of the guideline was executed in locations with annual values of 650-800mm, while in the city the media is 846mm (Climate data, 2020). Nevertheless, by incorporing coir fiber, water retention might be improved. For this reason, it will be considered a 50% as the water reterntion

1.2.1.2 Storage reseivour:

- Proposal A: In the case of a disposition of 50% of plastic cap's linear capacity in one square meter surface, the maximum water retention capacity would be 5,2L/m^2.
- Proposal B: Seeing that the disposition is a random distribution, the measurement of water retention capacity is complex to execute.

1.2.1.3 Backup tank:

A supplementary tank fulfilled with harvested water from the roof of the access volume will be emplaced for its utilization in critical periods. Owing to this, the definition of the tank size will be calculated in base of the annual requirement. In order to determine the tank dimension as idicated by the normative *EN DIN 1989-1:2000-12* [21] it must be employed:

$$Vc=TSM*VMF/365$$

where *Vc* is the volume of the tank based in the annual plant requirements (volume della cisterna), *TSM* is the mean dry time (tempo secco medio) and *VMF* the maximum volumen of hydric requirement (volume massimo di fabbisogno idrico).

Then, knowing that:

- The mean of rainy day in Turin is 75 days[22], the mean of dry days can be dertermined by:

$$TSM = (365 - n\ of\ wet\ days)/12$$
$$TSM = 24,1$$

21 Kessel. (2000). *EN DIN 1989-1:2000-12. Sistemi di recupero delle acque piovane*. Retrieved from: https://www.kessel-italia.it/fileadmin/pdf/IT/010-775_(07-Sistemi_di_recupero_delle_acque_piovane).pdf
22 Media from 1984 to 2016 (Agenzia Regionale per la Protezione Ambientale, 2018)

- For the obtention of the VMF is employed:

VMF=E*S
VMF=60L*2

where E is the requirement and *S* the green surface.

As indicated in the normative, the minimum referential yearly value for irrigation requirements in plants is 60L per square meter [23] [appendix 18].

By sustitution the resulting volume of the tank is:

Vc=TSM*VMF/365
Vc=480,7L

This is suitable with a commercial tank of 500L [appendix 21].

In order to achieve the best performace of the vegetation, it is desirable to reach an equitative amount of water storage in the tank seasonally. For this reason, the maximum accumulative water volume capacity of the catchment roof is calculated as indicated in the normative *EN DIN 1989-1:2000-12* by:

VMC = S x Y x P x Hfil

where VMC represents the maximum volumen accumulative, S the surface area of catchment, C the runoff coefficient, P the seasonal intensity of precipitation and Hfil the filter efficiency

- As indicated in the normative, the runoff coefficient for a flat metal roof is 0,98 [appendix 20]
- And for filter efficiency it will be used 0,9 which is the most common value.
- The seasonal precipitation in Turin can be found in the appendice. [appendix 23]

As a result, the precipitation in Turin permits the full tank capacity in a year basis with an equitative distribution by season.

In conclusion, the total hydration of the plants and best performance can be reached just by employing metheoric discharge as unique source of water. Hence, the vegetation can be automatically supplied by the use of the hydric measuring device, a suitable irrigation method and a reseivour tank.

1.2.1.4 Irrigation method:

The selected irrigation method is the drip irrigation. This methods is based on a slow release mechaninsm, granting a precise supply by saving the water resource. The amount of water is not variable in contrast to different methods. Yet, the water is applied precisely where is needed (Schwanki, 1999).

1.2.2 Energetic autonomy:

Energy requirements are limited to the powering of the supplementary irrigation system, the supply for the equipment of researches (laptops, measurement devices, among others) and for the illumination network during night. The totality of the enlisted needs are actually referred to occasional situations instead of frequent ones. Nevertheless, to the fullfilment of these necessities, it is proposed to incorporate

23 This value is refered to the yearly irrigation of gardens, but seeing that Sedums water requirements are below regular plant's need, this was considered as referential value.

organic translucent lightweight flexible solar cells. The cells would be placed on the top of the pergolas which are purposely design with an inclination in the direction of the south to capture major amounts of solar energy. The commercial cells of ASCA ® weights around 450g/m^2 and produce up to 40 Wp/m^2 (Armor, 2021). The captured energy would be storaged in a battery for its posterior utilization for the irrigation and lighting of the pergolas.

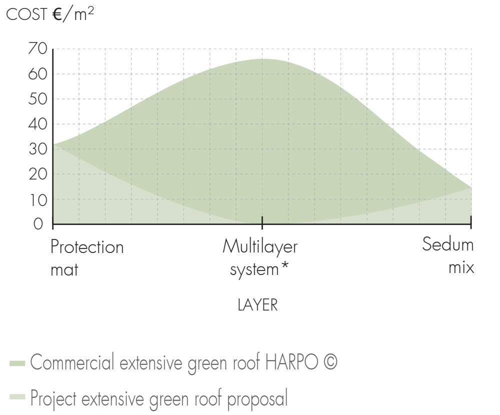
In the interest of granting nocturnal visits for investigations that might require the mentioned conditions, two illumination lines will be implanted though the longitudinal area of the greenings. Permitting the lighthing of the main paths. The selected lighting devices consist in lightweight solar powered outdoor leds. These devices are designed to be simply fixed in the growing media. Each single individual stainless steel lighting device posses photoreceptors for the sun light catchment and sensors for their automatic programming[24].

2. Economical viability:

As it was mentined multiple times, the proposal is mainly based on the recovery of waste for its reuse, recycle and posterior implementation as construction material. Even though the project is not exempt of the application of virgin elements with a certain inversment requirement, it is still expected a reduction of the cost in the initial phase of the life cycle of the green system statigraphy. Precisely, by the implementation of the mentioned typology of materials in three of the five layers [figure 69].

The use of reused and recycled materials will not only erradicate the specific layers suply expenses but possibly, transportation costs as well. Furthermore, even though the integration of the students and volunteers is not proposed with the purpose of reduce costs, it can contribute to the economical workforce savings by their didactical participation during the installation process.

Figure 69
Geen roofs stratification cost.
Commercial vs. Proposal



[*] The multilayer system of the commercial version includes growing media, filter mat, drainage layer, mecanical protection sheet. Its equivalent, in the propose includes: Growing media, filter and drainage.
Elaborated by the author using as reference cost reports provided by Harpo

From the table 10 it can be assumed that the total cost would be around 11.491,29EUR. Considering, in one hand, the mentioned stratification, impermeabilization constuctive details and accessories[25]. Excluding, in the other hand, demolition, cleaning, lisence authorization, pertinent verification studies, the exe-

24 Reference lightning system: Luci Solari Giardino Tomshine 12LED Luci Solari da Esterno Faretti Solari a LED da Esterno IP68 Impermeabile(Bianco caldo) www.amazon.com

25 For the calculation is considered the implementation of 1 inspection chamber for the full area.

Table 10

Economical approximation - Green system stratography

DESCRIPTION		MATERIAL QUANTIFICATION/m²		COST €/m²	
STRATIGRAPHY		UNIT	REFERENCE VALUE	U.O.M.	TOTAL
A. ANTIROOT IMPERMEABILIZATION Synthetic membrane HARPOPLAN ZD UV		m^2	1	m^2	32,50
B. HYDRIC STORAGE & DRAINAGE HDPE containers		Pieces/m^2	1111-2222	m^2	0
C. FILTRATION SUBSTRATE Polyester mat		Pieces/m^2	4-6	m^2	0
D. GROWING MEDIA Organic matter & aggregates	D.1 COMPOST	Kg/m^2	2,8	m^2	0
	D.2 GRAVEL MIX	Kg/m^2	49	m^2	0
E. VEGETATION Mix of sedum species		Pieces/m^2	4-16	m^2	7,00
				TOTAL €/m²	
				m^2	39,50

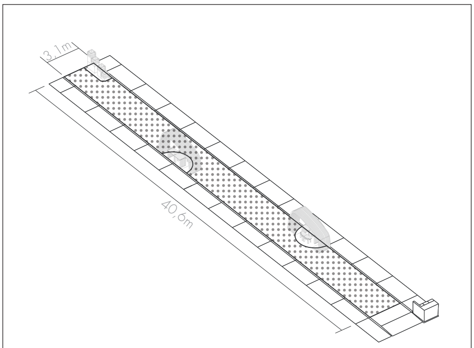
Economical approximation - Green system accesories

COMPULSORY ACCESORIES	COST €/piece	
ELEMENT	U.O.M.	TOTAL
A. DRAINAGE RAIL Linear double slit rail CL2F-PRO PAV	m	130,00
B. DRAINAGE PIPE PVC Pipe 8mm diameter	m	2,00
TOTAL		
	m	132,00
C. INSPECTION CHAMBER For water flow in cover PK 5	piece	165,72
TOTAL		
	piece	165,72
	COST €/m²	
D. IRRIGATION SYSTEM Drip system	m^2	12,00
TOTAL		
	m^2	12,00

ADDITIONAL ACCESORIES	COST €/m²	
ELEMENT	U.O.M.	TOTAL
A. WATER MEASURE Media WaterSafe	m^2	15,00

Note: The cost of the impermeabilization construction details is not considered in the table. According to Harpo, cost for a 500m² system would be 109,52EUR. Suply, transportation, installation and burden costs are considered.

Project green area



Green area: 112,7m²

Elaborated by the author in based of the proposal plan. Taking as reference for commercial elements, the price list provided by Harpo and the web: www.leroymerlin.it/catalogo/

Table 11
Green covers life cycle: Proposal vs. Commercial
Stratification green roof life cicle comparison

	PROPOSAL				LIFE CYCLE PHASE	ZINCO				
MATERIAL	1	2	3	4		1	2	3	4	5
FIRST USE				✓	Material extraction		✓		✓	✓
				✓	Transportation		✓		✓	✓
				✓	Production		✓		✓	✓
				✓	Transportation		✓		✓	✓
				✓	Construction		✓		✓	✓
				✓	Operation & maintenance		✓		✓	✓
				✓	Disposal, reuse or recycle		✓		✓	✓
SECOND USE		✓	✓		Transportation	✓		✓		
	✓	✓	✓		Second use	✓		✓		
	✓	✓	✓		Treatment & preparation	✓		✓		
					Transportation	✓		✓		
	✓	✓	✓		Construction	✓		✓		
	✓	✓	✓		Operation & Maintenance	✓		✓		
	✓	✓	✓		Disposal, reuse or recycle	✓		✓		

The proposal is mainly based in providing a second life to the majority of the implemented stratification materials. Avoiding the implementation of virgin materials and reducing pollutant emissions from the transportation and production phases. As it can be noted, must of the stratums of the proposal proceed from materials that accomplished their life cycle but were given with a second use. The following table compares the procedence of the stratigraphy life cycle of the proposal versus a commercial version (Zinco). Intending by procedence the life cycle phase of each material (virgin or first use and recycle/reuse or second use). Legend: Proposal: [1] Growing media, [2] Mechanical protection or filter, [3] Water accumulation and drainage, [4] Waterproof and root barrier Harpo. Zinco: [1] Substrate Zincoterra, [2] Zinco filter, [3] Floradrain filter, [4] Antiroot WSF40, [5] Protection matSSM45. Note: Elaborated by the author, based on information from appendixes 1, 2, 3, 4, 5, 7, 8 and the commercial companies (Harpo Group, 2008; Zinco, 2021)

cution of a 1-2% cement mortar slope, the plastic water tank, illumination, surrounding elements and maintenance[26].

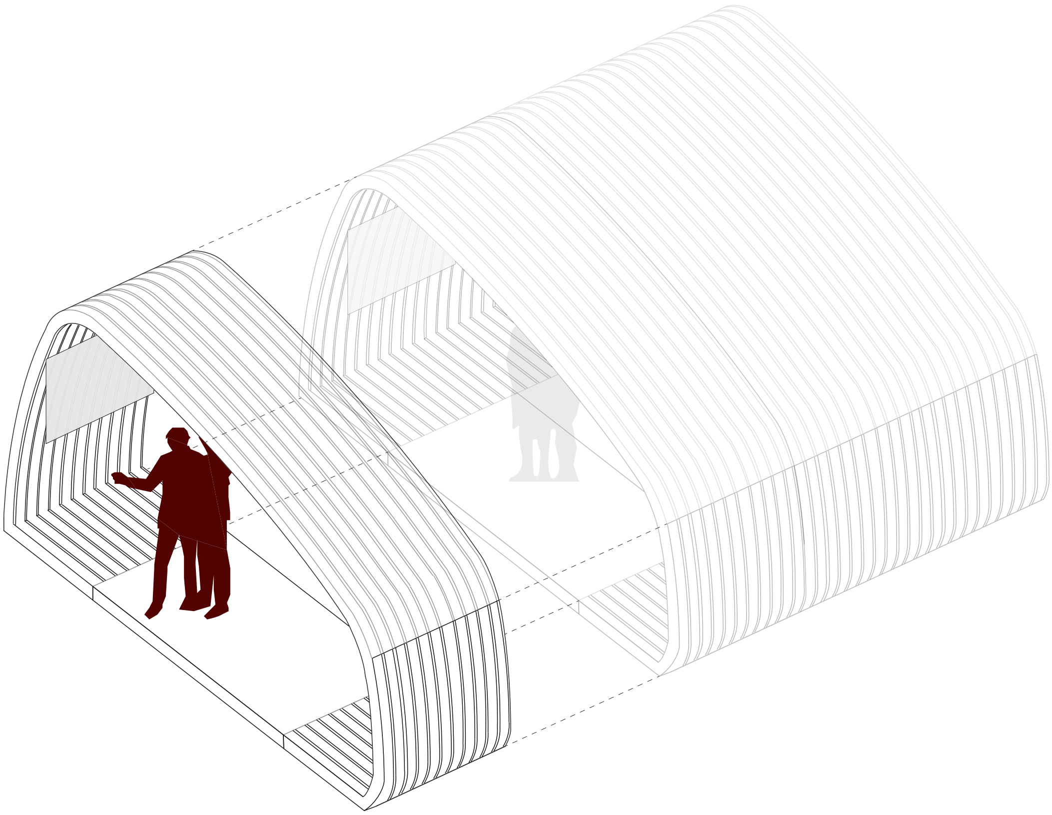
3. Life cycle outline:

In order to understand if the environmental impact of determinate aspects of the proposed green cover are improved, a general comparison between the mentioned and a commercial version is presented in the following part. The comparation between the layers of the GR comprehends materiality, production and transportation.

The strict requirements of elevated resistance and duration of green covers lead to a proposal with a majority of synthetic materials, as well as the study case. Nevertheless, focusing in the reuse and recycle of waste materials as a primary source for

26 It must be study the behaviour of the selected materials in long term in order to determinate if the number of maintenance visit per year remain in a range of 1-2 as dictated by UNI 11235 or if instead, more visits are required.

Figure 70
Modular element posterior use



Exemplification of posterior application of the modular element; it is proposed to be implemented as a linear pavillion for squares exhibitions which is a common activity in squares at the city. For instance, in Piazza Castello there are typically expose intinerant educative exhibitions, installed over similar structures. Note: Elaborated by the author

the construction of the system. That is to say, enhancing a second life of particular waste materials. Even though three of the five layers of the proposed GR are based on polymers, two of them totally are based on recovered materials of reduced impact treatment need. Regarding the production (better called treatment phase in this case), it is sought to employ processes of minor impact to the environment. The proposed treatments are based on crushing, cutting, cleaning and mechanical comprehension, which in their majority consist in minor interventions that could be manually executed due to the scale of the project.

In contrast, four out of six layers offered for Zinco's extensive roof possess in their composition at least one kind of polymer. These polymers include polyolefin and polyethylene which allow a higher resistance and durability but all of them require manufacturing processes of major impact. In fact, three of the mentioned parts of the green cover are produced from scratch, specifically for the green roof. Not taking advantage of the potential of waste materials. But even in the case of the drainage sheets (Floradain FD 25-E), which are indeed composed of recycled polyolefin, require thermoforming operations. Operations that might need at least 125°C to 190°C temperature to be able of reshapening (Ashter, S.A., 2014; Throne J.L., 1981).

The proposal transportation demands are minor because of the advantage of the university waste utilization as the main source of various materials as well as the collaboration of the users from the campus. Excluding the protection layer, additional materials for the layering composition will proceed from the local area. Furthermore, the transportation necessities result reduced by the propose of treatment of these elements in situ. In opposition, the commercial example would require at least two transportation phases for each single component of the layers.

Regarding the modular structure for the semi-permanence over the roof, it is proposed a structure of simple disassembly for a posterior use as a linear pavilion for expositions.

A PATH TO SUSTAINABILITY

The sustainability concept is "the quality of causing little or no damage to the environment and therefore be able to continue for a long time" (Cambrige Dictionary, 2020). The most spread definition proceeds from the Brundtland Commission Report in which it is described as the development to meet the present necessities avoiding to compromise the following generations capacity to meet their own (International Institute for Sustainable Development, 2020). However, in architecture the concept achieves a different level of complexity, involving economical, ecological, social and cultural aspects.

Hence, with the purpose of really achieve a certain level of sustainability in the projectual proposal, it is suggested to spread the green roof application, generating a system of vegetative covers in the campus. In doing so, it is possible to integrate the social and cultural aspecs and amplify the radio range of the project in regards to the ecological and econominal impact. For this, it is impertative the targeting of additional building roof surfaces in which the installation of green structures seems possible. The diverse vegetative gardens should be projected for different uses, related to the host volume. In order to expand the research possibilities, each of these top green areas should also posses variations in the layering composition and dimensions. This is how, all the selected green areas should permit also different levels of accesibility.

1. Roof selection[27]:

The selection is essencially determined by the site analyses. Prioritising the following characteristics:

- Heavy weight structures, in order to reduce the complexity of the interventions and as a consequence, the costs. Lightroofs require additional structuctures for the installation of vegetatives covers.
- Inclination of <10 degrees. Greater slopes require additional infrastructures.
- Surfaces with maximized sun exposure. Based on the volume heights, surroundings and solar path.

2. Green covers use:

27 Feasibility studies result indispensable for the roof selection.

The goal of the installation of green covers is to favor the ecological scope of the university, serving as objects for reserch. Therefore, the totality of the surfaces will permit the exploration of different academic aspects of the mentioned systems, while the variations in their stratigraphy will contribute to amplify the range of the investigations.

So all in all, every selected rooftop must serve the research purpose. Nontheless, the green gardens are attatched to a main use in corrispondance to the internal activities developed or in the volume itself or inmediate ones. Previously existent green areas uses are considered as well. The uses take into advantage the characteristic of being "isolated" by their location of the top, to develop principally activities with the necessity of calm. Green roof uses are:

- Researching: Dedicated exclusively for researches linked to the roof gardens. Accessively for specicific researches and students with this aim.
- Studying: Conditioned areas to allow the activity in open areas, serving as open study rooms.
- Recreation: Generating green paths that fomentate the biodiversity. For the enjoyment and calm. Places to "clear the mind" and exchange light social interactions during the week days and for eventual dinamic social and cultural activities in scheduled ocassions.
- Relaxation: Areas dedicated to the relax and rest during break times. Focused specially for the university staff (administrative staff, professors, employees)
- Food production: Terraces to the production of food to supply the bar and eventually the food court.

3. Context relation:

The relation with the surroundings is defined by the existing activities. Reinforcing the existing green network and enhacing the link between the upper building surfaces and their interior. The studying and recreational areas located on the top of buildings with classrooms, studyrooms and libraries, relaxation areas located on top of offices and administrative areas, food production in the proximity of the bars and research covers in the proximity of laboratories and studyrooms.

4. Aspects of sustainability:

How this project would reach the sustainablity? By incorporating the dimensions of sustainabiliy and creating a real impact due to the proposed scale of the project. Since a small green area would not create a real benefit in the area, whilst a system of various green covers with the promotion of various activities and dinamics could create a major impact.

4.1 Ecological:

It is expected to achive an impact regarding the environmental dimension by the addition of green surfaces over the roof areas. In total, the realization of the proposal would imply the covering of around 7.500m^2 of new green spaces. Contributing in first place, to the internal conditions of the buildings. And possibly to external factors as amelioration of air quality, the reduction of water pollutants, runoff absorbtion as well as the promotion of the biodiversity.

This intervention would objectively mean an addition of around a +5,0% of greenings over the headquarter. It must be noted those would be new accesible and exploitable areas constructed over unitilized ones. Therefore, not only new vegetation is being added but unused spaces are gaining usefulness. Meaning that the porcentage of green areas over the area would increase from a 6% to a 11%[28]. Percentage that could rise even more with the instalation of vegetative covers over challenging surfaces, but probably sacrificing accessibility[29].

It is also expected to extent the life cycle of the selected materials waste materials. Reducing the impact they would have if disposed as lanfill or if they were incinarated. Using this kind of material should serve as well to encourage the creation of similar iniciatives to future projects.

4.2 Economical:

Besides of serving as motors to generate savings due to the isolation effect over the building. Proposed green covers are autonomous systems, allowing a certain level of self sufficiency regarding the energy use. The creation of diverse green rooftop surfaces will inebitably generate employment, owing to the necessity of a periodic maintenance. In addition, the utilized non recycled or reused materials are from the area, impulsing the local economy.

4.3 Social & cultural:

In first place, all the green rooftops posses a certain degree of accessibity to allow their profitability. In doing so, vegetated roofs are not mere accessories but their potential is fully exploded and integrated to the campus, allowing the users the appropriation of the rooftop areas. Zones as relaxation and recreation areas are projected to enjoy alone or in company.

The Polytechnic is well known to fomentate the cultural integration and the inclusion of foreign population (exchange students). For this reason, it is expected to complement the mentioned aim with the addition of eventual temporary cultural and social activities on the green paths and free areas.

TECHNICAL DATA & DESCRIPTION

1. Green area: 423,6m^2
Primary users: University staff
Permanece: Low to medium
Description: Resting areas. Equipped with furniture to lie down, and relax.

2. Green area: 168m^2
Primary users: University students.
Permanece: Medium to high
Description: Roofted passing through capsules. Dedicated to the study. The inclination is porpusely disposed to allow an optimal sun cathching for plants and perforations permit natural illumation. The disposition of the capsule provide a sensation of isolation.

3. Green area:1804,4m^2
Primary users: University students.
Permanece: Medium
Description: Green path with ramps. Dedicated to social exchanges to provide the users a place to clear their minds. Equipped with brench and tables for the repose and study.

28 This occurs because the optimal roof surfaces over the Citadel have a predetermined use and adding additional vegetated covers would imply a major difficulty.
29 For instace sloped roofs

4. Cover area: 600 m^2
Primary users: University students.
Permanece: Medium to high
Description: Lightweight raincatcher. Open roofted space conditioned for the execution of multiple activities such as: social reunions, open classes and physical practices.

5. Green area: 470,4m^2
Users: Food court and bar employees.
Permanece: Medium to high
Description: Urban agricuture terraces. Taking advantage of the terrace disposition for irrigation, this spaces are dedicated to the food production. Specially for the near bar. The west part, with major shadow hours would be employed for vegetables with low solar requirements as potatoes, onions, etc.

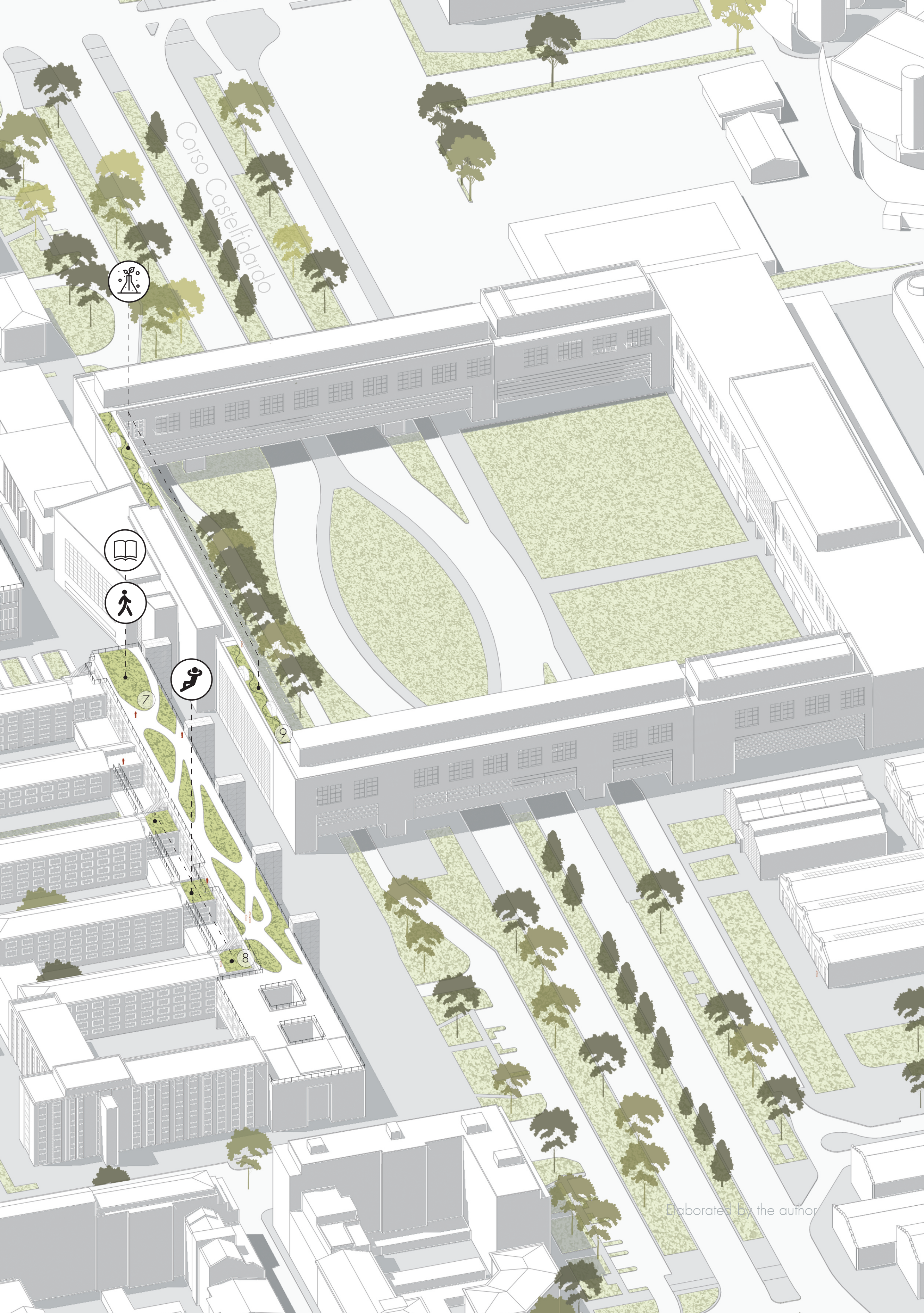
6. Green area: 920,3m^2
Primary users: University students and researchers.
Permanece: Low to medium (variable)
Description: Dedicated specially to the reseach. Equipped with pergolas, tables and brenches for the semi permanence of the users.

7. Green area: 1466,6m^2
Primary users: University students.
Permanece: Medium to high
Description: Green path dedicated to the rest, study and social interactions. Linked to smaller spaces in lower levels. The path is equipped with brench and tables

8. Green area: 243,5m^2
Primary users: University staff
Permanece: Low to medium
Description: Relaxitation green areas oriented. By being individual small spaces in lower levels they provide a certain sensation of privacy. Equipped with lounge type furniture.

9. Green area: 225,5 m^2
Primary users: University students.
Permanece: Low to medium (variable)
Description: Research area. Equipped with pergolas and flexible forniture to permit a fluid circulation and conditioning research.

Figure 70
A path to sustainability. Greening roofs proposal at the Polytechnic



Corso Castelfidardo
7
8
9
Elaborated by the author

CONCLUSIONS:

The fundamental objective of this thesis was to stablish the viability of a greener roof system composed on its majority by waste materials. It was seek not only to propose an ecological rooftop garden, but to propose a system able to incorporate the other dimesions of sustainability (economical, social and cultural) and produce a real impact in the selected area. It was also seek to serve as informational guide for further investigation, desmitifying statements that ignore possible disadvanges of the green cover systems. The main apportation of the project is the proposal of a green system, elaborated after a detailed breakdown of a solid research background that conducted to the exposed final projectual result.

In the first chaper was imperative to introduce to the main general concepts and composition of vegetated rooftop, enlisting advantages and razionalizing the drawbacks of the mentioned. Although the disadvantages are not as concise as the spread benefits of the literature, it was possible to determinate a group of negative consecuences influenced by a group of variables. This chapter was specially useful to understand the skeleton of the vegetated covers and vital components for their functionality. The following chapter reviewed similar waste project proposals for green roofs, serving as a reference for the stratigraphy determination.

The thirth chapter was indispensable to undertand the context, the viability regarding the place conditions and some of the guidelines for the projectual section. The results of the contrasted information revealed the necessity of expanding the green areas for two main reasons: The percentage of vegetation versus inhabitants results under regular normative requirements and the presence of air pollutants remains still over the healthy recommendation. Resulted analysis shown as well that the environmental conditions of the city, mainly the ones of the specific target roof, are optimal for the development of local Sedum species, which are adapted in general terms to the circunstances of the area. It was possible to slect the roof surfaces of most optimal condition for the installation of green covers, by the consideration of the pointed variables and the superposition of the schematic plans of the university campus. Determinative characteristics of the target roof building were yet illustrated for the design of the specific roof area.

The last chapter is a descriptive passage through the design and its factibility. Passing through the premises, the green roof system proposal, its architectonic application and use and the economical and technical feasibility. In this part, non escential strates were descarted and critic layers were defined. The argumentation of the selection of waste material for non critic layers was based on the existent waste opportunies, the italian normative and commercial green roof systems. Key elements that provide an idea of the resource availability and the quailification of the materials. At this point resulted problematic the lack of access to measurment systems for an experimentation phase, being vital to corroborate the correct performance of the proposal. It was also necessary to sintetize the dranaige layer to a system of minor complexity in order to simplify its excecution.

It was also proved in this chapter that it is possible at structural level to install the proposed roof and how excuting the waste materials green roof, costs of stratigrafy are shortenen. It was demonstrated as well how it is possible to create a self sustained system, capable to satisfy the users and vegetation basic requirements.

Is important to note that this thesis is a first glampse investigatigation that embraces a general perspective of a variety of topics, serving as the foundation and bridge for future reviews. Next researches supported in this one precise a detailed reach in order to develop in further the topics discussed in this thesis. Experimental stages and deepest feasibility studies should be considered as following investigation lines to follow this one.

In conclusion, this investigation, which yet requires a deeper expansion, determines it is possible to create a greener roof garden if planification and local resources are optimal. This system would be more ecological and potentially more economical. However, is relevant to mention that certain criteria must be sacrificed. In particular, time requirements for material collection and installation of non prefabricated elements could be longer. The system load is other topic to consider since in this case, it resulted major in contrast to a commercial opcion. The performance and maintenance requistes, these are topics to evaluate in deeper throgh the mentioned experimentation process and tests.

Finally, in order to create a measurable ecological impact, the scale of the proposed project, which was initially limited to a reduced roof surface area, was expanded. In doing so, and by the integration of the other dimensions of sustainability it was possible to create a green system that leads to the sustainability path.

APPENDIX:

Appendix 1
Product Data Sheet Root Barrier WSF 40

Established, proven and tested sheet, easy to install, made of environmentally-friendly polyethylene for the use as rootprotection under extensive green roofs.

Technical Data

Root Barrier WSF 40

Seamless membrane of high-pressure polyethylene (PE-LD).

Thickness:	ca. 0.36 mm	
Weight:	ca. 330 g/m²	
Colour:	black	
Density:	0.94 g/m³	
Tensile strength:	at 20° C:	ca. 40–47 N/mm²
	at 120° C:	ca. 20–25 N/mm²
Tensile expansion:	> 400 %	
Water vapour permeability of air layerthickness according to German Standard DIN 52615:	s_d> 200 m	
Coefficient of sliding friction:	0.29	

Dimensions:	Roll width:	Order No.
ca. 8.00 m x 25.00 m	ca. 2.00 m	1040
ca. 6.25 m x 20.00 m	ca. 1.60 m	1041
ca. 2.00 m x 50.00 m	ca. 1.00 m	1043
ca. 3.00 m x 33.50 m	ca. 1.50 m	1044

Delivery in rolls with the above widths.

ZinCo (2021) Product Data Sheet Root Barrier WSF 40. Retrieved June 2021, from https://www.zinco.ca/assets/pdf/ZinCo_PDB_Root_Barrier_WSF40_engl.pdf

Appendix 2
Product Data Sheet Protection Mat SSM45

Water and nutrient storage mat of synthetic fibres, for the application as a protection layer under green roofs, gravel fills, slab pavings, etc.

Technical Data

Protection Mat SSM 45

High quality fibre mat made of polyester/polypropylene, with fleece backing.

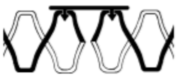
Thickness:	ca. 5 mm
Weight:	ca. 470 g/m²
Colour:	brown mottled
Water storage capacity:	ca. 5 l/m²
Tensile strength according To EN ISO 10319:	> 8.5 kN/m
Extension lengthwise:	> 90 %
Penetration force according To EN ISO 12236:	> 2400 N
Strength class:	3
Dimensions:	
Roll width:	ca. 2.00 m
Roll length:	ca. 50.00 m

ZinCo (2021) Product Data Sheet Protection Mat SSM45. Retrieved June 2021, from https://www.zinco.ca/assets/pdf/ZinCo_PDB_Protection_Mat_SSM45_engl.pdf

Appendix 3
Product Data Sheet Floradrain FD 25-E

Pressure resistant drainage and water storage element of recycled polyolefin for use on extensive green roofs.

Plastic Connector



Technical Data

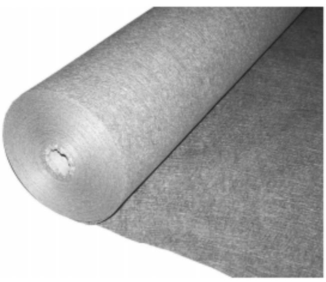
Floradrain® FD 25-E

Drainage and water storage element of thermoformed recycled polyolefin.

Material:	Polyolefin, mainly PE
Colour:	dark grey
Height:	ca. 25 mm
Weight:	ca. 1.6 kg/m²
Diffusion opening:	ca. 2 mm
Water storage capacity:	ca. 3 l/m²
Filling volume:	ca. 10 l/m²
Max. compressive strength (without filling):	ca. 270 kN/m²
In-plane water flow capacity (EN ISO 12958):	
roof slope 1 %:	ca. 0.59 l/(s·m)
roof slope 2 %:	ca. 0.85 l/(s·m)
roof slope 3 %:	ca. 1.05 l/(s·m)
Dimensions:	ca. 1.00 x 2.00 m
Accessories:	
Plastic Connector (to be pressed into diffusion openings)	Order No. 9620

ZinCo (2021) Product Data SheetFloradrain FD 25-E. Retrieved June 2021, from https://zinco-greenroof.co.uk/product_data/ZinCo_PDB_Floradrain_FD25-E_UK.pdf

Appendix 4
Product Data Sheet ZinCo Filter Sheet SF



Geotextile of thermally strengthened polypropylene, applicable as filter sheet above drainage elements for normal mechanical stress.

0799-CPD-74

Technical Data

Filter Sheet SF

Thermally strengthened filter sheet of Polypropylene.

Thickness:		ca. 0.60 mm	
Weight:		ca. 100 g/m²	
Penetration force according to EN ISO 12236:		ca. 1100 N	
Strength class:		2	
Tensile strength (200 mm) according to EN ISO 10319:	Lengthwise	ca. 7.0 kN/m	
	Crosswise	ca. 7.0 kN/m	
Tensile extension:		ca. 40% / 55 %	
Flow rate (H_{50}) according to EN ISO 11058:		ca. 70 l/(m²·s)	(≙ 0.07 m/s)
Effective opening width (O_{90}) according to EN ISO 12956:		ca. 95 µm	
Dimensions:			
length:	ca. 100.00 m	width: ca. 2.00 m	Order No. 2100
		width: ca. 1.00 m	Order No. 2102
length:	ca. 10.00 m	width: ca. 2.00 m	Order No. 2101

ZinCo (2021) Product Data Sheet Filter Sheet SF. Retrieved June 2021, from https://www.zinco.ca/assets/pdf/ZinCo_PDB_Filter_Sheet_SF_engl.pdf

Appendix 5
Product Data Sheet Zincoterra Substrate

ystem Substrate for intensive landscapes
n roofs or on underground car parks.

Technical Data

System Substrate "Roof Garden"

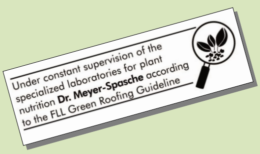
Substrate consisting of Zincolit® (high-quality crushed bricks) and other selected mineral aggregates, enriched with Zincohum (substrate compost enriched with fibre and clay materials). Particularly suitable for intensive green roofs with demanding perennials. Deeper thicknesses* can support shrubs, bushes and trees. The vegetation can be established by planting plug plants.
Intensive roof gardens require irrigation during dry periods. For optimal plant development the use of an appropriate slow release fertilizer (e.g. ZinCo Plantfit 4 M) is recommended (as shown in a special data sheet).

Available in Big Bags and as loose material in lorries.
Please calculate with a compaction factor of 1.3. That means for every square metre and 10 mm of substrate you order 13 l.

Delivery options	Order No.
in Big Bags	616101
loose on lorry	616201

Features

- **high-quality recycled product**
- **excellent water retention**
- **high air content – even at max. water capacity**
- **frost resistant and stable in structure**
- **basic component Zincolit® is under constant quality control by the Labor Dr. Meyer-Spasche**



Chemical and Physical Properties

Parameter	Reference Value
Volume weight - dry - at max. water capacity	 1000 g/l (+/- 100 g/l) 1500 g/l (+/- 100 g/l)
Maximum water capacity	ca. 50 Vol. %
Water permeability mod. K_f	0.3–30 mm/min
pH value (in $CaCl_2$)	6.0–7.5
Salt content (gypsum extract)	< 1.5 g/l
Organic content	< 90 g/l
Compaction factor	ca. 1.3

* At thickness of more than 350 mm please install additional the mineral sub substrate Zincolit® Plus.

ZinCo (2021) Product Data Sheet Zincoterra Substrate. Retrieved June 2021, from https://zinco-greenroof.co.uk/product_data/ZinCo_PDB_System_Substrate_Roof_Garden_UK.pdf

Appendix 6

ZinCo Loads	
Vegetation layer	25 kg/m²
Growing medium	67 kg/m²
Filter	0,1 kg/m²
Drainage layer	1,7 kg/m²
Protection layer	0,47 kg/m²
Anti-root layer	0,31 kg/m²

Extensive ZinCo Roof Total Loads
95 kg/m²

Elaborated by the autor. Data from ZinCo (2021) Product Data Sheet. Retrieved June 2021, from https://zinco-greenroof.co.uk/

Appendix 7

Product Data Sheet Harpoplan Impermeabilization Membrain ZD UV 2.0

Descrizione

Membrana in PVC, spessore nominale 2 mm rinforzata velo vetro.

Applicazioni

Particolarmente idonea a svolgere la funzione d'impermeabilizzazione in coperture piane, zavorrate ed accessibili.

Metodologia di posa.

La metodologia di posa è:

posa libera sotto la zavorra con fissaggi perimetrali (ghiaia, pannelli di calcestruzzo o giardini pensili).

Nelle fasi di posa dei rotoli bisognerà prevedere opportune sovrapposizioni in corrispondenza delle quali verranno realizzate le saldature ad aria calda con apparecchiature manuali e/o automatiche.

Per quanto qui non indicato, si fa riferimento alle istruzioni di posa.

Proprietà

- resistente ai raggi UV;
- elevata resistenza all'invecchiamento;
- elevata resistenza agli agenti ambientali comuni;
- elevata stabilità alle variazioni dimensionali;
- elevata resistenza alle sollecitazioni meccaniche;
- elevata resistenza a trazione ed elevato allungamento;
- eccellente flessibilità a freddo;
- elevata permeabilità al vapore acqueo;
- ottima saldabilità.
- resistenza alla penetrazione delle radici

Caratteristiche tecniche

HarpoPlan ZD UV 2.0	Unità	Valore medio	Norma EN 13956
Spessore	mm	2.0	
Difetti visibili	-	superata	EN 1850-2
Comportamento sotto pressioneidrostatica	-	≥ 400 Kpa	EN 1928 (B)
Comportamento al fuoco esterno	-	B Roof (t1)	EN 13501-5 ENV 1187
Reazione al fuoco	-	Class E	Classificazione dopo EN 13501-1
Resistenza al peeling sulle giunzioni	N/50 mm	≥200	EN 12316-2
Resistenza al taglio sulle giunzioni	N/50 mm	≥700	EN 12317-2
Resistenza alla trazione	N/50mm	≥ 600	EN 12311-2

Harpo Group (2008) HarpoPlan ZD UV 2.0. Retrieved June 2021, from https://www.harpogroup.it/sites/default/files/harpogroup.it/media-areatecnica/allegati/ST%20HarpoPlan%20ZD%20UV%202.0_versione%2005.08_0.pdf

Appendix 8

Product Data Sheet Harpoplan impermeabilization membrain ZD UV 2.0

Resistenza al carico statico	kg	≥20	EN 12730 (B)
Resistenza alla lacerazione	N	≥150	EN 12310-2
Stabilità dimensionale	-	≤ 0,25 %	EN 1107-2
Flessibilità a freddo	C	≤ - 30°	EN 495-5
Effetti di liquidi aggressivi e acqua(28 giorni/23° C)	-	superata	EN 1847
Resistenza ai raggi UV (1000 h)	-	superata	EN1297
Resistenza alla grandine	m/s	≥17	EN 13583
Permeabilità al vapore acqueo	μ	25.500 ± 7.500	EN 1931
Resistenza alle radici	-	Nessuna perforazione	EN 13948

Dimensioni e pesi*:

Tipo	**membrana**	**Rotoli**	
	Spessore mm	Larghezza m	Lunghezza m
HarpoPlan ZD UV 2.0	2.0	1,62	20

* Valori indicativi

Harpo Group (2008) HarpoPlan ZD UV 2.0. Retrieved June 2021, from https://www.harpogroup.it/sites/default/files/harpogroup.it/media-areatecnica/allegati/ST%20HarpoPlan%20ZD%20UV%202.0_versione%2005.08_0.pdf

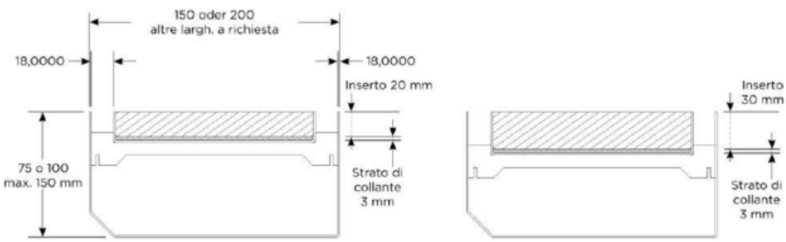
Appendix 9

Product Data Sheet Harpo CL2F - PRO PAV

Dimensioni:
Altezza totale: 75/100mm
Lunghezza: 1000/2000mm
Larghezza: 150/200mm
Materiale: Acc zincato protezione contro corrosione, Acciaio Inox V2A o V4A

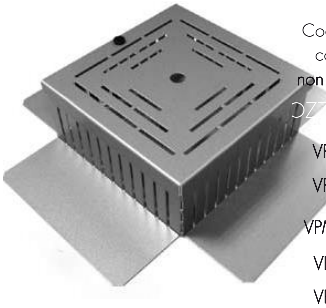
Differenti accessori disponibili su richiesta:
forma angolare 90°
pozzetto ispezione
terminali
uscita scarico con flangia

Sezione della canaletta con altezza pavimentazione di 20 e 30 mm



Harpo Group (n.d.) Canaletta Fessura. Retrieved June 2021, from https://www.harpogroup.it/sites/default/files/harpogroup.it/scheda/schede-tecniche/ST%20Canaletta%20a%20fessura%20CLF-PRO%20PAV%20pedonale-rev%20 2020.pdf

Appendix 10
Product Data Sheet Harpo Pozzetti di Controllo Drenante PK5 / PK10 / PK12



Cod. art. con coperchio non coibentato	Cod. art. con coperchio coibentato	Denominazione pozzetti	Altezza (mm)	Misura (mm)
VPM597A	VPM597AC	PK5-ALU alluminio verniciato	50	250x25
VPM598A	VPM598AC	PK10-ALU alluminio verniciato	100	250x25
VPM599A*	VPM599AC*	PK12-ALU alluminio verniciato	120	250x25
VPM597E	VPM597EC	PK5–E acciaio inox	50	250x25
VPM598E	VPM598EC	PK10–E acciaio inox	100	250x25
VPM599E	VPM599EC	PK12–E acciaio inox	120	250x25
VPM601A	VPM601AC	PK5-ALU alluminio verniciato	50	300x3C
VPM602A	VPM602AC	PK10-ALU alluminio verniciato	100	300x3C
VPM603A	VPM603AC	PK12-ALU alluminio verniciato	120	300x3C
VPM604A	VPM604AC	PK5–E acciaio inox	50	300x3C
VPM605A	VPM605AC	PK10–E acciaio inox	100	300x3C
VPM606A	VPM606AC	PK12–E acciaio inox	120	300x3C

Harpo Group. (2010) Sistemi di drenaggio per aree a verde pensile. Retrieved June 2021, from https://www.harpogroup.it/sites/default/files/harpogroup.it/scheda/schede-tecniche/vpe-mgr-pozzetti_pkf.pdf

Appendix 11
Loads cofficients

		Coefficiente γ_F	EQU	A1	A2
Carichi permanenti G_1	Favorevoli		0,9	1,0	1,0
	Sfavorevoli	γ_{G1}	1,1	1,3	1,0
Carichi permanenti non strutturali G_2 [1]	Favorevoli		0,8	0,8	0,8
	Sfavorevoli	γ_{G2}	1,5	1,5	1,3
Azioni variabili Qi	Favorevoli		0,0	0,0	0,0
	Sfavorevoli	γ_{Qi}	1,5	1,5	1,3

(I) Nel caso in rui l'intensita dei carichi permanenti non strutturali o di una parte di essi (ad es. carichi permanenti portati) sia ben definita in fase di progetto, per detti carichi o per la parte di essi nota si potranno adottare glistessi coefficienti parziali validi per le azioni permanenti.

Ministero delle Infrastrutture e dei Trasporti. (2018). Norme tecniche per le costruzioni. Roma: Ministero delle Infrastrutture e dei Trasporti. Retrieved from: https://www.gazzettaufficiale.it/eli/gu/2018/02/20/42/so/8/sg/pdf

Appendix 12
Material weight

MATERIALI	PESO UNITA DI VOLUME [kN/m^3]
Calcestruzzi cementizi *e* malte	
Calcestruzzo ordinario	24,0
Calcestruzzo armato e/o precompresso	25,0

Ministero delle Infrastrutture e dei Trasporti. (2018). Norme tecniche per le costruzioni. Roma: Ministero delle Infrastrutture e dei Trasporti. Retrieved from: https://www.gazzettaufficiale.it/eli/gu/2018/02/20/42/so/8/sg/pdf

Appendix 13
Variable actions categories

CATEGORIA/AZIONE VARIABILE	Ψ_{0j}	Ψ_{1j}	Ψ_{2j}
Categoria A - Ambianti ad uso residenziale	0,7	0,5	0,3
Categoria B - Uffici	0,7	0,5	0,3
Categoria C - Ambienti suscettibili di affollamento	0,7	0,7	0,6
Categoria D - Ambianti ad uso commerciale	0,7	0,7	0,6
Categoria E – Aree per immagazzi1lamanto, uso commererciale e uso industriale Biblioteche, archivi, n1agazzi11ie ambienti ad uso industriale	1,0	0,9	0,8
Categoria F - Rimmesse parcheggi ed aree per il traffico di veicoli (per autoveicoli	0,7	0,7	0,6
Categoria G – Rimesse, parcheggi ed aree per ii traffico di veicoli (per autoveiooli di peso > 30 kN)	0,7	0,5	0,3
Categoria H- Coperture accessibili per sola manutenzione	0,0	0,0	0,0
Categoria I -Coperture praticabili	da valutarsi caso per caso		
Categoria K -Coperture per usi spedali (impianti, eliporti, ...)			
Vento	0,6	0,2	0,0
Neve (a quota ; 1000 m s.Lm.)	0,5	0,2	0,0
Neve (a quota > 1000 m s.Lm.)	0,7	0,5	0,2
Variazioni termiche	0,6	0,5	0,0

Ministero delle Infrastrutture e dei Trasporti. (2018). Norme tecniche per le costruzioni. Roma: Ministero delle Infrastrutture e dei Trasporti. Retrieved from: https://www.gazzettaufficiale.it/eli/gu/2018/02/20/42/so/8/sg/pdf

Appendix 14
Variable actions. Categories

Cat.	Ambienti	qk (kN/m²)	Qk (kN)	Hk (kN/m)
B	Uffici			
	Cat. Bl Uffici non aperti al pubblico	2,00	2,00	1,00
	Cat. B2 Ulfici aperti al pubblico	3,00	2,00	1,00
	Scale comuni, balconi e ballatoi	4,00	4,00	2,00

Ministero delle Infrastrutture e dei Trasporti. (2018). Norme tecniche per le costruzioni. Roma: Ministero delle Infrastrutture e dei Trasporti. Retrieved from: https://www.gazzettaufficiale.it/eli/gu/2018/02/20/42/so/8/sg/pdf

Appendix 15
Exposition coefficient

Topografia	Descrizione	C_E
Battuta dai venti	Aree pianeggianti non ostruite esposte su tutti i lati, senza costruzioni o alberi piu alti	0,9
Normale	Aree in cui non e presente una significativa rimozione di neve sulla costruzione prodotta dal vento, a causa del terreno, altre costruzioni o alberi	1,0
Riparata	Aree in cui la costruzione considerata esensibilmente piit bassa del circostante terreno o circondata da costruzioni oalberi piu alti	1,1

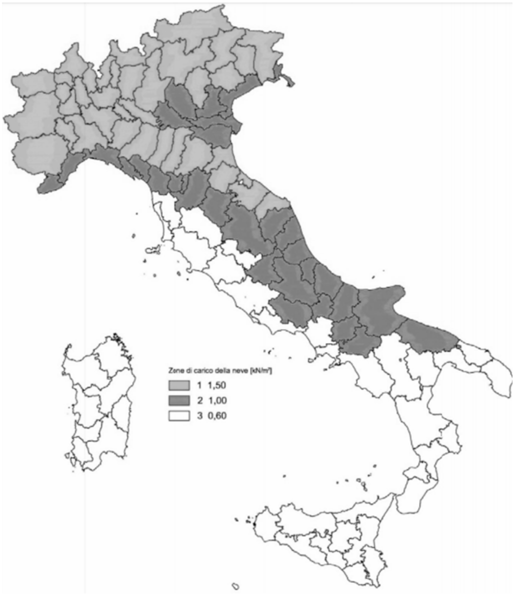
Ministero delle Infrastrutture e dei Trasporti. (2018). Norme tecniche per le costruzioni. Roma: Ministero delle Infrastrutture e dei Trasporti. Retrieved from: https://www.gazzettaufficiale.it/eli/gu/2018/02/20/42/so/8/sg/pdf

Appendix 16
Shape coefficient

Coefficiente di forma	$0° \leq \alpha \leq 30°$	$30° < \alpha < 60°$	$\alpha \geq 60°$
μ_1	0,8	$0,8 \cdot \frac{(60-\alpha)}{30}$	0,0

Ministero delle Infrastrutture e dei Trasporti. (2018). Norme tecniche per le costruzioni. Roma: Ministero delle Infrastrutture e dei Trasporti. Retrieved from: https://www.gazzettaufficiale.it/eli/gu/2018/02/20/42/so/8/sg/pdf

Appendix 17
Reference value of the snow loads



Ministero delle Infrastrutture e dei Trasporti. (2018). Norme tecniche per le costruzioni. Roma: Ministero delle Infrastrutture e dei Trasporti. Retrieved from: https://www.gazzettaufficiale.it/eli/gu/2018/02/20/42/so/8/sg/pdf

Appendix 18
Hydric requirement

IRRIGATION TYPOLOGY	REQUIREMENT (L/year • m²)
Garden	60
Sportive fields	200
Green areas - light substrate	200
Green areas - heavy substrate	150

Kessel. (2000). *EN DIN 1989-1:2000-12. Sistemi di recupero delle acque piovane*. Retrieved from: https://www.kessel-italia.it/fileadmin/pdf/IT/010-775_(07-Sistemi_di_recupero_delle_acque_piovane).pdf

Appendix 19
Asca Transluscent Panel Data

Cell type	Organic
Thickness	< 400 μm
Weight	500g/m²
Transparency	Up to 20%
Dimensions	Customizable
Power	Up to 40 Wp/m²

Note: Shown power under STC Conditions (Standard Test Conditions): 1000 W/m², AM 1.5, 25°C. Adapted by the author from Armor (2021). Asca module general data. Retrieved June 2021, from https://www.asca.com/wp-content/uploads/2021/07/ASCA-General-datasheet_EN.pdf

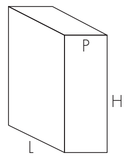
Appendix 20
Runoff coefficients

TYPOLOGY OR NATURE OF THE SURFACE EXPOSED TO PRECIPITATION	COEFFICIENT
Flat roof covered in plastic material	1,00
Flat roof covered in metallic material	0,98
Pitched roof covered in metallic material	0,95
Pitched roof covered in plastic material	0,93
Pitched roof covered waved plastic	0,90
Pitched roof with roof tiles	0,90
Flat roof covered in cement tiles	0,80
Flat roof covered in generic tiles	0,80
Flat roof covered in asphalt	0,80
Gravelly flat roof	0,60
Intensive green roof	0,50
Extensive green roof	0,30
Altro	0,30

Kessel. (2000). *EN DIN 1989-1:2000-12. Sistemi di recupero delle acque piovane*. Retrieved from: https://www.kessel-italia.it/fileadmin/pdf/IT/010-775_(07-Sistemi_di_recupero_delle_acque_piovane).pdf

Appendix 21
Water tank 500L

L	H	P
1140	1150	520



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Appendix 22
Seasonal water roof catchment capacity

ROOF	AREA	SEASON	CATCHMENT (L)
b	675,30	Summer	124,42
		Autumn	128,30
		Winter	99,59
		Spring	166,36
c	304,95	Summer	56,18
		Autumn	57,94
		Winter	44,97
		Spring	75,12

Seasonal water catchment capacity over the specific roof of the Polytechnic of Turin of figure 60. Elaborated by the author. Based on rainstorm data from appendix 23.

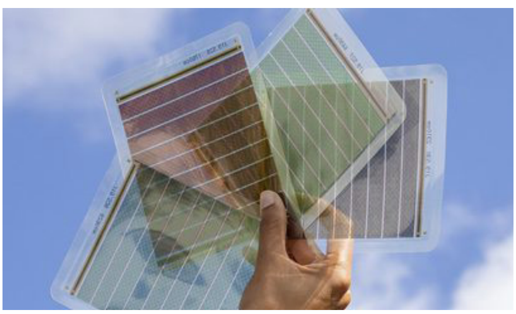
Appendix 23
Seasonal rainfall in Turin

	SUMMER (mm)					AUTUMN (mm)				
YEAR	June	July	August	September	TOTAL	September	October	November	December	TOTAL
2009	39,3	18,5	16,7	64,4	138,9	0	26,0	39,4	10,8	76,2
2010	4,3	15,1	116,9	39,7	176,0	12,4	57,9	111,2	6,2	187,7
2011	0,4	109,0	15,3	71,1	195,5	0	13,3	187,6	0,7	201,6
2012	12,8	44,5	30,7	36,9	124,9	9,9	45,1	127,5	7,2	189,7
2013	7,0	150,0	105,0	4,6	266,4	21,0	60,3	98,1	12,6	192,0
2014	6,2	152,0	73,5	29,7	261,0	4,8	22,7	209,6	74,0	311,1
2015	0	21,7	162,8	44,4	228,9	0,6	182,6	0,2	0	183,4
2016	31,2	55,8	60,2	23,8	171,0	0	54,0	149,6	53,0	256,6
2017	34,0	33,6	35,4	21,0	124,0	0,4	0	33,4	27,8	61,6
2018	2,0	130,0	17,6	42,6	192,6	1,2	154,2	112,8	5,8	274,0
2019	10,4	219,0	108,8	80,1	418,5	3,0	115,6	257,2	60,2	436,0
				Mean (mm)	208,9				Mean (mm)	215,4

	WINTER (mm)					SPRING (mm)				
YEAR	December	January	February	March	TOTAL	March	April	May	June	TOTAL
2009	17,7	52,2	27,7	44,6	142,2	13,6	211,6	6,1	1,6	232,9
2010	77,4	50,0	68,3	35,7	231,4	18,4	35,1	134,0	154,0	341,1
2011	0	18,1	39,9	170,0	227,9	10,9	20,5	3,6	219,0	254,3
2012	0,8	45,7	8,3	45,8	100,6	0	165,3	120,4	34,8	320,5
2013	65,9	16,8	17,7	65,7	166,1	40,7	157,5	156,7	10,0	364,9
2014	0	76,8	112,4	69,0	258,2	74	62,2	79,0	20,3	235,5
2015	0	16,2	86,3	76,2	178,7	47,9	111,6	35,8	90,3	285,6
2016	0	6,4	107,0	76,2	189,6	1,8	65,4	143,2	67,0	277,4
2017	6,2	4,2	39,2	19,2	68,8	40.8	38	55,4	42,8	136,2
2018	0,4	97,2	66,2	72,6	236,4	1,8	84,6	214,4	82,2	383,0
2019	4,2	4,8	22,4	8,0	39,4	0	106	120,6	14,4	241,0
				Mean (mm)	167,2				Mean (mm)	279,3

Adapted by the author from: Stazione Meteo Amatoriale. (2019). *All Times Records Data*. Turin: Stazione Meteo Amatoriale. Retrieved from http://www.torinovest.org/record.php; Università degli Studi di Torino, Dipartimento di Fisica. (2018, 04 24). *Storico dati*. Retrieved from Meteo: http://www.meteo.dfg.unito.it/

Appendix 24
Flexible translucent panels



Note: Photo from Armor (2021). *ASCA® technical properties*. Retrieved in June 2021, from https://en.asca.com/cell-solar-flexible-transparent/

Appendix 26
Lightning system

Note: Luci Solari Giardino Tomshine 12LED Luci Solari da Esterno Faretti Solari a LED da Esterno IP68 Impermeabile(Bianco caldo 4PC- www.amazon.com

Appendix 25
Exposition

Topografia	Descrizione	C_E
Battuta dai venti	Aree pianeggianti non ostruite esposte su tutti i lati, senza costruzioni o alberi più alti	0,9
Normale	Aree in cui non è presente una significativa rimozione di neve sulla costruzione prodotta dal vento, a causa del terreno, altre costruzioni o alberi	1,0
Riparata	Aree in cui la costruzione considerata è sensibilmente più bassa del circostante terreno o circondata da costruzioni o alberi più alti	1,1

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