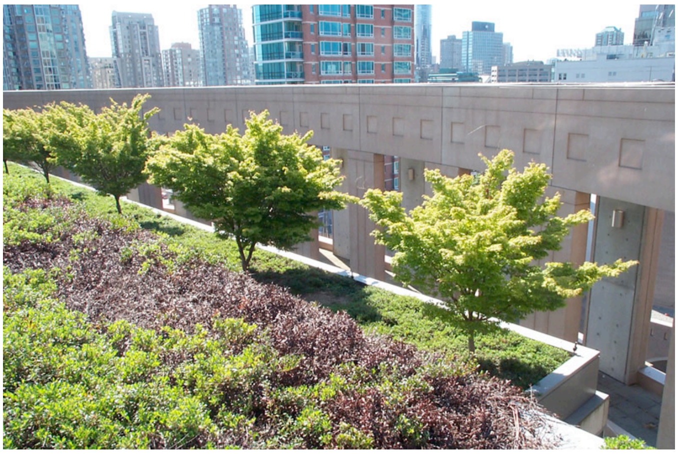
> INTENSIVE GREEN ROOF

I/ General description and characterization of the NBS type

I.1 Definition and different variants existing

Definition

Roofs do not all have the same carrying capacity, therefore depending on the structures, and the type of plantation must be adapted. Intensive green roofs (living roof) are those with the more substrate, usually with a total thickness starting by app. 20 to 200 cm, therefore the stress imposed on the structure is very large. Usually, either roofs that have an intensive green roof were planned to accommodate the green roof at the time of the construction of the building or there have been structure reinforcement works. An intensive green roof weighs from 170 kg m^{-2} to over 970 kg m^{-2}, then given the large amount of soil, plant options are extremely large, ranging from shrubs to urban agriculture to trees.(32) Since the plants are large gauges, it requires an irrigation system and major maintenance. Often, intensive green roofs can serve as parks open to the public.



Intensive green roof, Vancouver Public Library (Photo: Terri Meyer Boake B.E.S. B.Arch. M. Arch., Université de Waterloo)

Different variants existing

Two kinfs can be identified, depending on the plant properties and the height of plants:

=> Recreation rooftop or roof garden

The philosophy of a roof garden relies on the fact that the plant material that is destroyed during the construction phase will be restored at the top of the building and will reduce the adverse effects of urbanization and deforestation (Osmundson, 1999). The characteristics of a good crop is used for the roof garden is resistant to exposure to direct sunlight.

It is important to note given the location of the plant growth will have a shorter distance to the sun than usual garden. Also, avoid plants that have roots growing down. The contribution of roof gardens to the urban environment is manifold. It has been established that roof gardens reduce temperature and solar irradiance, provide up to 50% reduction in the heat flux into building (Onmura et al., 2001). Thus resulting in significant building energy saving. In addition, roof gardens contribute to the Urban Heat Effect mitigation (Osmundson, 1999), protect and secure the longevity of the roof structure, grade rainstorm water distribution (Nektarios et al., 2011).

Blackfriars House roof garden in Manchester © Jamie Boulger

=> Roof terrace garden

Roof terraces are designed specifically for recreation, although the inclusion of vegetation in planters (such as on terraces or balconies) is often used to enhance their visual attractiveness. Roof terraces are those that have no substrate and no intentionally vegetated part to their construction. Because of this, they have limited SUDS (sustainable urban drainage systems) or climate change adaptation benefit (Authority, 2008). Roof terraces, where there is adequate space available, are well suited for sports such as ball games.

The Orchid Hotel, Beijing, China
© Tripadvisor (link)

Clubhouse Mongkok Skypark / concrete, Mong Kok, Hong Kong
© Manufacturers Fritz Hansen, HAY, Tom Dixon, Vitra, e15, Carl Hansen, Marset, Droog, De La Espada, Kasthall

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-2 Climate adaptation 02| Urban water management and quality > 02-1 Urban water management > 02-2 Flood management 3 | Air quality > 3.2 | Air quality locally 07| Public health and well-being > 07-2 Quality of life > 07-3 Health	- The tree canopy reduces solar radiation reaching the roof surface (Jim and Tsang, 2011) - (Berndtsson et al., 2009) studying intensive roof (in Japan) constructed with inorganic light weight soil found that the green roof contributed to the substantial decrease of total nitrogen in runoff - German studies from 1987 to 2003 as summarized by (Mentens et al., 2006) report that intensive green roofs showed annual runoff Reduction being equal 85–65% of annual precipitation (100%) - Air pollution due to the polymer production process can be balanced by green roofs in 13e32 year (Bianchini and

		Hewage, 2012) - Intensive green roofs produce a remarkable aesthetic improvement, especially important for surrounding buildings.
Co-benefits and challenges foreseen	06| Resource efficiency > 06-1 Food, energy & water 04| Biodiversity and urban space > 04-1 Biodiversity > 04-2 Urban space development and regeneration > 04-3 Urban space management 5 | Soil management > 5.1 | Soil management and quality 7 | Public health and well-being > 07-1 Acoustics  Greenery seems to be taking over the roof of one building in lower Manhattan. Author: Alyson Hurt, CC-by-2.0	- The surface temperature of the green roof is found to be up to 15°C lower than that of a conventional roof (Karachaliou et al., 2016), decreasing buildings energy consumption. - Green roofs could provide equivalent habitat value to many urban insects, and thus an opportunity to increase and manage their associated ecosystem services, in combination with habitat space at ground-level (MacIvor and Lundholm, 2011) - Green roofs act as habitats for native plants species in urban landscape.(Madre et al., 2014) - The green roof substrate is able to support vegetation. In addition, it can store carbon(Bouzouidja et al., 2018). In addition, it can store carbon. - Green roofs decrease sound propagation.
Possible negative effects	07| Public Health and well-being > 07-3 Health 10I People security > 10.3 Other: bad structural designs 04| Urban space management	- The higher consumed level of energy for green roof maintenance (Carpenter and Zhou, 2013) - The concentration on the economical aspect of green roofs in the present green roof situation undermines the opportunities in ecology and society (Pedersen, 2014)

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Buildings and sometimes only partially
Impacted scales	At building scale and depending on the number of green roofs existing. At neighbourhood or city scale, the impact of green roofs is less relevant. It is depend of green roof area coverage

II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	> Build up green roof depends on the selected plants and/or tree: · flowering plants, herbs, taller grasses, and small shrubs: 1 to 2 years · large shrubs and trees: 3 to 5 years > Can be immediately ready (e.g., if you plant large trees and/or a turf lawn). Most of time, the customer of an intensive green roof want to use it immediately
Life time	30-50 years
Management aspects (kind of interventions +	- Does require irrigation - Nutrients - Maximal maintenance, at least 2, but depending on the intensity of plants (e.g., if

intensity)	there is a lawn, you have to mow it nearly weekly in summer if customer want that aesthetic). Maintenance can be like in garden, very intensive. - Range from weekly checks during summer on an intensive roof garden

II.3 Stakeholders involved/ social aspects

Stakeholders involved in the decision process	- Private owners, or co-owners of buildings - Municipality in case of public buildings - Experienced engineers, - Building surveyors, - Property managers
Technical stakeholders & networks	- Landscape architect, planer, designers, - Structural engineers, - Architects - Specialized green spaces management firms and gardeners.

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- Decision between the type of use to which it is put; an occupied roof or not occupied roof garden design - On a new building or existing one, that needs a structural engineer investigation. - Selection of plant adapted to: • the local climate • Sunlight orientation and overshadowing • Wind exposure - Set up the maintenance keeping plants in the right conditions. - Maintaining services in the right conditions. Care must be taken to keep roots and leaves out of the drainage system
Materials involved	- moisture barrier (roofing membrane) - thermal insulator - waterproofing membrane (root barrier) - drainage layer - filtering layer - growing medium (substrate) - sedum plants most of the time

II.5 Legal aspects related

- Ownership and tenant. There is a clear difference between an owner (landlord) and a tenant (lessee). A landlord has exclusive rights to their property to use in any manner according to the planning constraints and permissions in each jurisdiction (and no third-party consent is generally required to create a green roof or wall). A tenant is bound by the terms of their lease, and a green roof or wall may be prohibited or a permissible use with consent. Consent is likely to be required from the landlord (1).
- Structural loads. Analysis by a structural engineer is required (1).
- Irrigation and drainage: Water supply is usually a simple tap, but if irrigation is needed, and a hydraulic engineer is required to review how it is to be serviced and drained and it is likely need irrigation licence (1).
- Access permit to the roof (1)
- Insurance. Insurance will be required by the party maintaining the garden or produce area, as well as insurance for visitors and general public; also liability for work, health and safety legislation (1).

II.6 Funding Economical aspects

Range of cost	Calculating the average cost of green roofs can be difficult because there a number of variables, not just the size and accessibility of the site but the types of plants that are going to be grown on it. In the United Kingdom one can expect to pay around 100 €/m^2. In addition to the initial cost of designing and installing green roofs, there are also running costs, which need to be taken into consideration, such as maintenance and regular gardening. The cost of a standard intensive green roof in

	Britania, Canada, starts around 340€ m^{-2} (Bianchini and Hewage, 2012) Green roof components: · Substrate · Plants · Filter fabric · Drainage Board · Root barriers · Protection fabric Irrigation system Drainage system
Origin of the funds (public, private, public-private, other)	- Private: the ownership is a private as business building, hotels, apartments - Public. The building ownership is a public owner like City councils, museums, schools, etc.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Green roofs provide habitat to many bee species. For example, in New York City, U.S.A., a study of the bee diversity in urban gardens found a total of 54 species from 19 sites (Matteson et al., 2008). In Vancouver city, Canada, gardens and urban parks obtained a total of 56 bee species from 25 sites; species richness did not differ significantly among site types (Tommasi et al., 2004).

Implementation of beehive on a green roof
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III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors

- **Green Roof Goal**: It is essential to start project planning with the purpose of the green roof. Is it intended primarily to deliver environmental, cost-saving benefits? Is it expected to serve as a decorative landscape element? Is it for urban farming? To set the direction for any project, first define the purpose of the green roof, establish priorities for specific goals and align stakeholder expectations (Rugh, 2014).
- **Architectural Factors**: Roof structural load capacity is the most basic issue (Rowe et al., 2003)

Location: Regional climate determines what type of green roof and plants you can and should have (Rowe et al., 2003).

Limiting factors	- Take into account the new structural load when refurbishing a building: One important item to be considered is the increased structural load. The structural engineer must factor in the weight of completely saturated soil since the plantings and the soil will hold a significant amount of water (1).

City University of Hong Kong Hu Fa Kuang Sports Centre roof collapses site

Author: exploringlife-CC BY-SA 4.0

- **Lifetime of the roof membrane.** Green roofs tend to improve the life of the membrane because it is completely covered by plantings and is not exposed to the sun's harsh UV rays. However, the membrane may be exposed to plant roots, animals and insects, and fertilizer chemicals. It is important that a protective barrier be used over the waterproofing membrane.
- **Maintenance ongoing cost. is also important to consider** that a green roof requires routine landscape maintenance, which can vary from occasional to regular and can add a significant ongoing cost. In addition, space should be allocated for storage of maintenance materials

III.2 Comparison with alternative solutions

Grey or conventional solutions counterpart

- White or cool roof: the green roof decreases the annual building needs for heating and cooling by 1.2% while the white roof contributes to decrease the needs just by 0.4%. This small difference is mainly attributed to the higher insulation capacity of the green roof and the lower calculated surface temperatures on it (Santamouris, 2014)

White or light-colored roofs

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- Gravel roof: The gravel in a ballasted roof helps absorb heat, preventing the sun from heating the roof materials below and making the roof more energy-efficient. In addition, gravel also protects against hail and from foot traffic during repair or maintenance work. The gravel is easy to move when conducting repairs or maintenance

	 Gravel roof © Anderson Roofing
Close NBS	- Other green roof types (semi-intensive and extensive green roof) - Build or attached planter systems (including balconies)

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