LIFE @ URBAN ROOFS

MKBA multifunctionele daken - Algemeen

Gemeente Rotterdam, Stichting Arosa, De Heuvel, De Rotterdamsche Vastgoed Maatschappij, Vestia

25 MAY 2018

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1 INTRODUCTION IN LIFE@URBAN ROOFS

1.1 Problem statement

In the urban environment, there is little space at ground level to tackle climate and water related issues. At the same time, a large amount of roof space in the city is unused. Roofs offer all kind of opportunities for use, and can make an important contribution to the quality of life and the quality of life in the city. Roofs can therefore be seen as an extension of the use area in the city. In accordance with the approach of the municipality of Rotterdam, we distinguish the following four categories of roofs (and preferably combinations of these):

- Green roofs include vegetation. This can vary from sedum roofs or grass to higher vegetation, such as shrubs or trees.
- Blue roofs are roofs that are specially designed to store and/or buffer as much water as possible. This can be done in combination with vegetation, such as on green roofs, or by building temporary rainwater storage.
- Yellow roofs generate sustainable energy, for example by using solar panels, windmills and / or solar boilers.
- Red roofs have space for recreation. You can think of a terrace, a sports field or a swimming pool. Ideal for efficient and effective use of living space in a busy city.

Multifunctional roofs combine these green, blue, yellow and/or red elements for maximum efficiency. For example, a roof is not only usable and ecologically sound, but also attractive for users and local residents.

Everybody would like to have their view on a multifunctional roof or would like to benefit from such a roof (e.g. through use, energy, noise reduction). However, it is difficult to find parties willing to pay for it. This has various reasons. The main reason is that the benefits of multifunctional roofs are not always clear. Not all benefits can be directly valued in money terms and not all benefits are directly visible to all users (or more importantly, to the payer). These social costs and benefits, in addition to the financial costs and benefits, are made transparent using the calculation tool developed for LIFE @ Urban Roofs.

1.2 The program LIFE

In the framework of the EU program LIFE, the City of Rotterdam, in cooperation with a number of Rotterdam partners, started the LIFE @ Urban Roofs project. The aim of the project is to develop methods and value cases, respectively, to unlock investments in multifunctional roofs in the private and (semi) public sector. In addition, the EU program LIFE @ Urban Roofs aims to share knowledge between cities and/or countries with the same type of issue.

1.3 Calculation tool for multifunctional sustainable roofs

The City of Rotterdam has asked Arcadis / CE Delft to develop a calculation tool for property owners who are considering investing in a multifunctional roof. The assignment from the municipality of Rotterdam consists of two parts that are obviously closely related:

1. The development of value cases for five practical cases. The value cases form direct input for the investment assessment that the relevant owners have to take. From the value cases it becomes clear to what extent the investments outweigh the benefits and how they are distributed among the various stakeholders.
2. A generic calculation tool that is applicable to other parties and with which they gain insight (in broad outline) into the investments required for a sustainable multifunctional roof and the benefits that such a roof entails.

The calculation tool that has been developed offers insight into the relevant aspects (both qualitatively and quantitatively) when considering the decision for investment in a certain type of multifunctional roof.

This project fits seamlessly into the Rotterdam Resilience Strategy (RRS). The RSS gives a vision on how to deal with climate challenges in the city. Actions from the RRS that are closely related to the project LIFE @ Urban Roofs are creating a ‘Sustainable Roof Landscape’ in the city and the 'Resilient Peperklip':

RRS action ‘Sustainable Roof Landscape’

'The multifunctional and sustainable use of flat roofs is in line with the further improvement of the quality and the urban climate in the center of Rotterdam. Specifically, this concerns: better water storage, more greenery, cleaner air, better health and stronger social cohesion. The initiative for sustainable roofs in the center also has a positive influence on the social resilience of the city, because the multifunctional roofs can also accommodate social functions. For example, meeting places for residents, cafes and restaurants. '

RRS action ‘Resilient Peperklip’

'The physical investments in the building offer advantages in the field of climate adaptation, energy saving and sustainable energy generation. By bringing people together and helping them with the renewal plans, the project also influences social resilience. '

1.4 Reading guide

In order to come to a practically applicable calculation tool which can determine social costs and benefits, we have worked with the following five practical cases: De Peperklip (Vestia), De Heuvel and the following three buildings on the Robert Fruinstraat: The Municipal Archive, The Rotterdam Real Estate Company (DRVM) and the Arosa Foundation. Each of these cases has been reported in separate reports.

This report describes the general method and findings in the project. The general explanation of the methodology as applied in the financial business case and the social cost-benefit analysis can be found in chapters 2 and 3. In chapter 4 the design of the calculation tool can be found. Chapter 5 contains the conclusions and reflection.

2 EXPLANANTION FINANCIAL BUSINESS CASE

2.1 Assumptions

In the financial business case, the costs (investment costs and operating and maintenance costs) are compared with the financial benefits (energy yield). This is done by determining the Net Present Value (NPV) of the project.

The NPV is a measure for displaying the current value of an amount for a given visibility year. The NPV takes into account the time value of money and the risks associated with an investment. In order to determine the NPV, the present value of future expenditure (total investment costs and operating and management costs) is deducted from the cash values of all future receipts (income). Future costs and benefits are discounted to the base year so that they become comparable.

Netto Contante Waarde

It is not simply possible to compare costs and benefits that occur in different periods. Investments are made at the time the project is executed, while the benefits occur later. Moreover, these effects could occur more often.

To be able to compare all relevant effects, cash values are used in the SCBA and the financial business case. Using a discount rate, the future values of costs and effects are recalculated back to today (price level 2017). Because of the time value of money, an Euro is now worth more than an Euro later in time. In addition, there are risks that the benefits will be lower in the future. These risks are also included in the discount rate.

The discount rate used by the case holders is used in the financial business case. In the SCBA, a real discount rate of 3% has been used, as prescribed by the national government. To illustrate: suppose that an effect occurs in 2018 and the effect is valued at € 100. Then the present value of this effect in 2017 is equal to € 97.09 ((€ 100 / (1 + 0.03) ^ 1)).

If the present value of the costs is deducted from the present value of the benefits, the balance remains: the Net Present Value.

The period of analysis can be set variably in the tool, varying from 10 to 40 years.

2.2 Financial costs and benefits

The investment costs for a multifunctional roof consist in principle of: start-up costs, costs for project management, monitoring costs, communication costs and costs for the material and the execution.

In a financial business case, the budget is also taken into account. Consider, for example, the budget for regular operation and maintenance and possible subsidies. Subsidies are included in the financial business case as financial benefits. The budget (reservation for regular maintenance) is included in the investment costs, making the investment costs the additional investment costs relative to the current situation.

The LIFE application and additional information from the caseholders was used to fill in the five cases. In addition, the annual operation and maintenance are included in the financial business case.

Yellow roofs are equipped with solar panels and / or wind turbines. The energy yields generated by the roof are expressed in Euros and are included as a benefit.

3 EXPLANATION SOCIAL COST-BENEFIT ANALYSIS

3.1 Assumptions

To determine the social costs and benefits, the General Guidance for Social Cost-Benefit Analysis (General SCBA Guidance) is followed as much as possible. This guidance describes step-by-step the approach of a SCBA. The guidance is written by the Dutch Centraal Planbureau (CPB) and the Dutch Planbureau voor de Leefomgeving (PBL).

General Guide to SCBA

Strictly speaking, different steps must be taken - in accordance with the aforementioned General Guidelines - for the implementation of an SCBA, including an problem analysis and the development of several variants that could solve the problem. For example, the municipality of Rotterdam could also reduce CO_2 in a different way than by solar energy on roofs, for example by using extra energy-efficient transport.

However, this study focused on the social costs and benefits of multifunctional roofs, because an analysis of alternative climate measures was not within this study's scope. In addition, multifunctional roofs may contribute to more issues than just the climate problem (e.g. biodiversity, water retention, heat stress etc.), making it difficult to develop alternatives that contribute to a solution for all these issues.

Additionally, the same basic principles apply as described in the financial business case (see chapter 2.1).

3.2 Determining and valuation of relevant effects

In determining the relevant effects in the social cost-benefit analysis (SCBA), a distinction has been made between effects that primarily occur to owners / users of objects (private) and the social effects (public). The private and public effects are both reflected in the SCBA. The table below presents the effects included in the SCBA and the method of valuation. The following sources have been consulted (see also the broader Literature List in Chapter 6):

- General Guide to SCBA and the various SCBA tools ("MKBA werkwijzers"), such as Nature, Environment and Social Domain
- Handboek Milieuprijzen;
- Valuation characteristics from among others TEEB city, WaterSchadeSchatter, RWS economy;
- Similar SCBAs on green roofs;
- KNMI'14 climate scenarios;
- Other sources (see literature list).

Effect	Description	€/ Qualitatively
Investment costs roof	Additional costs € per m^2 of the roof w.r.t. the reference alternative	€
Operation and maintenance costs roof	Additional costs € per m^2 of roof w.r.t. the reference alternative	€
Energy yields	Energy yields (in particular yellow roof)	€

Reputation and business climate	Effects on the reputation and business climate are approached from several indicators:
	
	• *Property values*: A 10% rise in property value (due to green roof) is assumed. This assumption is based on literature which suggests a spread of 1-21% real estate value increases due to green roofs. In the calculation tool, this value can be changed within this range. The default value is set on 10%. The property value increase reflects the following sub-effects: aesthetic valuation, noise reduction, productivity and comfort. Although an increase in the real estate value can in principle be both a financial benefit and a social benefit, a change in property value is only included as a social benefit (and not included in the financial businesscase). The starting point is that the owners will not raise the rents. This means that these benefits settle in the form of a higher quality of living for the tenants of the buildings, but do not return to the business case for the property owners.
	• Vacancy / average number of responses to dwelling
	  ◦ In the case of private homes, the focus is on vacancy and the associated loss of rental income. Subsequently, an assumption is made of the impact of a multifunctional roof on this vacancy. The reduction of vacancy reflects the increase in the comfort of residents and the willingness of the building.
	  ◦ When it comes to social rent, vacancy is not (or hardly) applicable. Therefore, the qualitative description of the effect on the number of responses to a home is described here. It is assumed that more responses to a home correspond to an improved reputation of the home.
	• *Reputation of the owner*: does the project contribute to a green / innovative profile of the owner of the building? We discuss this indicator qualitatively.
	• *Business location climate of the district and city*: does the project contribute to an improved business climate for residents and businesses? We discuss this indicator qualitatively.
		• Property value and vacancy: €
		• Responses to housing (for social rent), reputation owner and location climate for the neighborhood and city: Quality

Water retention	In the case of water retention, the physical criterion is the number of extra m^3 water retention by the project. In the valuation of the effect, a distinction is made between the financial businesscase and the SCBA: • Financial: scope of relevant subsidies. • SCBA: shadow costs / avoided costs alternative retention provision (€ 500 per m^3). The calculation tool uses a range between € 300-800 per m^3. The value € 500 per m^3 is set as the default value.	€

Water quality	Water storage on a multifunctional roof can lead to a reduction in the number of m^3 of rainwater that reaches the water treatment system via the sewer system. Theoretically, this can result in a reduction in the energy and operating costs of water purification. However, the effect of a green roof is marginal and is therefore not included in the SCBA. The same reduction in the number of m^3 of rainwater reaching the sewer can in principle locally reduce the number of overflows of sewage water on the surface water. This benefits the quality of the surface water. This effect is qualitatively included in the report.	Qualitatively
Climate	Climate is valued using avoided emissions from fossil plants (Handboek Milieuprijzen). The capture of CO_2 from roofs is limited. See section 3.2.5 for a further explanation.	Avoided emissions: €
Air quality	The effects of avoided emissions from fossil plants are valued using the Handboek Milieuprijzen. This includes environmental prices for more than 2000 environmentally hazardous substances. The use of environmental prices is recommended by the Ministry of I & W. We will determine the benefits for the saved emissions of CO_2 and air-polluting emissions that are avoided (particulate matter, NOx, SO_2). The effects of particulate matter on air quality through capture are limited (RIVM, 2007) and are therefore not included. For a substantiation, see section 3.2.5.	Avoided emissions: €
Heat stress	The effects on heat stress are determined by: • Albedo effect; different reflection of sunlight (assuming that there is a black roof in the reference situation); • Increasing insulation; • More evaporation; cooling effect of the environment (blue roof). In other words, heat stress is visible in two ways: the effect on energy in the building (albedo and insulation) and the effect on energy outside the building (cooling environment by evaporation). The effect on energy costs in the building is almost zero. The effect on energy outside the building (cooling environment) runs via the health effect (see below, other is qualitatively described).	Qualitatively
Health (physical and mental)	The health effect has been approached from two sub-effects: • *Avoided health care costs*: 0.835 fewer patients per 1000 inhabitants at 1% more green within a radius of 1 km around the building; € 868 per patient. (TEEB city). For roofs it is assumed that 0.835 / 5 = 0.167 fewer patients within a radius of 200 meters. It is assumed that only residents of the building benefit from it. • *Prevented labor loss*: € 6,341 per patient. Assuming 0.835 fewer patients per 1000 inhabitants at 1% more green, this amounts to € 5,294.74 less loss of work per year. (TEEB city) The health effect includes both physical and mental health effects. The effect of heat stress is also included. The effects on well-being are also qualitatively substantiated.	• Health effects (physical and mental): € • Welfare effects: Qualitatively

Implementation of the project	Details of the building (monument status, view, etc.) can have an influence on the speed of implementation of the project. This effect is described in the report.	Qualitatively
Biodiversity	The non-use value of biodiversity is used in the calculation tool. The key figures of (Witteveen + Bos, 2011) are used: € 8-20 per person (with a view of greenery) per year. In this study, € 10 per person (with a view of greenery) is assumed per year.	€
Social cohesion	With this effect we describe whether the project leads to additional opportunities for personal contact (at ground level or on the roof) and less crime due to greening	Qualitatively
Climate awareness	When the project is visible to users of the buidling it can lead to extra awareness of the climate challenge.	Qualitatively
Cultural history	Inspiration from historical water system solutions. For each project it is checked whether historical water system solutions are available and whether these can be made visible.	Qualitatively

3.2.1 Costs

The investment costs for a multifunctional roof consist in principle of: start-up costs, costs for project management, monitoring costs, communication costs and costs for the material and the execution. For the details of the five cases, use was made of the estimates for the LIFE application. Please note: in the SCBA is calculated with gross costs, or without deduction of subsidies (as is the case with the financial business case). In addition, the annual management and maintenance costs are included in the SCBA.

The investment costs entered in the SCBA are additional costs compared to the reference alternative. This means that it concerns net investment costs, or the investment costs where (if available) the budget for major maintenance of the roof (the reference alternative) has been collected.

3.2.2 Energy yields

Yellow roofs are equipped with solar panels and/or wind turbines. The energy yields generated by the roof are expressed in euros and are included here as an effect.

3.2.3 Reputation and business climate

Effects on the reputation and business climate are indicated using several indicators: real estate value, vacancy/ number of responses to social rental housing, owner's reputation and location climate of the district and city.

Property Value

It is assumed that green roofs cause a 10% increase in property value. This assumption is based on literature in which a range of 1-21% of real estate value increase caused by greenery is indicated. This range is used in the calculation tool, and the default value is 10%. The property value increase reflects the following sub-effects: aesthetic valuation, noise reduction, productivity and comfort). A view of a green / blue roof or greening at ground level results in a higher aesthetic value. This translates into real estate value (already included in the property value increase of 10%). The same applies to noise reduction. It is assumed that a green / blue roof leads to a decrease in noise from outside to inside of approx. 3 dB. The valuation of this noise reduction is included in the property value increase of 10%.

Research by (Lee, 2015) shows that a 40-second microbreak with a view of a green roof leads to higher employee productivity. This may be a reason for employers to pay for a green roof and has a positive effect on real estate value. However, there is no research that describes the increase in the real estate value of this effect.

Vacancy/ Number of responses to social housing

The caseholders have discussed the average vacancy rate in the current situation and the loss of rental income is. Subsequently, an assumption was made of the impact of a multifunctional roof on this vacancy. The reduction of vacancy reflects the increase in the comfort of residents and the popularity of the building.

When the building only has social rental housing, vacancy does not apply. In this case, qualitative descriptions can be made of the effects on the number of responses to the social rental housing offered by the lessor. When the number of responses to offered social rental housing in the building increases, it is assumed that the reputation and location climate of the building has improved.

Reputation of the owner

The reputation of the owner of the building may be improved by publicity that entails an innovative roof. This is valued qualitatively.

Business climate for the neighborhood and city

"Landscape has a reciprocal relation with business climate - not every company fits everywhere" is one of the conclusions of Landscape as Location Condition (Vereniging Deltametropool, 2017). The Deltametropolis Association suggests that the city also belongs to thinking about landscape. Roofs can be designed in such a way that they are part of, for example, green connections and structures in the urban environment. This contributes to the increased value of urban areas and the urban landscape can therefore have a positive influence on the business climate.

3.2.4 Water retention and water quality

Water retention is valued differently in the financial businesscase and SCBA. In the financial business case, any subsidies for the construction of water retention are included. These are of course only included when a roof with additional water storage capacity is installed.

In the SCBA, water retention is valued based on avoided costs for alternative retention facilities (storage at ground level or underground). This is also called the shadow price. In this SCBA, € 500 per m3 was used as shadow costs for water retention.

As far as water quality is concerned, only a possible effect occurs due to avoided energy costs of water treatment plants. However, research shows that the effect is nil (€ 0.03 / m² per year). This effect is therefore not quantitatively included in the SCBA, but is described qualitatively.

More extreme climate change can affect the water retention and water quality effects. This is especially the case when there is more and heavier rainfall than expected. The effect water storage is then an overestimation.

3.2.5 Air quality and climate effects

The effects on air quality and climate are valued using avoided emissions by the Handboek Milieuprijzen. This includes environmental prices for more than 2000 environmentally hazardous substances. The use of environmental prices is recommended by the Ministry of I & W. The calculation instrument determines the benefits for the saved emissions of CO2 and air-polluting emissions that are avoided (particulate matter, NOx, SO2).

The effects caused by the capture of particulate matter by vegetation in urban areas are marginal, according to an extensive literature study by RIVM and GGD Amsterdam (RIVM, 2011). If the vegetation is located along roads, the air quality can even deteriorate because the wind speed decreases and the concentrations of substances increase. The presence of vegetation in a large area can positively influence the background concentrations of nitrogen, but this effect is also limited according to the RIVM (order of half a percent to a few percent in the case of large-scale use of vegetation). No benefits have therefore been included for the improvement of air quality.

3.2.6 Heat stress

Multifunctional roofs (ie green and blue roofs) can potentially reduce heat stress by reducing heat transfer from inside to outside and from outside to inside. This has the following causes:

- Albedo effect[1]: other reflection factor of sunlight;
- A green/blue roof functions as a thicker insulation layer;
- More evaporation (ie important effect with blue).

The above factors lead to a reduction of heat stress in a building. This can translate to *lower energy costs* (both cooling and heating). Research shows, however, that the effects on energy costs due to green roofs are marginal (van Hooff, 2014).

In addition to the effects in a building, roofs can also have effects on the street level (outside effects). Research shows, however, that the change in heat emission through a green roof of a building to the outside is marginal (Gromke, 2015). This may be different for a blue roof. Blue roofs lead to more evaporation and thus reduce the amount of available energy in the atmosphere to heat the air. Blue roofs have a *cooling effect on their immediate surroundings*. This is a local effect. This effect only occurs when there is water on the blue roof and when this water is of a lower temperature than the temperature of the air around it. This cooling effect can lead to (positive) health effects and is therefore also included in it (see next section).

Also for heat stress, this can be influenced by differences in the degree of climate change. For example, there are more periods of heat. The effects of a green / blue roof can then be greater. This is described qualitatively per case.

3.2.7 Health (physical and mental)

Various studies (among others, the Delta Metropolis Association, 2017), (Lee, 2015), (Vries, 2014)) describe the relationship between greening and human health. A healthy living environment with good air quality, cooling, the presence of (more) possibilities to exercise, etc., leads to fewer health problems. In addition, a view on vegetation (either on a roof or on the street level) and / or access to a green environment in the city ensures a reduction of stress.

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[1] The amount of sunlight that is reflected by a surface is called albedo or reflection coefficient. This is usually expressed as a percentage value. The more radiation is absorbed by a surface and the less it reflects, the warmer that surface becomes. Black objects (eg bitumen roofs) have lower albedo than white surfaces. White or lighter surfaces (such as green or blue roofs) reflect more sunlight and heat up less.

One way to value these health effects is to calculate avoided healthcare costs and prevented labor loss. This is also done in the TEEB city tool (see, among others, (KPMG, 2012)). Both effects are further elaborated below:

- *Avoided health care costs*: 0.835 fewer patients per 1000 inhabitants at 1% more green within a radius of 1 km around the home; € 868 per patient. (TEEB city). For roofs it is assumed that 0.835 / 5 = 0.167 fewer patients within a radius of 200 meters. It is assumed that only residents of the building benefit from it.
- *Prevented labor loss*: € 6,341 per patient. Assuming 0.835 fewer patients per 1000 inhabitants at 1% more green, this amounts to € 5,294.74 less loss of work per year. (TEEB city)

Both physical and mental health effects are included in the above described indicators. The effect of heat stress is also included. The effects on well-being are qualitatively described in each report.

3.2.8 Implementation ease of the project

Details of the building (whether it has a monument status etc.) could influence the speed of implementation of a project: how much time does it take to realize it?

For example, if a building has a monument status, it can slow down the implementation speed of a project. However, when a building leads to more greening in the environment, this can lead to greater acceptance / less resistance among residents, which increases the implementation speed of the project. This effect is qualitatively described.

3.2.9 Biodiversity

Greening in the city leads to a positive effect on biodiversity. The space for green space in the city is limited, therefore green roofs could potentially contribute largely to urban biodiversity.

A method for determining biodiversity is the ‘Natuurpuntenmethodiek’ (see: SCBA Guide for Nature effects, text box below). To be able to use this method, relevant (urban) reference nature types need to be developed. According to the Natuurpuntenmethodiek, a type of ideal-typical maximum for the roof is determined, including species compositions. Subsequently, it can be determined to what extent existing or planned developments of green roofs score with respect to that maximum.

The use of the Natuurpuntenmethodiek is currently not possible, because there are no ideal-typical maxima of biodiversity for urban areas and green roofs developed yet.

Therefore, this study refers to existing indicators for biodiversity (Witteveen + Bos, 2011), namely € 10 per person per year (Witteveen + Bos, 2011) for local residents who are directly benefited by the increase in species richness.

SCBA guide for Nature effects

The SCBA guide for Nature effects, developed by Arcadis and CE Delft (December 2017) [2], is part of the formal SCBA instrumentarium, by the Dutch government. This guide focuses on changes in ecosystem end-services and biodiversity as the most important welfare effects of changes in nature. Ecosystem services are the flow of services supplied by ecosystems (e.g. water, air, forests and soil), which people use and thus contribute to prosperity. The three main categories of ecosystem services, in accordance with CICES (Common International Classification of Eco- system Services) are:

[2] The formal adoption of the SCBA guide for Nature effects by the government is expected at the end of March and the beginning of April 2018.

- Production services, such as food and drinking water;
- Regulatory services, such as coastal protection, soil fertility;
- Cultural services, such as green recreation and symbolic value.

Only ecosystem end-services contribute to human prosperity. These end-services are the 'output' of the ecosystems (natural, semi-natural or artificial), which directly influence the prosperity of people. Examples include food, drinking water and recreation in parks and other nature. Regulating ecosystem services are often intermediary ecosystem services; they are an input for ecosystem end services. Soil fertility is, for example, of great importance for production in agriculture. Effects on intermediary ecosystem services are indirectly included in the SCBA. Regulating ecosystem services that have an impact on the local living environment quality can also have a direct impact on human welfare.

Biodiversity is a stock quantity of natural capital: the variation, size and quality of species, populations and ecosystems. Biodiversity directly influences prosperity by providing cultural services (for example, a beautiful and species-rich walking area). Indirectly, the conservation of biodiversity is important for the delivery of ecosystem services now and in the future. A change in biodiversity is therefore given a place in the SCBA through its direct and indirect effect on the delivery of ecosystem terminal services. Due to the special nature of biodiversity and because specific policy is being pursued on the conservation of biodiversity, biodiversity is also treated separately in this working guide. In addition, the so-called Natuurpuntenmethodiek is presented as a concrete tool to make biodiversity visible.

3.2.10 Social cohesion

When a project leads to additional opportunities to meet other people (at ground level or on the roof), this leads to a strengthening of social cohesion. In addition, literature shows that greening leads to less crime and more social cohesion. The effect is described qualitatively in the reports.

3.2.11 Awareness of climate change

A project (and its effects) that is visible to residents, can lead to additional awareness of climate and water issues. When residents, for example, have a view of a roof with water storage (for example, a blue roof), this may increase the awareness of climate change. This effect intensifies when information boards are placed in or other means of information dissemination take place. This effect is described qualitatively.

3.2.12 Cultural history

Cultural history could be enhanced when historical water systems are present and are made visible by the project. This effect is describes qualitatively.

3.3 Revenue models

After the effects of the proposed investments have been inventoried and valued, the question arises whether and, if so, what kind of revenue model can be considered. It is important to know the specific context of the property owners and building. When a roof is more sustainable. this could lead to financial or qualitative (social) added value for which the parties are willing to pay. The experience of already developed green roofs around the Schouwburgplein in Rotterdam shows that greening of roofs is greatly appreciated. Everyone wants to have a view on a green roof. If you have to pay for it, however, the situation will change.

The cashing of income is often difficult. For example, there may be a 'split incentive' if the property owners invest in green roofs and / or solar panels / boilers, but the tenants benefit from a lower energy bill. The question then is whether property owners can increase the rent. Various considerations play a role in this, such as social considerations in keeping the rent affordable, attracting another market segment, wanting to invest in the living environment, reputation and so on.

It was discussed with the case holders what wishes and possibilities they have in relation to obtaining financial resp. social return on their investments. Also during the stakeholder meeting the 'cashing in' or 'Willingness to pay' were relevant topics. After all, these topics largely determine the return on investment for the investor.

4 USE OF THE CALCULATION TOOL

4.1 Introduction

Each roof type and design leads to different costs and benefits. We distinguish between the financial business case and the SCBA.

The financial business case shows the financial costs and benefits of the investor over a certain period of time.

In the SCBA, the costs and benefits are for society as a whole. All costs and benefits are included, regardless of who benefits or pays for them. In addition, qualitative benefits are taken into account; these are the benefits that can't be expressed in terms of money, but which benefit society as a whole. Examples are the reputation of the neighborhood and the city, heat stress, social cohesion and water quality.

In section 3.2 it is indicated which effects quantitatively resp. qualitatively included in the calculation tool.

The most important parts of the calculation tool are: *Introduction*, the various *Input* sheets and the *Results* sheet. These are the sheets that the user needs. There are also sheets where the underlying calculations are performed. The user does not need to enter / change anything here, but can only consider it as background information. The *Introduction* sheet describes step by step how the calculation tool should be used and read.

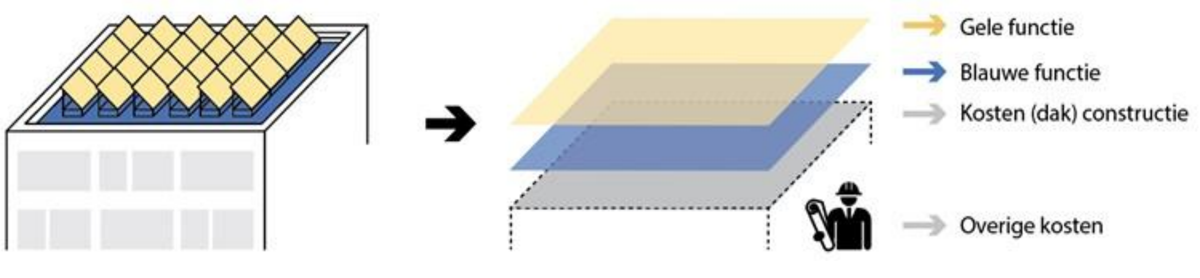
The following sections in this chapter provide the most important information about the use of the various *Input* sheets and the *Results* sheet. Subsequently, the underlying calculations that are carried out in the effect modules are briefly discussed. This chapter ends with a section on the use of a sensitivity analysis.

4.2 Input into the calculation tool

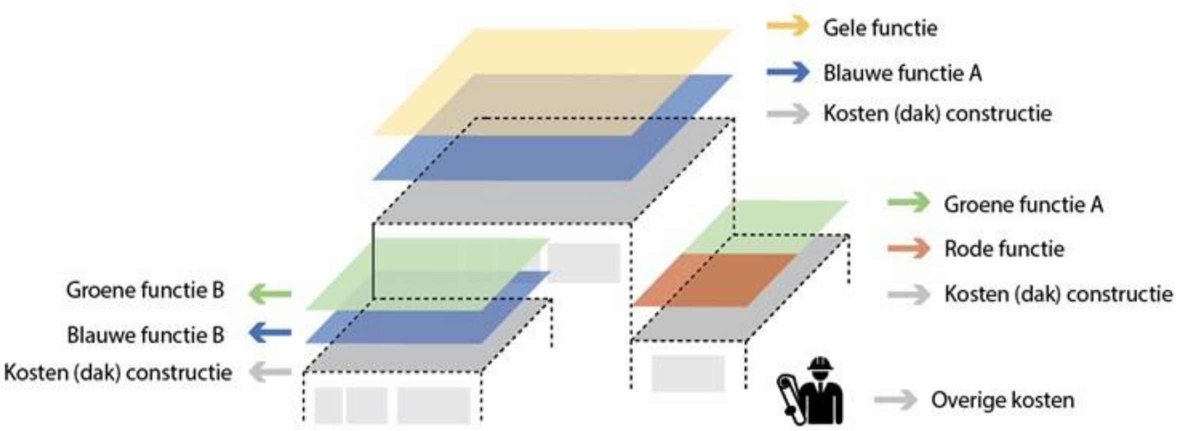
Input General sheet is used to fill in the most important information that the instrument uses to calculate financial and social costs and benefits of the (multifunctional) roof.

In the *Input General* sheet you will see a number of colored panels. The color of the panels correspond to the function types of the roof or the roof colors. Each roof type requires different input. For example, blue roofs a variable for the thickness of the water storage package is included for a blue roof, and the energy yield in kWh per year is included for a yellow roof. The surface area and investment costs per square meter are required input for every roof color.

When entering the required input, we consider each roof color, but also each roof surface separately. The figure below shows an example of a multifunctional roof consisting of solar panels and a water storage. The roof therefore has a yellow function and a blue function. There are general costs for adjusting the roof and the roof construction, such as the removal of gravel, adjustment of rising points, costs for vertical transport or the relocation of installations. There are also other costs, such as the costs for project management, start-up costs and the costs for annual management and maintenance. These are entered separately. Please note that there should not be any double costs included.



Larger buildings could have roofs consisting of several parts, with each a different color or combination of colors. The costs of these different roofparts are given separately. The figure below gives an example.



In order to be able to calculate with different energy yields per year, an extra sheet "Input energy yields" has been created. In this sheet you enter the yields and energy price for the respective area for each separate year. You can also choose to keep it the same for all years. In addition, it is often the case that general construction costs are incurred. These costs can also be entered separately under the "Construction" sheet. The re-entered posts under construction (demolition, risers, etc.) and other costs (start-up costs, project management, etc.) are indicative. The names can be adjusted to fit the cost structure you use. Always use the extra sheets "Input Construction" and "Input other costs" to enter all costs and names. Everything you enter in these two sheets automatically changes to the "Input General" overview. An extra sheet has also been created for the annual and periodic costs for management and maintenance; "Import management and maintenance".

Behind each plane is a square that can be checked on and off, for example: 

Check to include the entered area in the total of costs and benefits. By checking or unchecking areas you can play with the composition of the roof.

You can enter any subsidies in the "Coverage" area. These are deducted from the investment costs in order to arrive at net investment costs.

In the same plane you will also find the reference alternative (also called zero alternative). For the reference alternative, you enter the costs for management and maintenance that are also made in the event that no multifunctional roof is constructed. You do this in the sheet "Input management and maintenance". By filling in the reference alternative, the costs that are made in each case - multifunctional roof or not - are calculated, and you gain insight into the additional costs of a multifunctional roof.

It is also possible not to fill in a reference alternative, in which case all investment costs and costs for management and maintenance will be reflected in the results.

In the financial parameters plane, enter the discount rate that is used in the SCBA. This is set at 3.0% by default. The next line lets you adjust inflation, by default at 5.0%. This is used in the financial business case. The replacement term for the roof is entered on the next line. In this period, the complete multifunctional roof will be replaced, and all investment costs, in addition to the construction costs, will be renewed. All investment costs for the imported colored roof surfaces are covered and the other costs incurred for replacement, as entered in the "other costs" sheet. On the last line you adjust the analysis period of the financial business case and SCBA, ranging from 10 to 40 years.

In the purple area you will find the total overview of the costs, including:

- The investment costs of the multifunctional roof excluding subsidies (also known as the "gross investment costs")
- The investment costs of the multifunctional roof including subsidies (also called the "net investment costs"). These costs are included in the financial business case.
- The investment costs as additional costs compared to the reference alternative, excluding subsidies. These costs are taken into account in the social cost-benefit analysis.
- Annual management and maintenance
- Replacement costs (excluding subsidies), which is used in the financial business case.
- Additional costs for replacement (excluding subsidies). These costs are taken into account in the social cost-benefit analysis.

The social effects are partly determined on the basis of the parameters of the roof colors that you have introduced. In addition, there are qualitative benefits, which are also determined by the "Imports to determine the effects in the CBA". We explain the questions one by one:

- The input of the total surface of the roof speaks for itself. On the basis of this number, it is indicated how much of the rainwater is retained by the blue roof parts during an extreme period of 50 mm in one hour.
- The next two questions (accessibility of the roof and opportunity to meet) relate to social benefits. When a project leads to extra opportunities for meeting (at ground level or on the roof), this leads to a strengthening of social cohesion.
  Cultural history is enhanced when historical water systems are present and can be made visible by the project. The effect is valued qualitatively.
- When an intervention on the roof is made visible (by looking at the roof or by measures at ground level), residents have the opportunity to talk about this and / or learn from it. This increases the awareness of the climate challenge.
- When the building only has social rental properties, vacancy does not apply. In this case, qualitative descriptions can be made of the effects on the number of responses to the social rental housing offered by the lessor. When the number of responses to offered social rental housing in the building increases, it is assumed that the reputation and location climate of the building has improved.
- The 10% rise in property value due to a green roof is assumed. This assumption is based on literature in which a spread of 1-21% real estate value increases due to green. The calculation tool can be moved within this bandwidth. The default value is 10%. This was then multiplied by the number of households in the building with a view of the roof to arrive at a real estate value increase in euros per year.
- In the SCBA, water retention is valued on the basis of the avoided costs for alternative retention facilities (storage at ground level or underground). This is also called the shadow price. In this SCBA, € 500 per m3 was used as shadow costs for water retention.

4.3 Interpretation of the results

The *Results* sheet shows the costs, benefits and the balance of the financial business case and of the SCBA, starting with the results of the financial business case.

The financial business case shows the balance of the financial costs and benefits. The energy yield of the yellow roof surface and the exploitation of the red roof are the only benefits included in the financial business case. The results are quantitatively expressed. There are three graphs in the upper plane. The left-hand graph shows the discounted net investment costs (ie including subsidies and coverage from the reference alternative), income and balance over the analysis period. The middle graph shows the total size of the investment costs, and the part that is covered by subsidies. The right-hand graph shows the discounted management and maintenance costs and benefits from solar power over the analysis period.

In the next plane the results of the social cost-benefit analysis are included. The first graph shows an overview of the discounted quantitative social costs and benefits, and the resulting balance for the analysis period. The middle graph shows the structure of the quantitative social benefits. The traffic light model on the right indicates the qualitative benefits from the project. The most important qualitative benefits are further explained in the last part of the page.

4.4 Valuation of the effects in the calculation tool

All effects described in section 3.2 are shown on the Results sheet. Some effects have been qualitatively assessed on the basis of answering a number of questions at the bottom of the Import sheet. Other effects have been calculated and valued in the calculation instrument. These calculations were performed in different underlying sheets in the calculation tool. The Net Present Value (NPV) of the following effect modules has been calculated: reputation and location climate, water retention, climate, air quality, avoided health care costs (health effect), reduced work loss (health effect), biodiversity and energy yields. The underlying calculations of each of these modules are described in more detail below.

Property value (reputation and business climate)

It is assumed that the view of greenery leads to a real estate value increase of 10% (spread in the literature between 1.4% and 20%). This is then multiplied by the current rent (or real estate value) to calculate the absolute increase in the real estate value. This was then multiplied by the number of households in the building with a view of the roof to arrive at a real estate value increase in euros per year.

Vacancy (reputation and business climate)

In the case of private letting in a building, there may be vacancy. The average vacancy and the loss of rental income from this is discussed with the owner in question. Subsequently, an assumption is made in the purchase of vacant space due to the construction of the multifunctional roof. The reduced vacancy rate is then expressed in euros per year.

Water retention

A shadow price in urban areas has been adopted for water retention. The default shadow price is € 500 per m3. This shadow price is multiplied by the number of m3 of water storage that is realized by the roof in order to arrive at the one-off benefit of water retention that occurs immediately when the project is constructed.

Air quality and climate

The following emission factors and environmental prices (Handboek Milieuprijzen, CE Delft 2017) have been used:

Avoid emissions	Kg/kWh
CO2	0,69
NOX	0,00071
SO2	0,00039
VOS	0,00056
Fine particles	0,00003
Environmental prices	**Euro per kg**
CO2	0,048
NOX	35
SO2	24,4

VOS	2,29
Fine particles	43,5

The number of kWh generated on the roof is then multiplied by the key figures for the avoided emissions and the environmental prices in order to arrive at the annual CO2 gain and annual reduction in NOx, SO2, VOC and particulate matter in euros.

Avoided healthcare costs and avoided loss of work (health effect)

The following key figures have been used (source: TEEB city), see table

Key figures	Number	Unit
Fewer patients per 1000 inhabitants at 1% more green within 1 km	0,835	patients
Healthcare costs	€ 868	euro per patient
Avoided loss of work	€ 6.341,00	per patiënt

It has been assumed that in multifunctional roofs it is not necessary to count with a radius of 1 km but with a radius of 200 m. Here the figure for the radius of 1 km is divided by five (0.835 / 5 = 0.167 fewer patients at 1% more green within 200 meters). In addition, it is assumed that there is 1% more green after laying a green roof. The average number of people per household is estimated at two.

The avoided healthcare costs were calculated by multiplying the healthcare costs per patient by the number of fewer patients per 1000 inhabitants at 1% more green within 200 meters.

The benefits due to less loss of work are calculated by multiplying the costs of avoided work loss per patient by the number of fewer patients per 1000 inhabitants at 1% more green within 200 meters.

Biodiversity

The effects of biodiversity have been calculated by using the key figure of the non-use value of biodiversity (Witteveen + Bos, 2011): 10 euros per person with a view of a green roof per year. The biodiversity benefit per year is then calculated by multiplying this index number by the number of people who have a view of the green roof.

Energy yields

The energy yields are calculated by multiplying the number of kWh per year produced on the roof by the selling price per kWh. By using different sales prices different alternatives can be compared.

4.5 Sensitivity analysis

As a sensitivity analysis, the following changes can be made to the *General input* sheet:

- Alternative discount rate;
- Alternative value for inflation (financial business case);
- Alternative replacement term of the roof ;
- Alternative period of analysis.

The *Results* will show the updated results.

5 CONCLUSION AND REFLECTION

5.1 Discussion of the results

The developed tool for the financial business case and SCBA of multifunctional roofs has been applied to five cases. The extent to which the tool could be tested differs per case. The design and configuration of all five multifunctional roofs were still being developed to a greater or lesser extent at the completion of this project. The data input was only for one case (Vestia) complete, but not yet final. For the other four cases, the input was less detailed and / or incomplete, particularly in the areas "operation and maintenance", "energy yield" and the specification of the reference alternative. Where possible assumptions were made, based on key figures, to gain some results of the financial business case and SCBA.

With respect to the costs and benefits, the following observations were made:

- Two financial benefits have been identified: energy yields and exploitation of roofs with a red function (e.g. the exploitation of a roof terrace). Although the latter benefit is included in the tool, it has not been applied in any of the cases;
- Nineteen social benefits have been investigated and included in the tool. The benefits have been identified and valued in close collaboration with the case holders. Ten of these (social) benefits are valued in quantitative resp. monetary terms, the other nine are described qualitatively.

The results show the following:

- The balance of the SCBA of the multifunctional roof is positive in the case of Vestia (Peperklip). This is not (yet) the case for the other cases. It should be noted that some of the social benefits are only valued qualitatively, and therefore are not part of the monetarized balance.
- In all five practice cases, there is (still) no conclusive financial business case for the multifunctional roof. This means that the financial benefits for the owner / operator do not outweigh the costs of the multifunctional roof, as it is now composed. Using the calculation tool optimizations and / or a different configuration can easily be calculated.
- The reference alternative (the costs for a ‘regular’ replacement of the roof) has not been fully developed for any of the cases. The introduction of a reference alternative will positively influence the financial balance. The costs of the multifunctional roof are then considered as additional costs compared to the operation, maintenance and periodic replacement of a standard roof. Nevertheless, with this addition the balance of the financial business case will probably not be positive for any of the cases.
- Energy production on the roof generates financial benefits, but the construction and maintenance of a yellow roof is a costly affair. The resulting balance of a yellow roof is not necessarily positive.
- Red roofs, such as the exploitation of a roof terrace and meeting place, could generate financial benefits as well, but have not been applied in the five cases.

5.2 Applying the tool elsewhere

The tool has been constructed in such a way that it can be used elsewhere in a generic way. Furthermore, the tool can be used to combine different roof surfaces, by 'on' and 'unchecking' of roof surfaces. The calculation tool can therefore be used to compare different designs.

The instrument is not bound to a specific location or to Rotterdam, but can also be used for applications elsewhere. This also applies across national borders. Within the framework of the LIFE @ Urban Roofs project, a possible next step is to apply the tool to developments in other European cities. An English version of the tool is available for applications outside the Netherlands.

Additionally, the tool is not tied to a specific phase in the development of a multifunctional roof. If there is only an rough sketch for the development of a multifunctional roof, key figures and assumption (described in the tool) can be used. If there is already a detailed plan, the available information from, e.g. quotations or a concrete specification could also be entered in the tool.

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COLOPHON

LIFE @ URBAN ROOFS
SCBA MULTIFUNCTIONAL ROOFS – GENERAL REPORT

This LIFE SCBA tool and report were developed for the municipality of Rotterdam. It was realized by means of a LIFE European subsidy and in close cooperation with five real estate owners, under the direction of the municipality. The tool and report have been designed and produced by Arcadis and CE Delft.

CUSTOMER

Municipality of Rotterdam, Arosa Foundation, De Heuvel Foundation, De Rotterdamsche Vastgoed Maatschappij, Vestia.

In cooperation with the municipality of Vejle, Denmark (Boris Schønfeldt).

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