Stacking Green, Saigon, Vietnam, © vtnaa, Photographers: Hiroyuki Oki

Green structures and energy-efficient Building

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Nürtingen-Geislingen University of Applied Science

Hochschule für
Wirtschaft und Umwelt
Nürtingen-Geislingen

Frankfurt am Main-Zeil, view from Maintower (photo: © Mylius 2011/Wikipedia)

status quo cities

...surfaces are unprotected against weather influences, overheated, spreading noise and without rainwater retention

Magistratsabteilung 48, Wien (Foto: Nicole Pfoser 2012)

Roofgarden Immeuble Spirit of Future, Paris (Foto: Nicole Pfoser 2011)

green chance performance factors of building greenery

cooling, shading, protection of building envelope for weathering, cover against extremes of temperature, improve water retention, fixes and filters dust and pollutants, absorb noise, creates flora and fauna habitats, potential for design…

Musee du Quai Branly, Paris (Foto: Nicole Pfoser 2011)

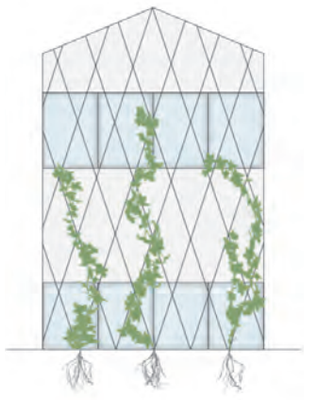
facade greening: determination of greening forms

greening form: ground based climbers - direct growth/climbing at the facade

ground based system

face-shaped, direct growth/climbing at the facade

adducible growth. Climbing aid/trellis required (rods, ropes, grids, nets)



hybrid forms

combination of ground based and facade based greening/ climbing or hanging

facade based system

plants in horizontal planters
Planting shelves as curtain facade

plants in vertical constructions „vertical gardens“

modular systems

areal extended

Parsonage Paulusgemeinde Darmstadt

University Aarhus, © martin8th/Flickr

State archives Liestal, EM2N, © Hannes Henz

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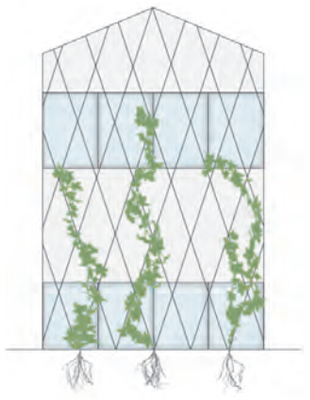

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Housing, Darmstadt (photo: Nicole Pfoser 2011)

system-typical characteristics

- low investment costs
- no secondary construction (the surface should be checked for cracks)
- rooting in ground
- no need for irrigation systems
- substitution of expensive building facade
- limited plant selection

greening form: ground based climbers - adducible growth

ground based system

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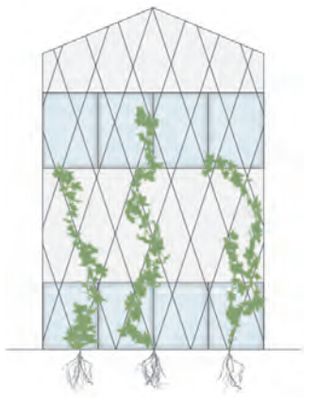
adducible growth. Climbing aid/trellis required (rods, ropes, grids, nets)



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Facade greening Prinz Georg Garten, Darmstadt (photo: Nicole Pfoser 2011)

Alpine Finanz, Opfikon, swiss 2009, © Jakob AG

greening form: ground based climbers - adducible growth

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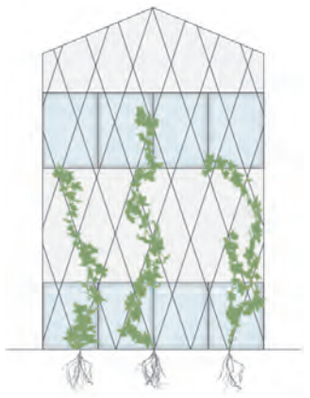

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Swiss Re Headquater, Unterföhring 2001, BRT Architekten, © May Landschaftsbau GmbH & Co.,

Surrounding portico/shading, PTH FFM, Kissler + Effgen (photo: Nicole Pfoser 2013)

system-typical characteristics

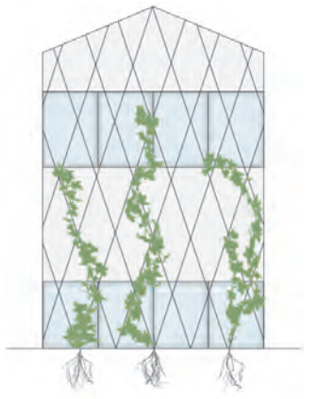
- adducible growth
- climbing aid/trellis required (rods, ropes, grids, nets)
- separate plant-layer (independent from facade materials)
- space-forming layer (simple maintenance)
- substitution of expensive building facade and/or railing
- rooting in ground
- no need for irrigation systems
- diversity of plants
- „vertical farming“ possible

greening form: facade based - plants in horizontal planters

ground based system

face-shaped, direct growth/climbing at the facade

adducible growth. Climbing aid/trellis required (rods, ropes, grids, nets)



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areal extended

Flower Tower, Paris 2004, Éduard François (photo: Nicole Pfoser 2011)

Stacking Green, Saigon, Vietnam, © vtnaa, Photographers: Hiroyuki Oki

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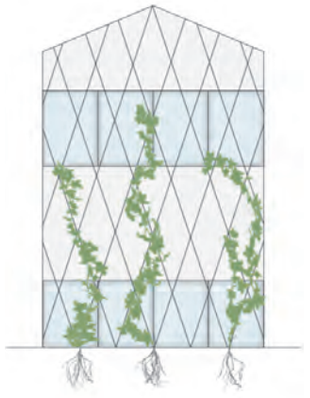

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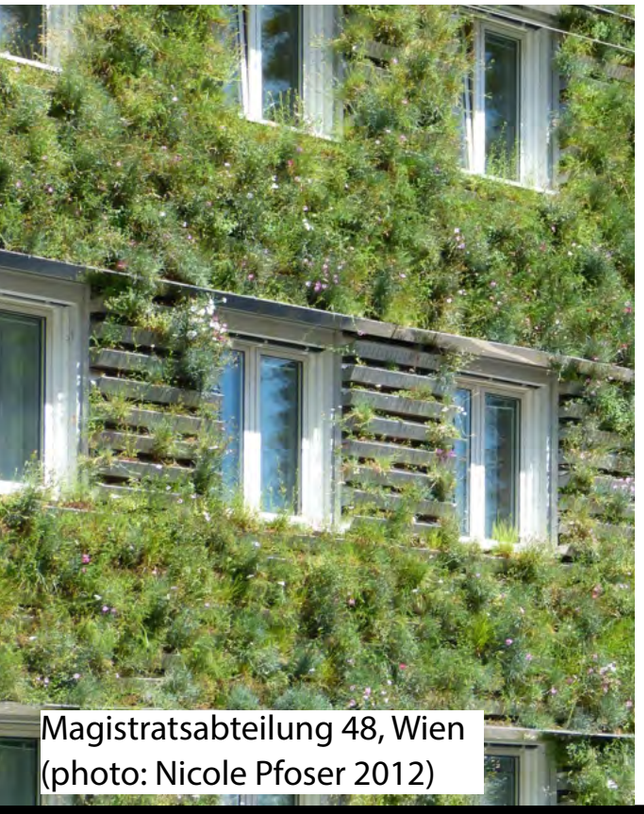


Magistratsabteilung 48, Wien
(photo: Nicole Pfoser 2012)

„Flower-shelve“ Stücki shopping-center
(photo: © Jacob Rope System)

system-typical characteristics

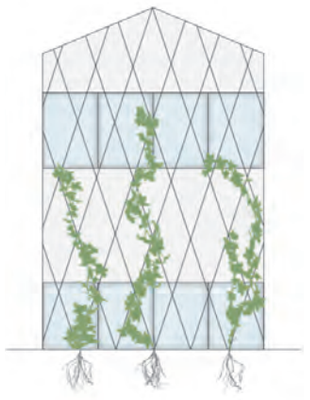
- variable planting, without contact to the ground
- no requirement for the ground (irrigation- and nutrient system necessary)
- huge diversity of plants (wide variety of design - colour/flowers…)
- surface effect immediately (precultur)
- possible substitution of expensive building facade and/or railing
- „vertical farming“ possible

greening form: facade based - modular systems (vertical construction)

ground based system

face-shaped, direct growth/climbing at the facade

adducible growth. Climbing aid/trellis required (rods, ropes, grids, nets)



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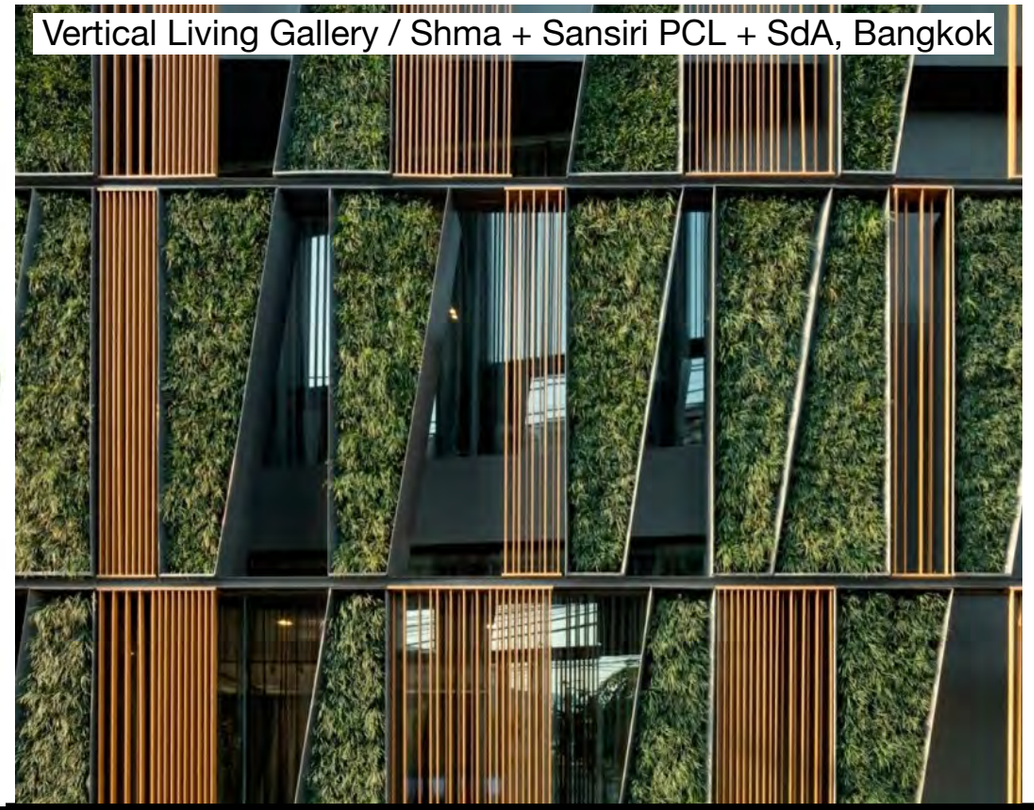
as curtain facade

plants in vertical constructions
„vertical gardens“

modular systems

areal extended

© Greenwall



Vertical Living Gallery / Shma + Sansiri PCL + SdA, Bangkok

www.geolam.com,
© Géomoss, Strasbourg

greening form: facade based - modular systems (vertical construction)

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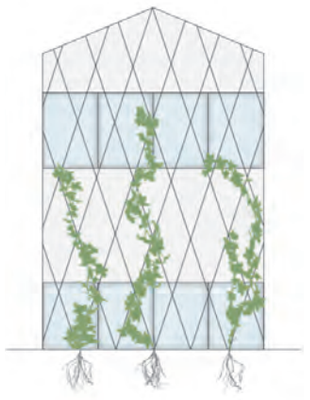

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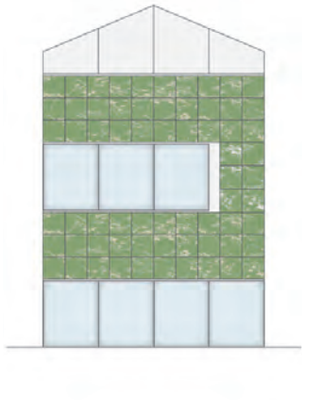


areal extended

Metrostation Flon, Lausanne (photo: © Peter Mauss)

system-typical characteristics

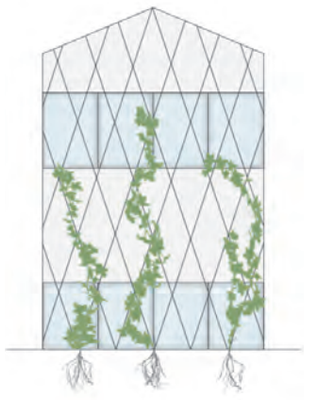
- variable planting, without contact to the ground
- no requirement for the ground (irrigation- and nutrient system necessary)
- surface effect immediately (precultur)
- diversity of plants (wide variety of design - colour/flowers…)
- simple replaceability (also partly)
- mounting speed like usual wallcovering
- removable to reach subsurface
- possible substitution of expensive building facade
- „vertical farming“ partly possible

greening form: facade based - areal extended systems (vertical construction)

ground based system

face-shaped, direct growth/climbing at the facade

adducible growth. Climbing aid/trellis required (rods, ropes, grids, nets)



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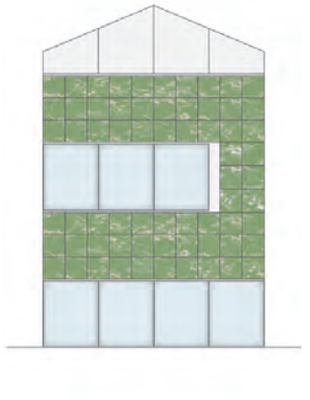

areal extended

Sportplaza Mercator, Amsterdam - Venhoeven CS, © Luuk Kramer

Magasin BHV Homme, Paris - Patrick Blanc

greening form: facade based - areal extended systems (vertical construction)

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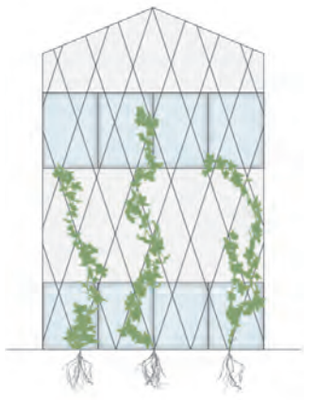

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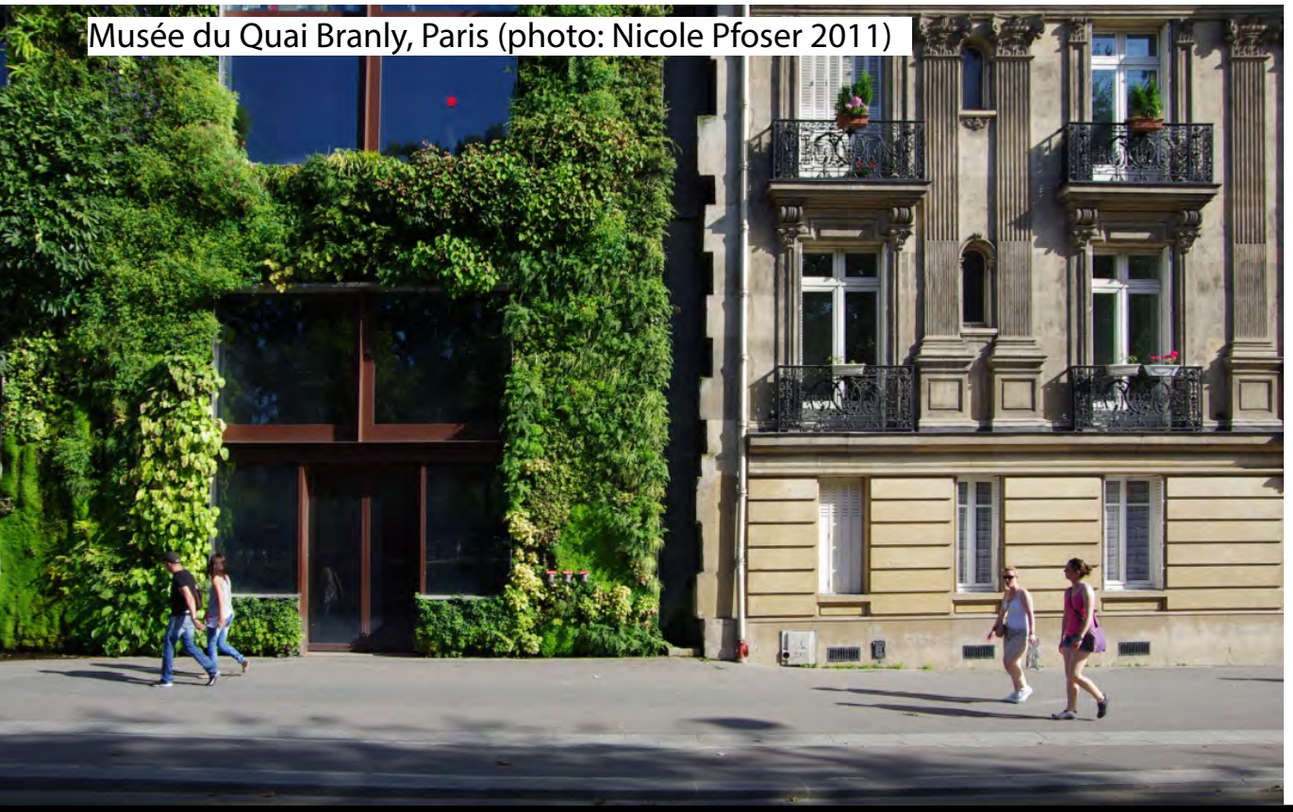

Musée du Quai Branly, Paris (photo: Nicole Pfoser 2011)

system-typical characteristics

- variable planting, without contact to the ground
- no requirement for the ground (irrigation- and nutrient system necessary)
- lightweight construction
- Installation: best value surface/time (afterwards plants need time to growth)
- short-term surface effect (2-3 months)
- substitution of building facade

greening form: combination of ground based and facade based greening

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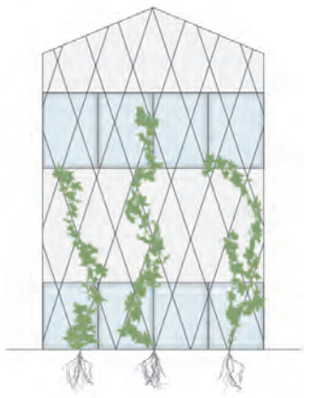

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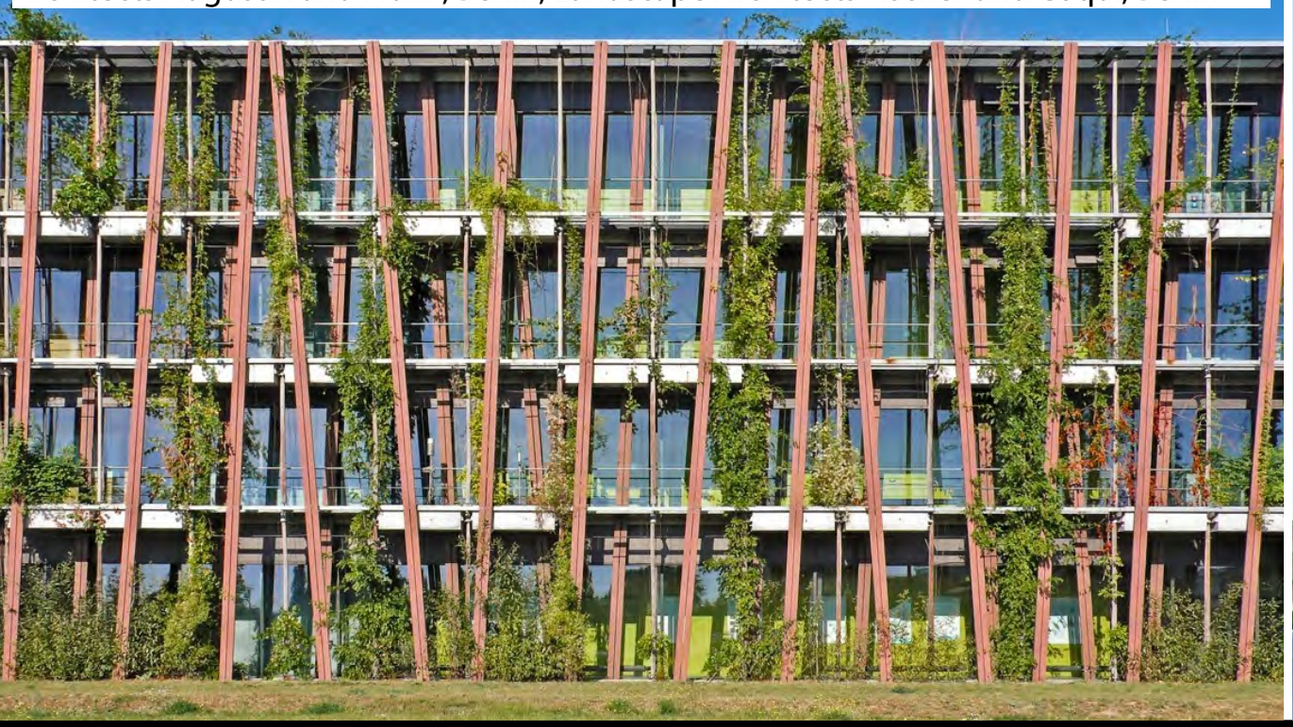
Institut of physics, Humboldt-University Berlin, Berlin-Adlershof 2003
Architects Augustin and Frank, Berlin; Landscape Architects Tischer und Coqui, Berlin



MFO-Park, Zürich Neu-Oerlikon 2002 - Raderschall Landscape Architects, © Jakob AG

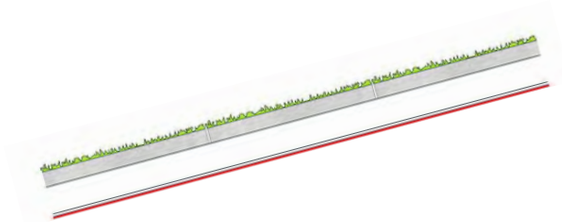
Metrostation Flon, Lausanne (Foto: © Peter Mauss)

roof greening: determination of greening forms

greening forms of green roofs

extensive green roofs

direct/spontaneous greening



mosses, lichens

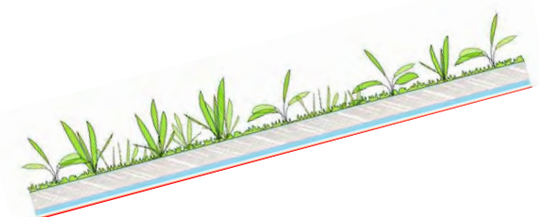
- Tiles/concrete/flag with growth supporting surface

textile-system

mosses

- synthetic fiber matting

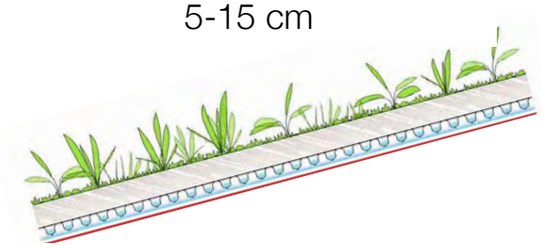
textile-substrate-system



perennials (including sedum, grasses, herbs), copses, mosses

- organic fiber matting on substrate layer

substrate layer 5-15 cm



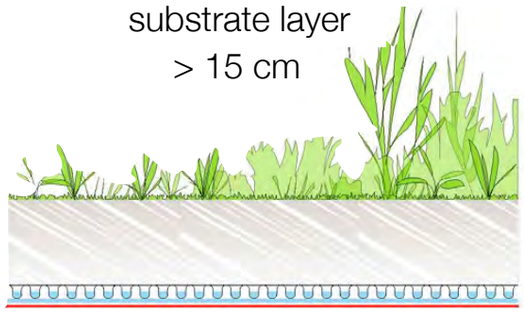
perennials (including sedum, grasses, herbs), copses, mosses

- variable hight of substrate above rainwater drainage

Naturally designed vegetation forms, self sustaining and developing. Installation with minimum effort, simple maintenance.

intensive green roofs

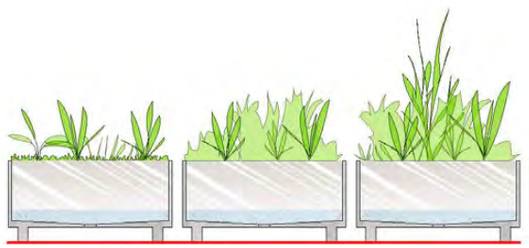
substrate layer > 15 cm



lawn, perennials (including sedum, grasses, ferns, partly bulbs), shrubs (partly trees - substrate layer >80 cm)

- variable hight of substrate above rainwater drainage

planters



perennials (including grasses, ferns, partly bulbs), shrubs (partly trees), mosses

- substrate in planters with rainwater drainage, possibly with insulation

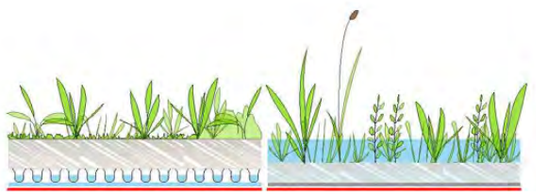
special forms

modular systems

perennials (including sedum, grasses, ferns), copses, mosses

- substrate in element-units of basket/gabion, caskets
- Nutrient-containing mat systems
- substrate-supporting gutter systems

retention systems



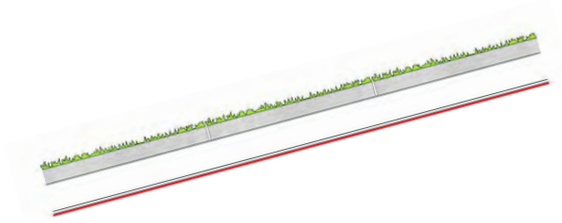
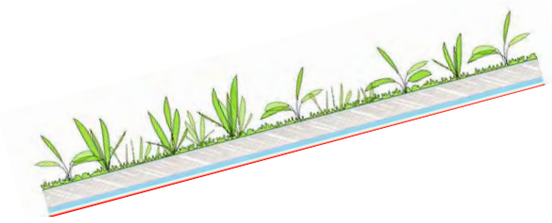
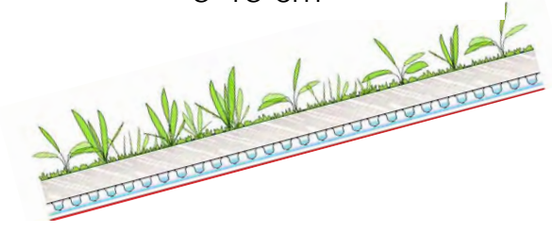
perennials (including sedum, grasses, herbs), copses, partly mosses

- water-layer above substrate
- water-layer in substrate
- water-layer below substrate

Comparably with ground based open spaces (use and design possibilities)
Plants have high demands on substrate layer. Intensive maintenance and permanent regular water- and nutrient supply.

greening form: extensive green roofs - direct/spontaneous

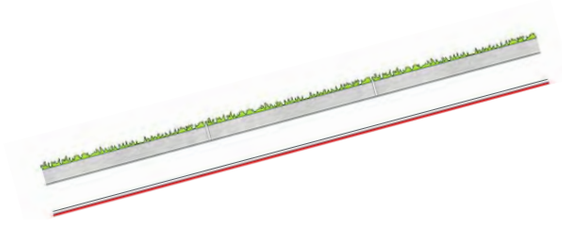
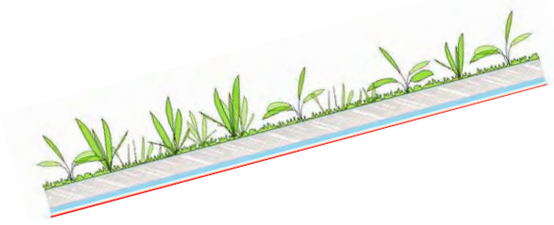
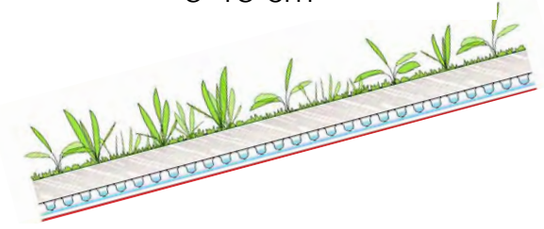
extensive green roofs

direct/spontaneous greening	textile-system	textile-substrate-system	substrate layer 5-15 cm
			
mosses, lichens	mosses	perennials (including sedum, grasses, herbs), copses, mosses	perennials (including sedum, grasses, herbs), copses, mosses
• Tiles/concrete/flag with growth supporting surface	• synthetic fiber matting	• organic fiber matting on substrate layer	• variable hight of substrate above rainwater drainage

spontaneous greening: wall with mosses, lichens (photo: Nicole Pfoser 2012)

greening form: extensive green roofs - direct/spontaneous

extensive green roofs

direct/spontaneous greening	textile-system	textile-substrate-system	substrate layer 5-15 cm
			
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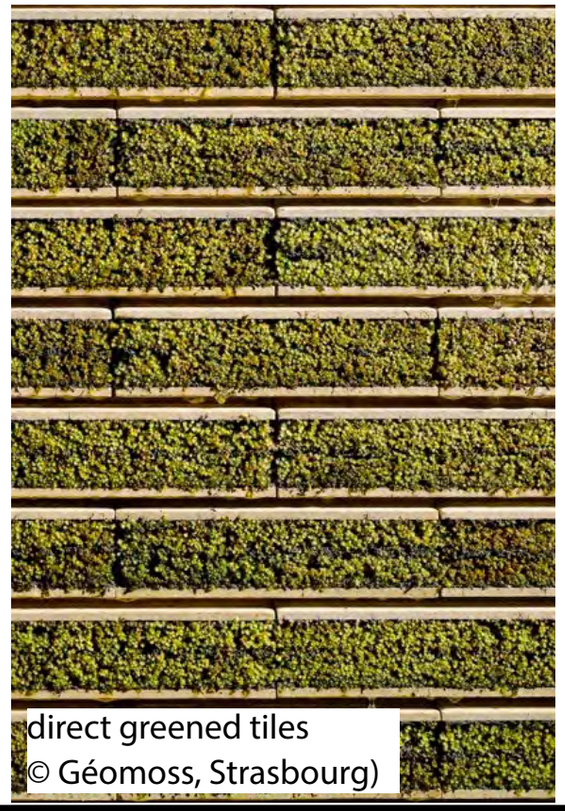
„biological concrete“. Simulation:
Aeronautical Cultural Centre, El Prat de Llobregat



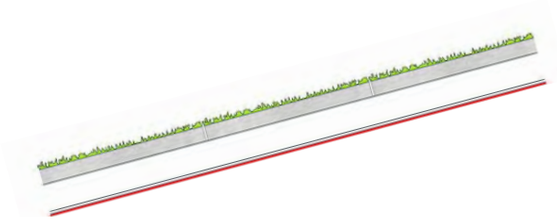
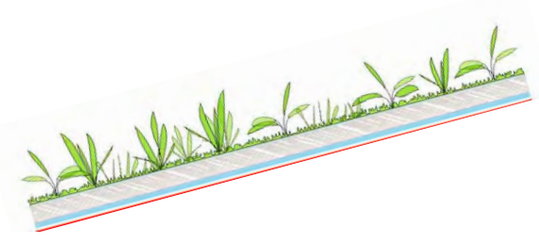
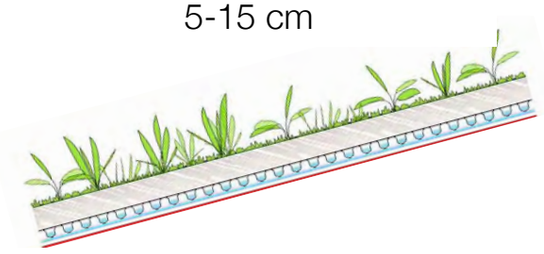
direct greened tiles
© Géomoss, Strasbourg)

system-typical characteristics

- simple maintenance
- surface effect immediately (precultur)
- natural play of varying colour
- irrigation necessary (rainwater required)
- resistant through weather influence and dryness (then orange/ rust brown)
- monochrome, flat surface
- water retention up to 20 l/m^2

greening form: extensive green roofs - textile-system

extensive green roofs

direct/spontaneous greening	textile-system	textile-substrate-system	substrate layer 5-15 cm
			
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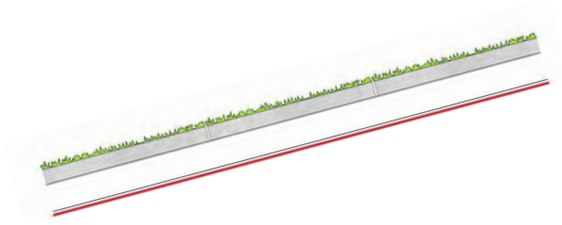
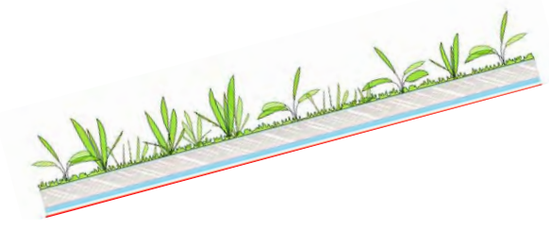
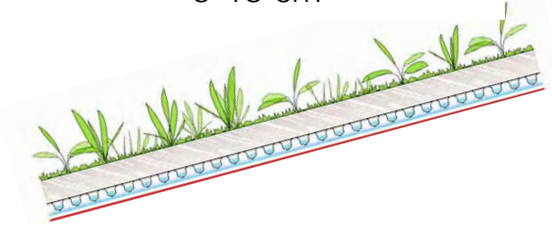
Prada, Tokyo, Herzog & de Meuron, 2003 (Foto: © Tim Brown Architecture)

greening form: extensive green roofs - textile-system

extensive green roofs

direct/spontaneous greening	textile-system	textile-substrate-system	substrate layer 5-15 cm
			
mosses, lichens	mosses	perennials (including sedum, grasses, herbs), copses, mosses	perennials (including sedum, grasses, herbs), copses, mosses
• Tiles/concrete/flag with growth supporting surface	• synthetic fiber matting	• organic fiber matting on substrate layer	• variable hight of substrate above rainwater drainage

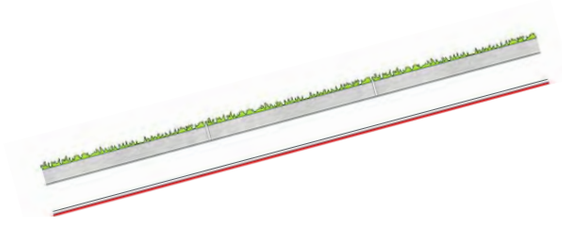
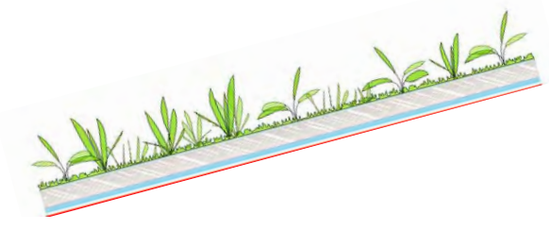
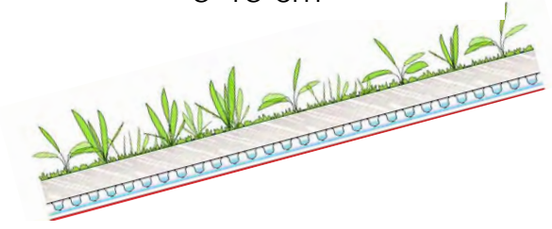
Extensive Dachbegrünung - Moosmatten (Quelle: Xeroflor)

system-typical characteristics

- precultivation possible
- lightweight
- suitable for all roof pitches
- fast mounting
- inexpensive production
- simple maintenance
- buffers water shortage
- in case of optical demands irrigation necessary (rainwater required)
- flat texture
- monochrome colour
- water retention up to 24 l/m²

greening form: extensive green roofs - textile-substrate-system

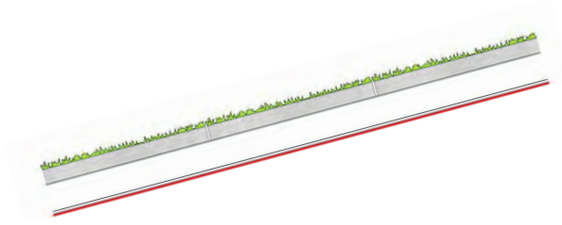
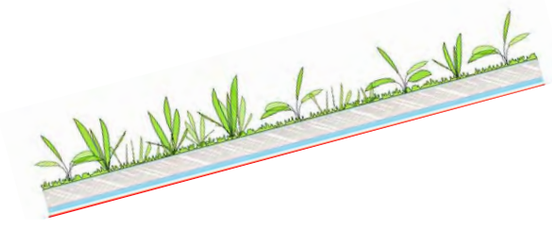
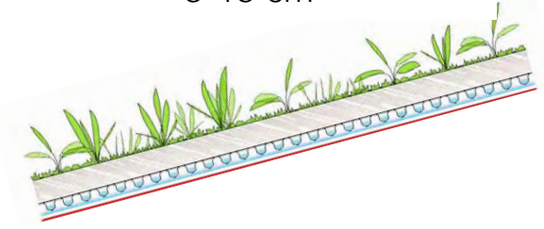
extensive green roofs

direct/spontaneous greening	textile-system	textile-substrate-system	substrate layer 5-15 cm
			
mosses, lichens	mosses	perennials (including sedum, grasses, herbs), copses, mosses	perennials (including sedum, grasses, herbs), copses, mosses
• Tiles/concrete/flag with growth supporting surface	• synthetic fiber matting	• organic fiber matting on substrate layer	• variable hight of substrate above rainwater drainage

extensive green roof - sedum-mat, © BOTT Begrünungssysteme GmbH

greening form: extensive green roofs - textile-substrate-system

extensive green roofs

direct/spontaneous greening	textile-system	textile-substrate-system	substrate layer 5-15 cm
			
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• Tiles/concrete/flag with growth supporting surface	• synthetic fiber matting	• organic fiber matting on substrate layer	• variable hight of substrate above rainwater drainage

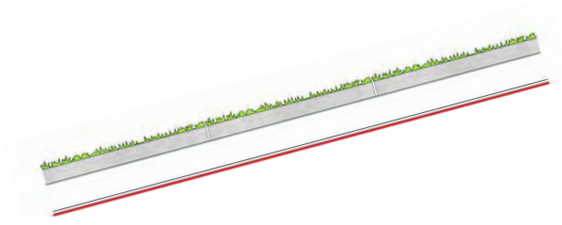
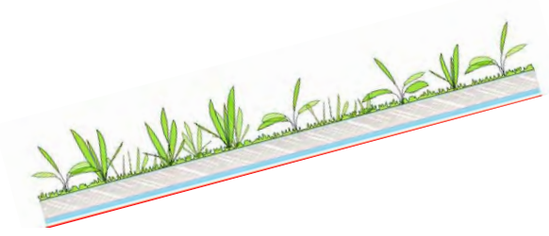
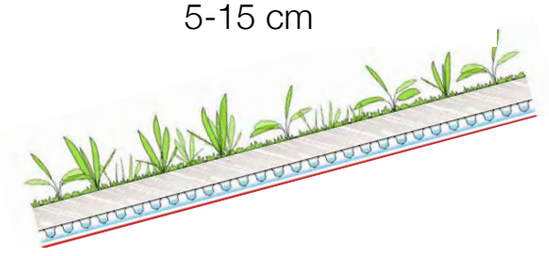
extensive green roof - ev. community centre,
© BOTT Begrünungssysteme GmbH

system-typical characteristics

- quick installation
- short-term surface effect, with preculture immediately
- diversity of plants (perennials – including sedum, grasses, herbs –, copses, mosses
- humidity of substrate, better maintenance in dry periods
- simple maintenance
- water retention up to 20 l/m²

greening form: extensive green roofs - substrate layer 5-15 cm

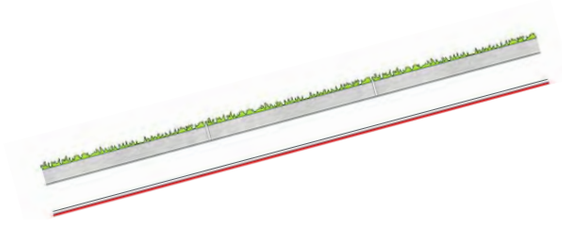
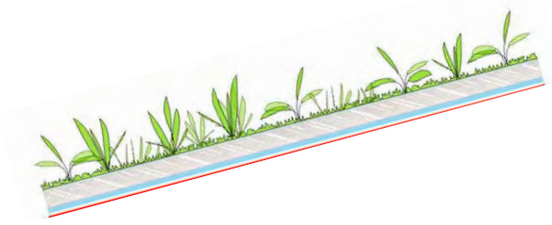
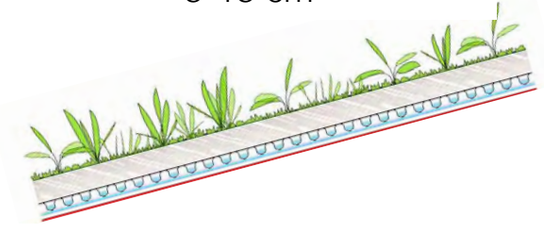
extensive green roofs

direct/spontaneous greening	textile-system	textile-substrate-system	substrate layer 5-15 cm
			
mosses, lichens	mosses	perennials (including sedum, grasses, herbs), copses, mosses	perennials (including sedum, grasses, herbs), copses, mosses
• Tiles/concrete/flag with growth supporting surface	• synthetic fiber matting	• organic fiber matting on substrate layer	• variable hight of substrate above rainwater drainage

extensive green roof - University College, Amsterdam, © Schadenberg

greening form: extensive green roofs - substrate layer 5-15 cm

extensive green roofs

direct/spontaneous greening	textile-system	textile-substrate-system	substrate layer 5-15 cm
			
mosses, lichens	mosses	perennials (including sedum, grasses, herbs), copses, mosses	perennials (including sedum, grasses, herbs), copses, mosses
• Tiles/concrete/flag with growth supporting surface	• synthetic fiber matting	• organic fiber matting on substrate layer	• variable hight of substrate above rainwater drainage

combination of extensive green roof and photovoltaic, © ZinCo

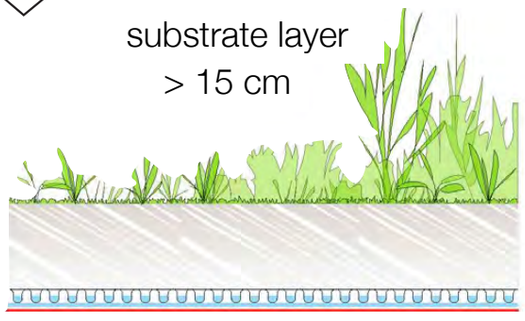
system-typical characteristics

- quick and easy installation
- medium-term surface effect
- durable, robust greening form
- humidity of substrate and water retention layer. Rarely additional irrigation (only in dry periods)
- diversity of plants (perennials – including sedum, grasses, herbs –, copses, mosses
- substitution of weight against suction forces
- water retention up to 30-50 l/m^2 (30-70% N/a)

greening form: intensive green roofs - substrate layer > 15 cm

intensive green roofs

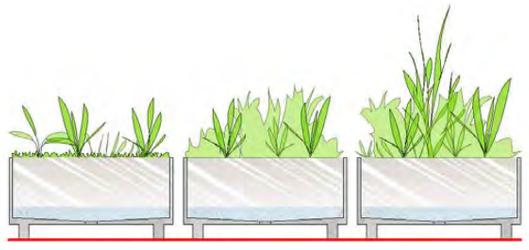
substrate layer
> 15 cm



lawn, perennials (including sedum, grasses, ferns, partly bulbs), shrubs (partly trees - substrate layer >80 cm)

- variable hight of substrate above rainwater drainage

planters

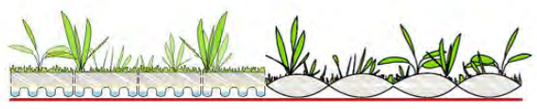


perennials (including grasses, ferns, partly bulbs), shrubs (partly trees), mosses

- substrate in planters with rainwater drainage, possibly with insulation

special forms

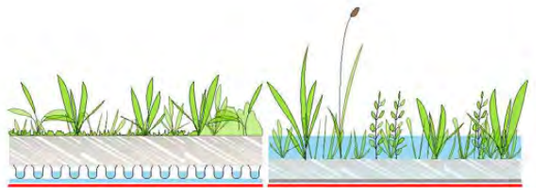
modular systems



perennials (including sedum, grasses, ferns), copses, mosses

- substrate in element-units of basket/gabion, caskets
- Nutrient-containing mat systems
- substrate-supporting gutter systems

retention systems



perennials (including sedum, grasses, herbs), copses, partly mosses

- water-layer above substrate
- water-layer in substrate
- water-layer below substrate

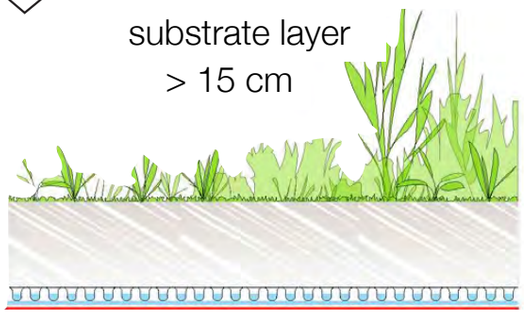
intensive roofgarden (source: OPTIGRÜN)

greening above underground parking - city center Konradinerallee, Wiesbaden

greening form: intensive green roofs - substrate layer > 15 cm

intensive green roofs

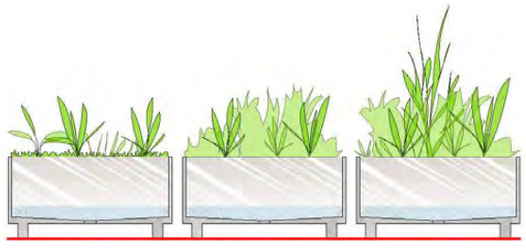
substrate layer
> 15 cm



lawn, perennials (including sedum, grasses, ferns, partly bulbs), shrubs (partly trees - substrate layer >80 cm)

- variable hight of substrate above rainwater drainage

planters



perennials (including grasses, ferns, partly bulbs), shrubs (partly trees), mosses

- substrate in planters with rainwater drainage, possibly with insulation

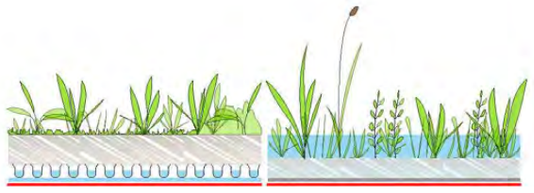
special forms

modular systems

perennials (including sedum, grasses, ferns), copses, mosses

- substrate in element-units of basket/gabion, caskets
- Nutrient-containing mat systems
- substrate-supporting gutter systems

retention systems



perennials (including sedum, grasses, herbs), copses, partly mosses

- water-layer above substrate
- water-layer in substrate
- water-layer below substrate

Urban Farming on the roof, © ZinCo GmbH

Summer meadow, © ZinCo GmbH

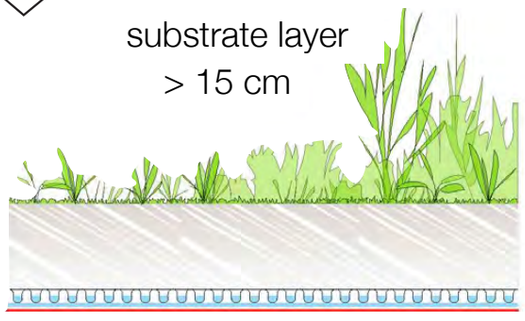
system-typical characteristics

- design as a „garden“ up to „landscape roofs“ possible (please note hight of substrate layer, irrigation system and final weight)
- highest range of plants-diversity (dependent only on location): lawn, perennials (including sedum, grasses, ferns, partly bulbs), shrubs
- tree plantations possible (substrate layer >80 cm)
- „urban farming“ possible
- substitution of weight against suction forces
- best ecological potential, also with regard to flora fauna habitat
- water retention up to 30-160 l/m^2 (60-90% N/a)

greening form: intensive green roofs - planters

intensive green roofs

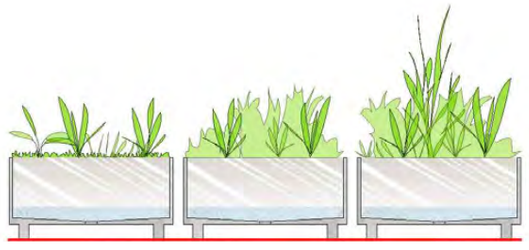
substrate layer
> 15 cm



lawn, perennials (including sedum, grasses, ferns, partly bulbs), shrubs (partly trees - substrate layer >80 cm)

- variable hight of substrate above rainwater drainage

planters

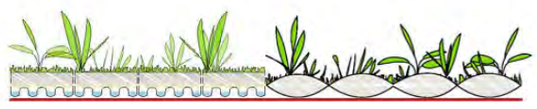


perennials (including grasses, ferns, partly bulbs), shrubs (partly trees), mosses

- substrate in planters with rainwater drainage, possibly with insulation

special forms

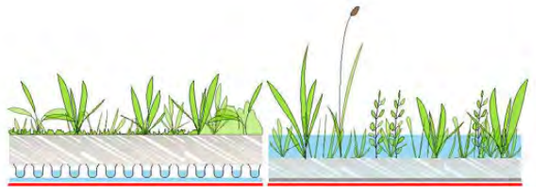
modular systems



perennials (including sedum, grasses, ferns), copses, mosses

- substrate in element-units of basket/gabion, caskets
- Nutrient-containing mat systems
- substrate-supporting gutter systems

retention systems



perennials (including sedum, grasses, herbs), copses, partly mosses

- water-layer above substrate
- water-layer in substrate
- water-layer below substrate

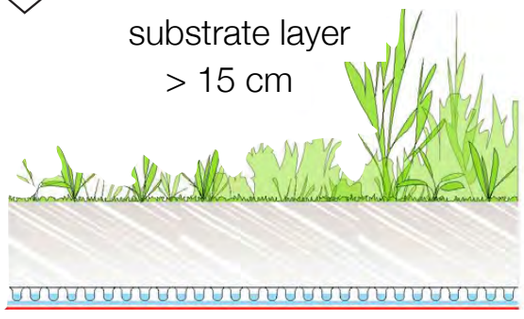
roofgarden Immeuble Spirit of Future, 7 rue du Docteur Lancereaux, Paris

Place de la bourse - Lyon 2ème, Bellecour, Lyon, source: http://s3-media3.ak.yelpcdn.com/bphoto/RkZk7k6bfMKLt4rxLKlQbw/l.jpg

greening form: intensive green roofs - planters

intensive green roofs

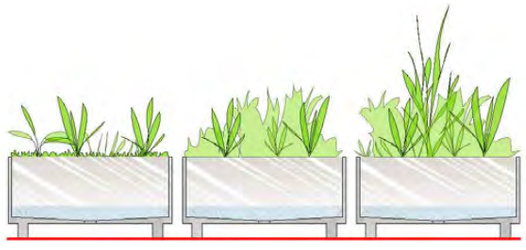
substrate layer
> 15 cm



lawn, perennials (including sedum, grasses, ferns, partly bulbs), shrubs (partly trees - substrate layer >80 cm)

- variable hight of substrate above rainwater drainage

planters



perennials (including grasses, ferns, partly bulbs), shrubs (partly trees), mosses

- substrate in planters with rainwater drainage, possibly with insulation

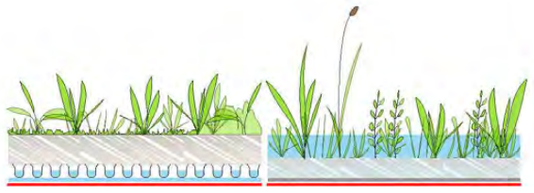
special forms

modular systems

perennials (including sedum, grasses, ferns), copses, mosses

- substrate in element-units of basket/gabion, caskets
- Nutrient-containing mat systems
- substrate-supporting gutter systems

retention systems



perennials (including sedum, grasses, herbs), copses, partly mosses

- water-layer above substrate
- water-layer in substrate
- water-layer below substrate

planters courtyard Württembergische Gemeindeversicherung (WGV)
(photo: © Kunder Landschaftsarchitektur)

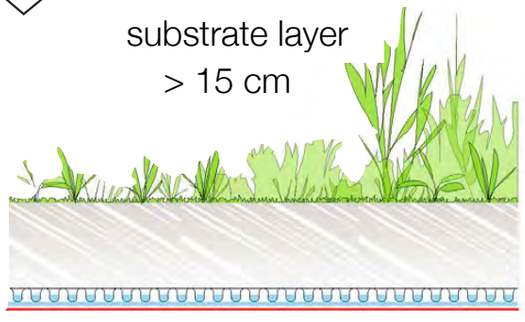
system-typical characteristics

- high range of plants-diversity, because of possible winter storage (suitability of not winter-hardy plants)
- design effect immediately (precultur)
- design changes by moving planters possible (mind the statics)
- interim solution with precultivated planters possible
- intensive roof greening without green roof structures possible (manual/artificial supply necessary)
- „urban farming“ possible

greening form: intensive green roofs - special forms - modular systems

intensive green roofs

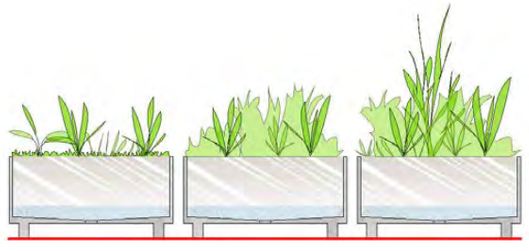
substrate layer
> 15 cm



lawn, perennials (including sedum, grasses, ferns, partly bulbs), shrubs (partly trees - substrate layer >80 cm)

- variable hight of substrate above rainwater drainage

planters



perennials (including grasses, ferns, partly bulbs), shrubs (partly trees), mosses

- substrate in planters with rainwater drainage, possibly with insulation

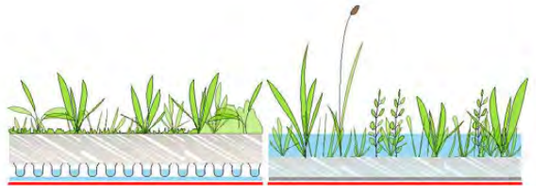
special forms

modular systems

perennials (including sedum, grasses, ferns), copses, mosses

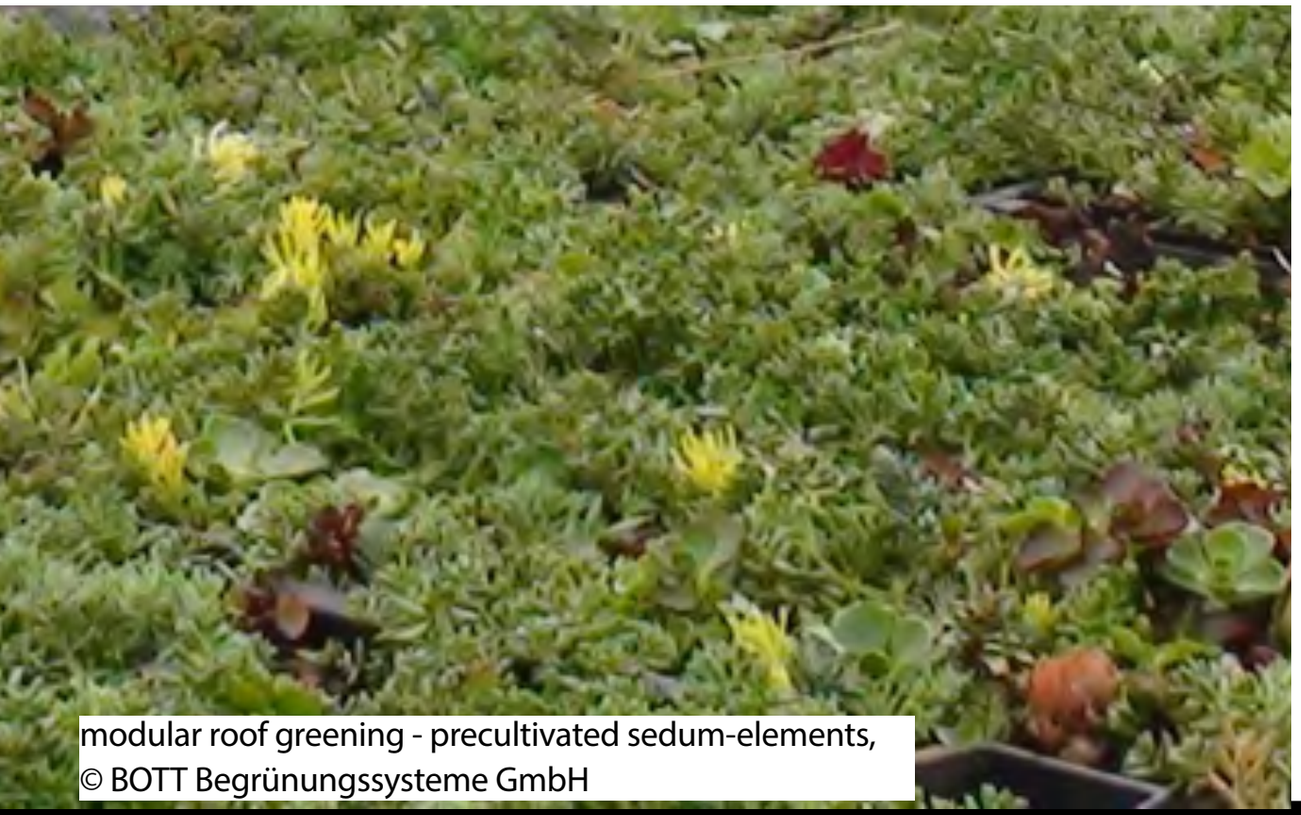
- substrate in element-units of basket/gabion, caskets
- Nutrient-containing mat systems
- substrate-supporting gutter systems

retention systems



perennials (including sedum, grasses, herbs), copses, partly mosses

- water-layer above substrate
- water-layer in substrate
- water-layer below substrate



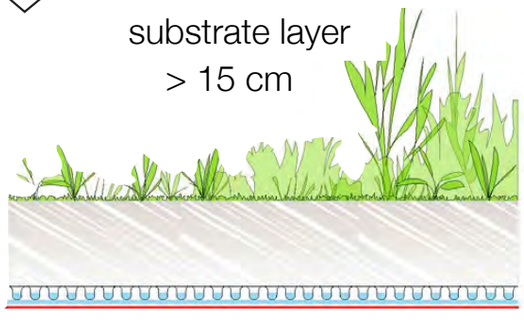
modular roof greening - precultivated sedum-elements, © BOTT Begrünungssysteme GmbH

temporary roof greening - mat-system Earth Cinch, © Freecell

greening form: intensive green roofs - special forms - modular systems

intensive green roofs

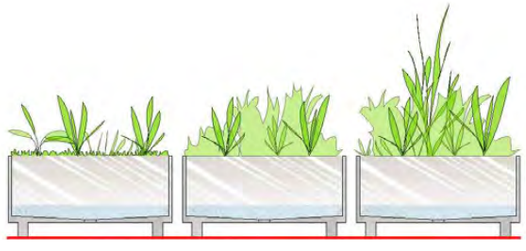
substrate layer
> 15 cm



lawn, perennials (including sedum, grasses, ferns, partly bulbs), shrubs (partly trees - substrate layer >80 cm)

- variable hight of substrate above rainwater drainage

planters



perennials (including grasses, ferns, partly bulbs), shrubs (partly trees), mosses

- substrate in planters with rainwater drainage, possibly with insulation

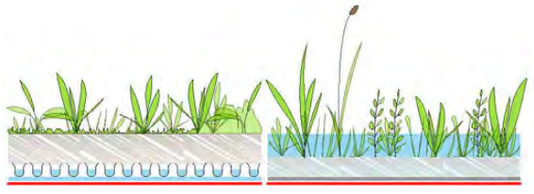
special forms

modular systems

perennials (including sedum, grasses, ferns), copses, mosses

- substrate in element-units of basket/gabion, caskets
- Nutrient-containing mat systems
- substrate-supporting gutter systems

retention systems



perennials (including sedum, grasses, herbs), copses, partly mosses

- water-layer above substrate
- water-layer in substrate
- water-layer below substrate

modular roof greening - precultivated sedum-elements,
© BOTT Begrünungssysteme GmbH

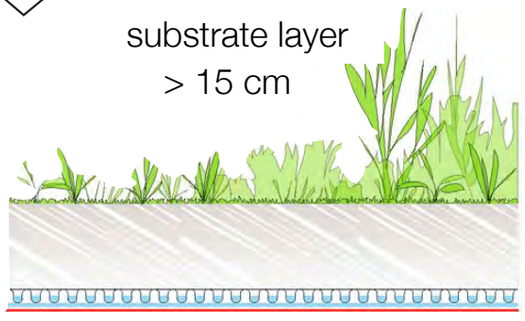
system-typical characteristics

- fast mounting
- precultivation possible (depends on system)
- surface effect short-term (precultivated immediately)
- temporary roof greening (as building container) possible
- green surface easy to extend or change
- humidity of substrate and water retention layer. Rarely additional irrigation (only in dry periods)
- substitution of weight against suction forces (depend on greening system)

greening form: intensive green roofs - special forms - retention systems

intensive green roofs

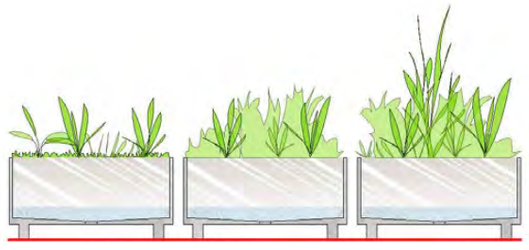
substrate layer
> 15 cm



lawn, perennials (including sedum, grasses, ferns, partly bulbs), shrubs (partly trees - substrate layer >80 cm)

- variable hight of substrate above rainwater drainage

planters

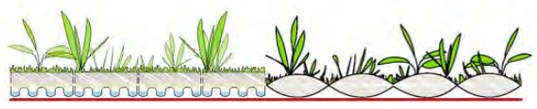


perennials (including grasses, ferns, partly bulbs), shrubs (partly trees), mosses

- substrate in planters with rainwater drainage, possibly with insulation

special forms

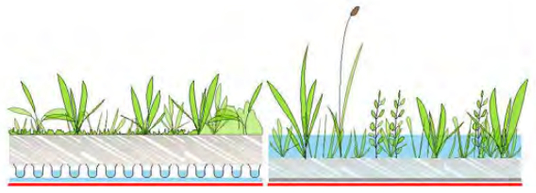
modular systems



perennials (including sedum, grasses, ferns), copses, mosses

- substrate in element-units of basket/gabion, caskets
- Nutrient-containing mat systems
- substrate-supporting gutter systems

retention systems



perennials (including sedum, grasses, herbs), copses, partly mosses

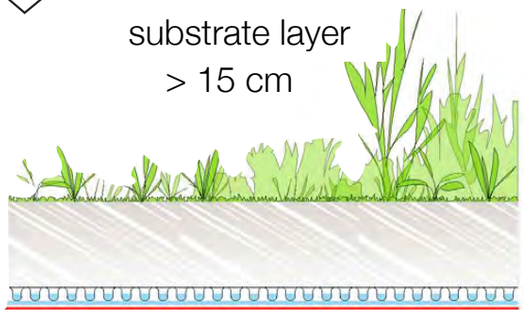
- water-layer above substrate
- water-layer in substrate
- water-layer below substrate

multifunctional green roof - retention roof pressing plant Possmann, Frankfurt/Main, 2012

greening form: intensive green roofs - special forms - retention systems

intensive green roofs

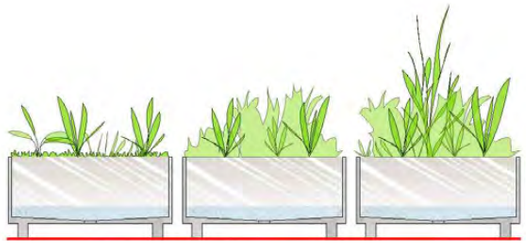
substrate layer
> 15 cm



lawn, perennials (including sedum, grasses, ferns, partly bulbs), shrubs (partly trees - substrate layer >80 cm)

- variable hight of substrate above rainwater drainage

planters



perennials (including grasses, ferns, partly bulbs), shrubs (partly trees), mosses

- substrate in planters with rainwater drainage, possibly with insulation

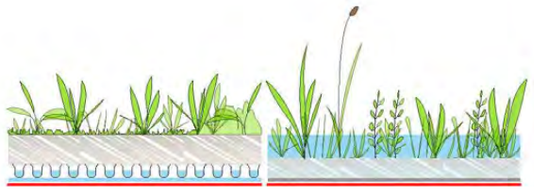
special forms

modular systems

perennials (including sedum, grasses, ferns), copses, mosses

- substrate in element-units of basket/gabion, caskets
- Nutrient-containing mat systems
- substrate-supporting gutter systems

retention systems



perennials (including sedum, grasses, herbs), copses, partly mosses

- water-layer above substrate
- water-layer in substrate
- water-layer below substrate

multifunctional green roof - retention roof pressing plant Possmann, Frankfurt/Main, 2012

system-typical characteristics

- surface effect in short-term (precultivated immediately)
- additional cooling by installing a water-layer above substrate
- direct cooling of production-process possible
- water-purification possible (chemical, grey water)
- expanded flora fauna habitat related to the water biotope (by water and marsh flora)
- water retention 8-50 l/m^2 (50-90 % N/a)

Smart is green (photo: © CHRISTIAN HACKER FOTODESIGN for zillerplus)

Principles of energy-efficient building
Building Greening Energy - Potentials and Interdependencies

The five energy issues

Energy Themes		Passive minimize energy demand	Active Building Technology Optomize energy supply
°C	Heat	keep heat	use heat efficiently
	Cold	avoid over heating	dissipate heat efficiently
	Air	natural ventilation	efficient technical ventilation
	Light	use daylight	optimize artificial light
	Electricity	use electricity efficiently	produce electricity decentrally

The main focus of „energy-efficient building“ is based on two steps

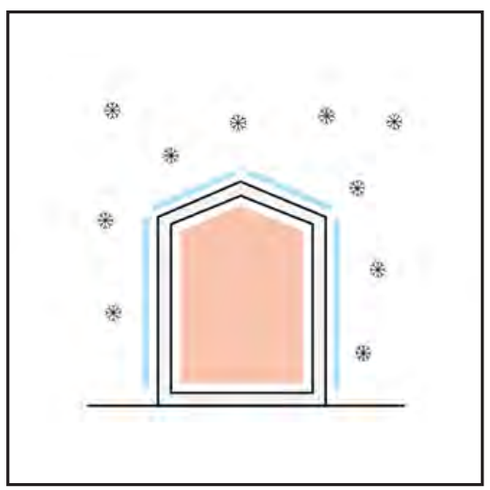
1. minimize energy demands
   - strength the passive strategy
2. develop renewable energy sources
   - optimize active systems

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 83, Abb. 81

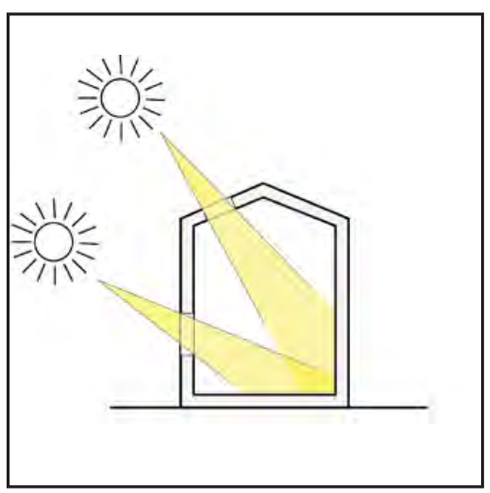
Principles of energy-efficient building

Passive systems and measures

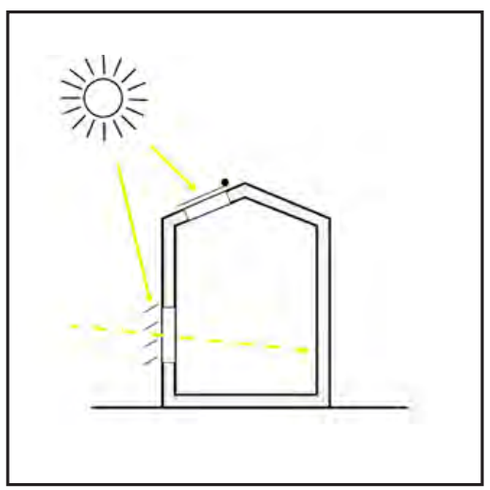
Insulation



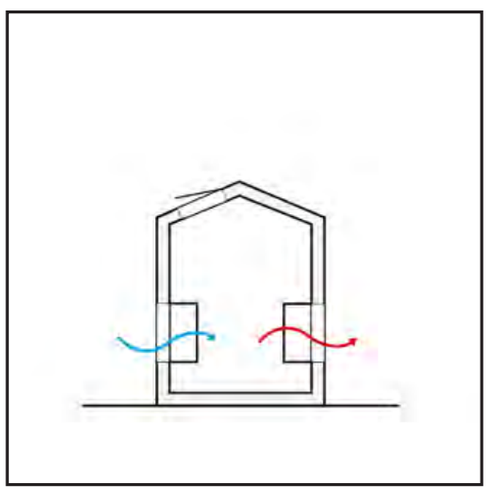
Openings



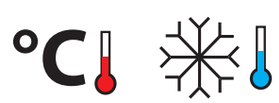
Sun protection

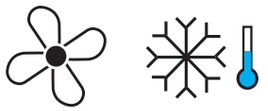


natural ventilation



Energy Themes





The first steps for energy-efficiency > balanced involvement of passive measures

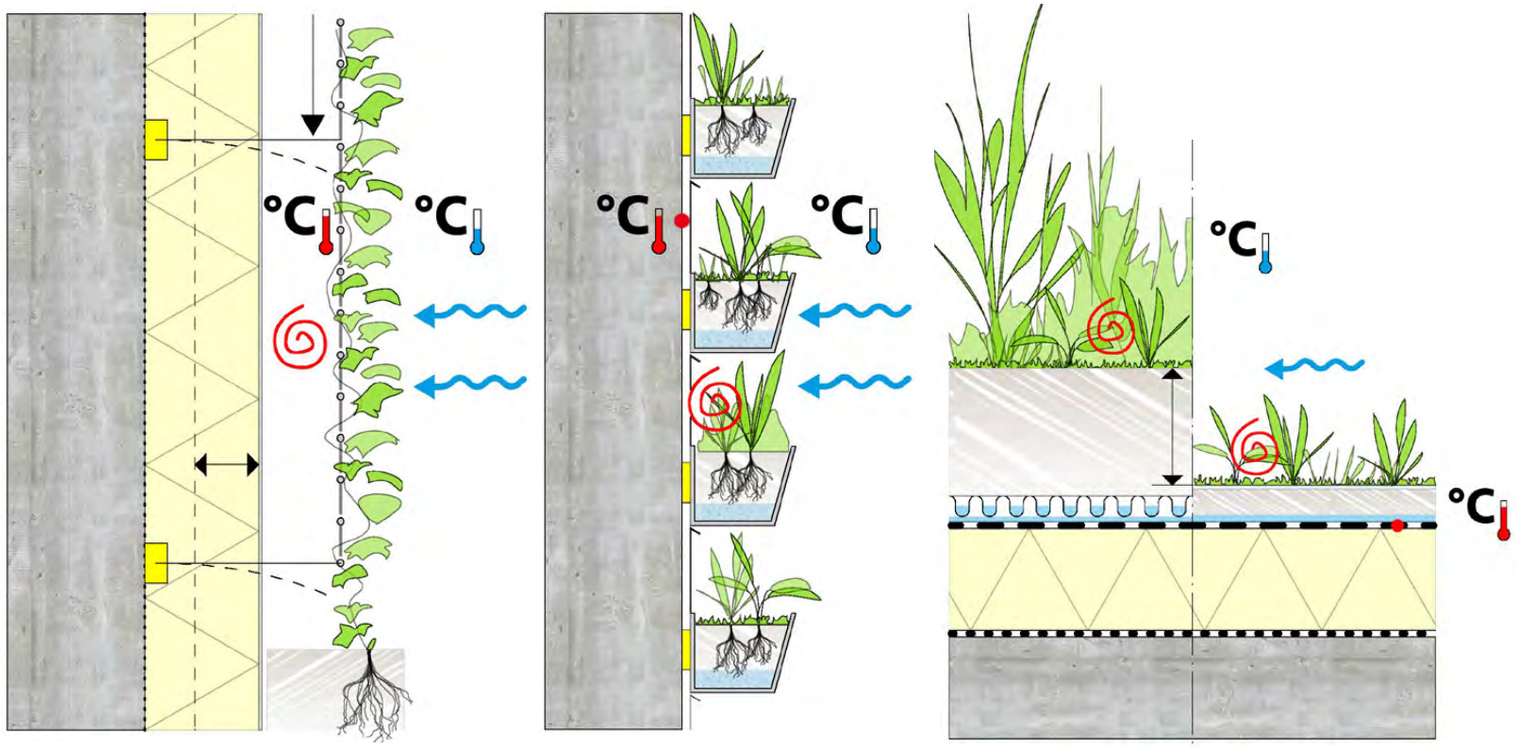
- avoid energy losses/high consumption of heat, cold, ventilation, light and electricity
- optimization of insulation standards
- building openings to the sun, for solar gains
- sun protection by providing shade
- night-time ventilation

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 84

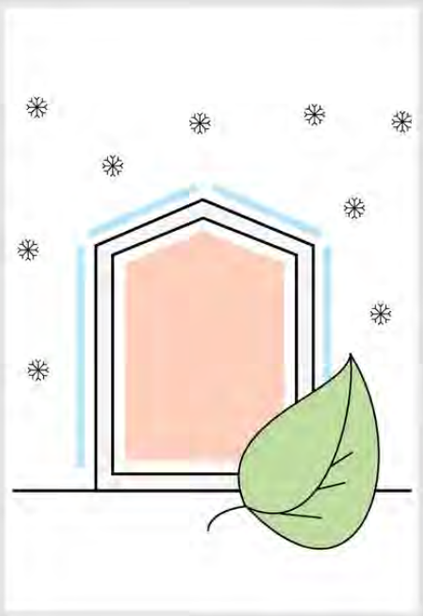
Heat insulation and building vegetation

Relevant factors to support the level of insulation: existing insulation thickness / buffer effect / volume and leaf mass of vegetation / Substrate layer (thickness, material, moisture and also air volume in drainage) / dimensioning of the supports of the planting construction (plant weight, thermal bridge)

MA 48, Wien (photo: Nicole Pfoser 2012)
50% reducing heat loss of non-insulated walls (GrünStadtKlima)



ground based system / facade based system, facade greening with linear planters; intensive / extensive green roof (© Nicole Pfoser, 2013)



Meeting demands

°C

Synergy

- insulation and buffer effect
- reducing thermal transfer
- contributes to heat protection in summer and winter

Energetic efficiency

- 10-15 cm of extensive green roof cover and increase the roof's insulation effect about 3 to10% [13]
- positive effect on the facade [3; 14; 23]
- Insulation effect

depends on: density and depth of vegetation, substrate, humidity, existing insulation standard.

Planting systems

- ground-based facade greening, dense and with high leaf volume
- wall-based facade greening (modular and flat)
- green roofs with high volume of substrate (extensive or intensive)
- preferably with ever-green plants

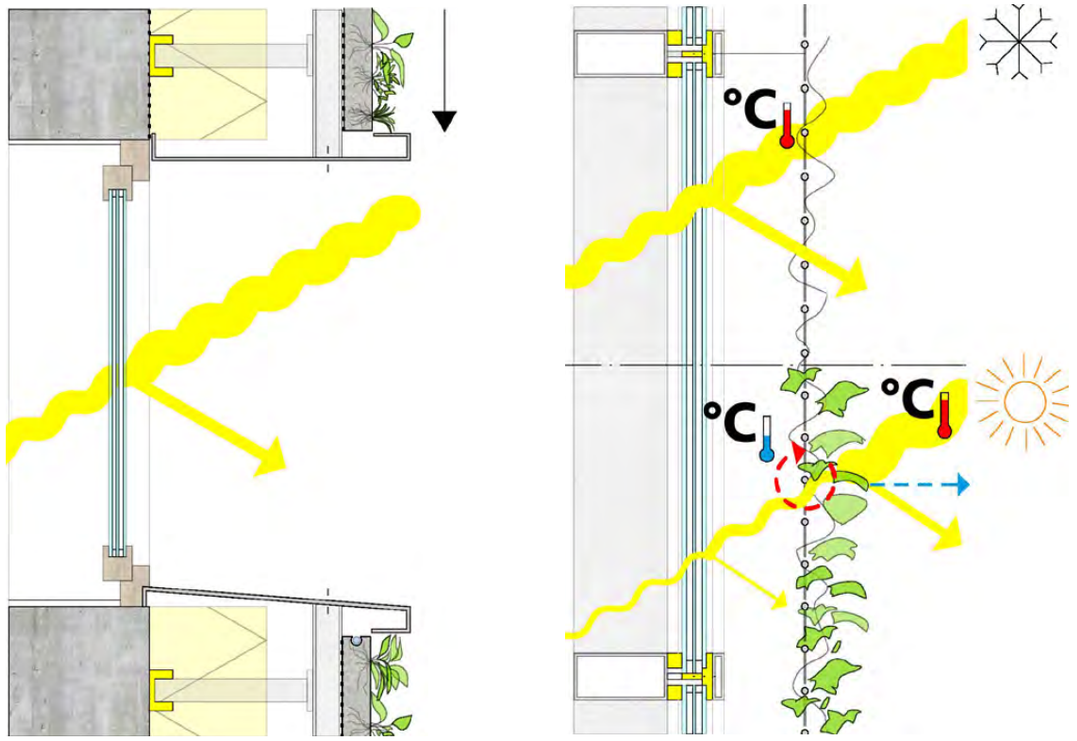
Error prevention

- does not account for thermal insulation certificates due to changing huminity
- avoid thermal bridges by underlying construction
- thermal insulation (WDVS) is not suitable for self-clinging plants

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 104-107

Openings: Solar gains and building vegetation

PTH St. Georgen, FFM (photo: Nicole Pfoser 2013)



Facade greening taking account into solar gains; left: facade based, right: ground based - using deciduous species (© Nicole Pfoser, 2013)

Meeting demands

°C

Competition

- shading of windows is not desirable in winter time

Energetic efficiency

- shading may reduce solar heating effects during heating period

Planting systems

This concerns primarily facade greening:

- use deciduous plants in front of permeable surfaces (windows, transparent thermal insulation (TTI), air collecting facades)
- Openings need to be kept free if evergreen plants are used

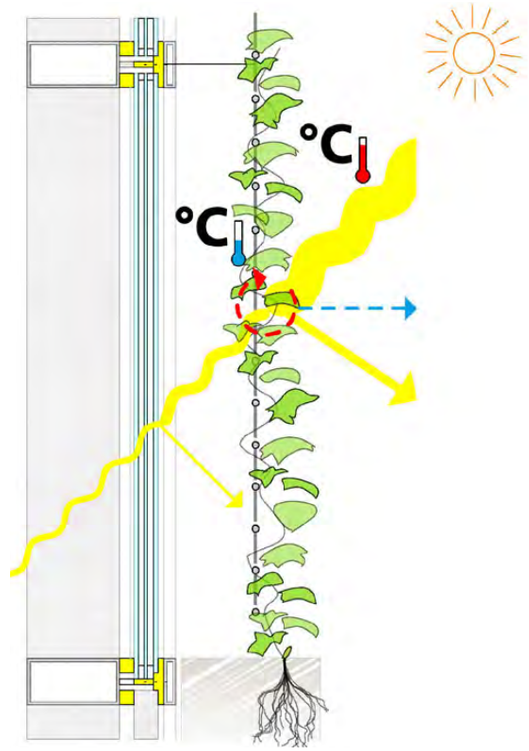
Error prevention

- set constructive limits for the plants
- adequate maintenance

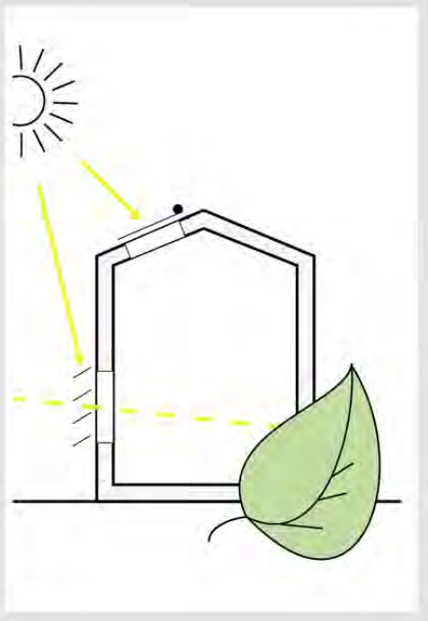
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 108-109

Sun protection and building vegetation

Swiss Re headquaters, Unterföhring, BRT Architects, © May Landschaftsbau



Vertical solar protection of deciduous trellis systems and their physical effects: reflection, absorption, evaporation and transmission (© Nicole Pfoser, 2013)



Meeting demands

Synergy
- cooling effect of shading and evapotranspiration
- replacement of constructive shading systems

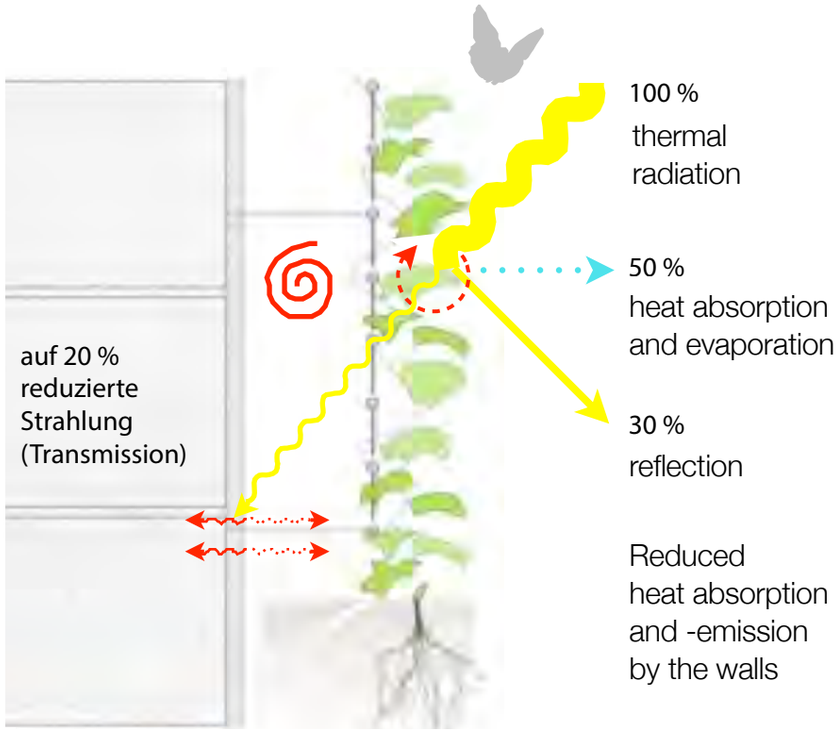
Energetic efficiency
- depends on plant type
- 85-95 % shading possible through trellis plants [5; 25]
- 40-80 % of solar radiation can be reflected and absorbed [22]
- 20-40 % transpiration [22]
- Reduction factor of trellis plants is: (Fc) 0,62-0,3 [4]

Planting systems
- trellis plants (deciduous)
- plants in single or linear pots (deciduous)

Error prevention
- distance, to avoid heat accumulation
- consider the weight of plants (structure/ substructure)
- avoid strong climbing plants
- strategic planning: allow view

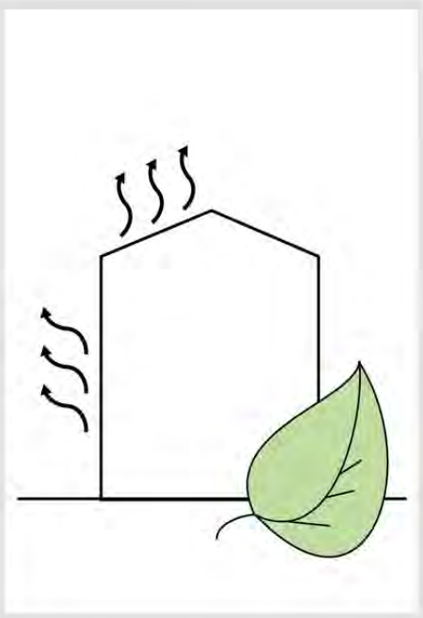
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 109-111

Adiabatic cooling and building vegetation



Cooling caused by evaporation, reduced thermal radiation and reflection - values: KIESSL/RATH/ GERTIS 1989 (© Nicole Pfoser 3/2013)

MA 48, Wien - 850 m² greened facade - unto 15° C reduce of surface temperature in summer
- Cooling performance hot summer day = 75 air-conditioners with 3000 Watts, 8 h operation
- Evaporation performance like 5 100 years old fagus (values: GrünStadtKlima)



Meeting demands

Synergy
- cooling effect of evapotranspiration
- reduction of surface heat

Energetic efficiency
- Transformation of 58 % of solar radiation balance into evaporation cooling [25]
- irrigation increases this effect
- reduction of extreme heat [1; 12; 14; 21]
- reduction of surface temperature 2–10 K (compared to natural stone facade) [21]
- strong impact on building and close vicinity

Planting systems
- roof and facade systems
- deciduous and ever-green vegetation
- evergreen plants achieve better rates of evaporation

Error prevention
- Evapotranspiration will increase the relative air humidity (unfavourable indoors on hot days)

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 112-114

Natural ventilation and building vegetation

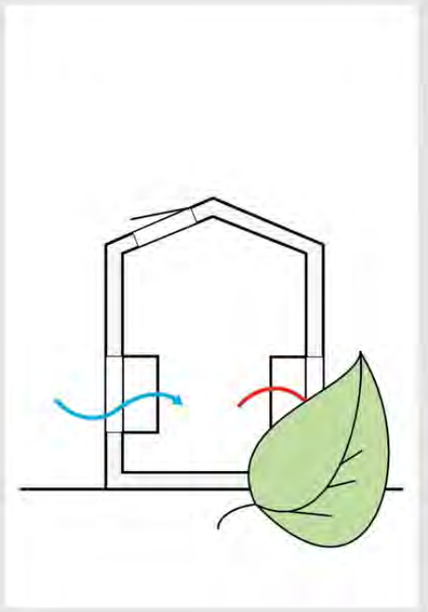
Roof gardens in Eindhoven
photo: Nicole Pfoser 2013)

Facade duplex Ohlystraße, Darmstadt
(photo: Nicole Pfoser 2011)

Sommerliche Kühlwirkung an Bauteiloberflächen am Beispiel von Selbstklimmern:
(Messungen im August 2011 an zwei verschiedenen Doppelhaushälften)

Temperatur	
1 Wandoberfläche (weiß verputzt) Hellbezugswert 83	36°C
2 cm vor Begrünung	28°C
Temperaturdifferenz	8 K
2 Wandoberfläche (dunkel verputzt) Hellbezugswert 64	52°C
2 cm vor Begrünung	33°C
Temperaturdifferenz	19 K

Measures on the facade of an duplex, with and without facade greening to quantify the cooling effect of climbing plants (values: Nicole Pfoser 2011)



Meeting demands

Synergy
- cooling of building surfaces (summer)
- Reducing temperature through natural ventilation in summer/ supporting ventilation at night
- dust filtration
- noise reduction [18; 28]

Energetic efficiency
- reduction of surface temperature 2–10 K (compared to natural stone facade) [21]
- air humidification: 20-40 % increas in summer, 2-8 % increase in winter) [22]

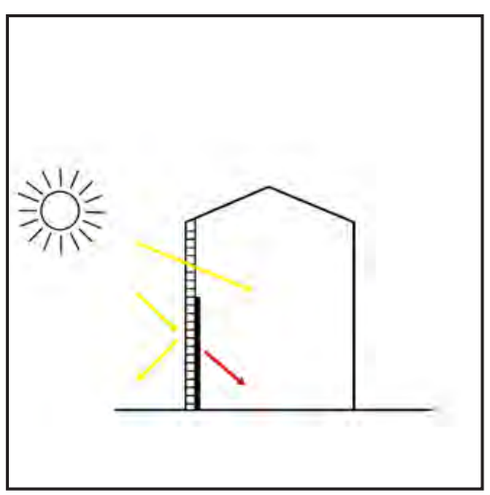
Planting systems
- roof and facade systems
- deciduous and ever green vegetation

Error prevention
- Entry of pollen possible
- avoide plants provoking allergies
- avoid development of high air humidity on warm/humid day

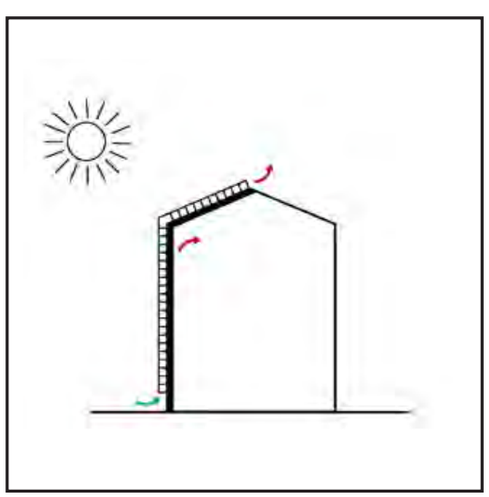
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 115-117

Partially active systems and measures

TTI



Air collectors



Energy Themes

°C ☀ °C

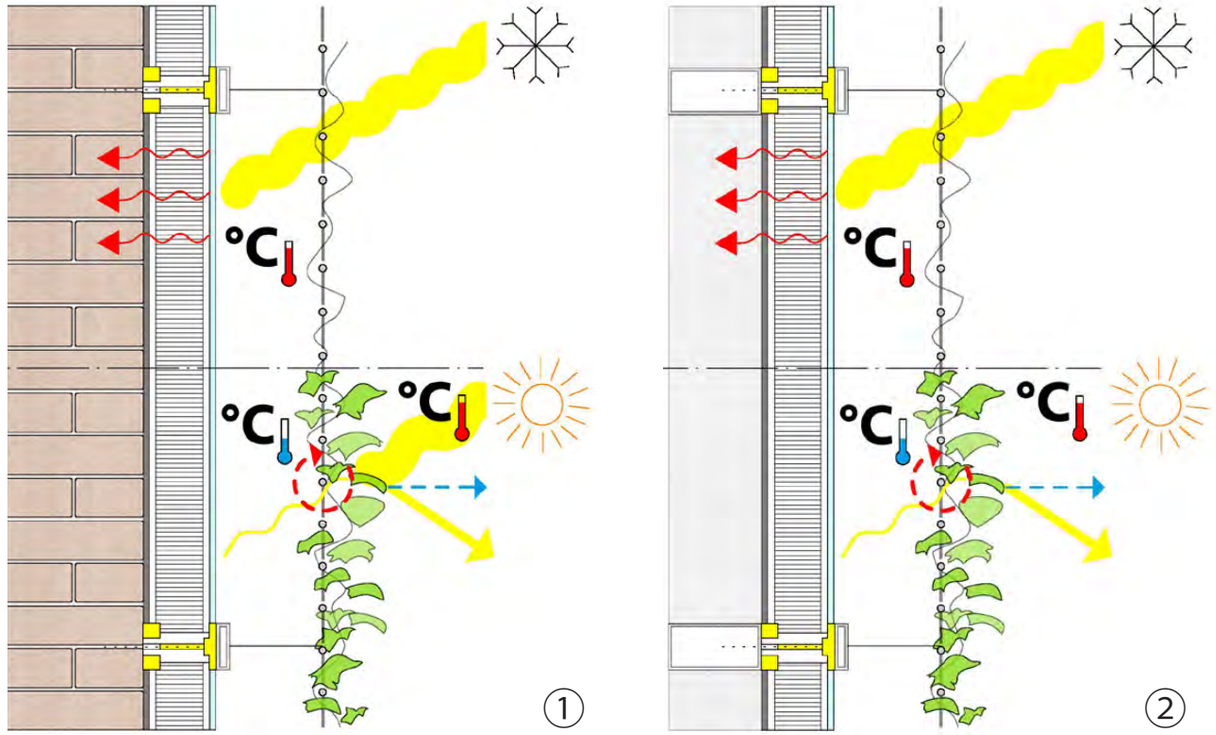
Dynamic insulation systems, using solar radiation to achieve an insulation effect (dynamic insulation), or to tempre the supply air to save fossil heat energy

- Transparent thermal insulation (TTI)
- Air collectors

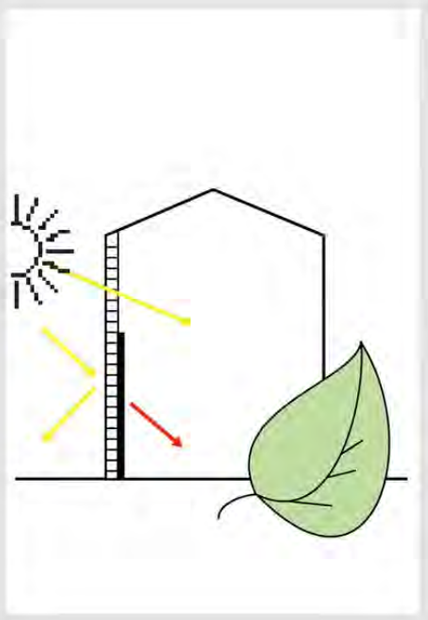
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 89

Transparent thermal insulation (TTI) and building vegetation

TTI-facade,
BERU Electronics GmbH,
Bretten (wacotech.de)



(1) Climbers in front of TTI and massiv, carrying construction and (2) as transparent curtain facade element. Schematic figure as well as functional principles of a TTI-facade in combination with deciduous building vegetation in summer and winter. (© Nicole Pfoser, 2013)



Meeting demands

°C

Synergy

- shading and adiabate cooling of absorbers
- avoid overheating of facade and indoor areas in summer

Energetic efficiency

- 85-95 % shading possible through trellis plants [5; 25]
- Reduction of maximum absorber temperatures up to 50% possible [14]
- shading effects depends on the planting system

Planting systems

- Facade greening with deciduous trellis plants

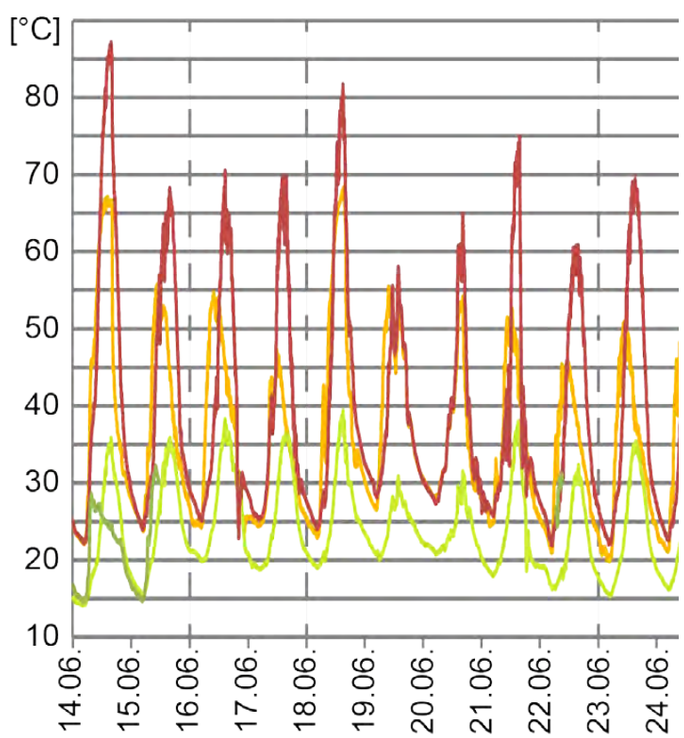
Error prevention

- no shading in winter
- enable backside ventilation
- underlying construction needs to be conceived without thermal bridges
- consider the play of light and shadow in the context of translucent facades

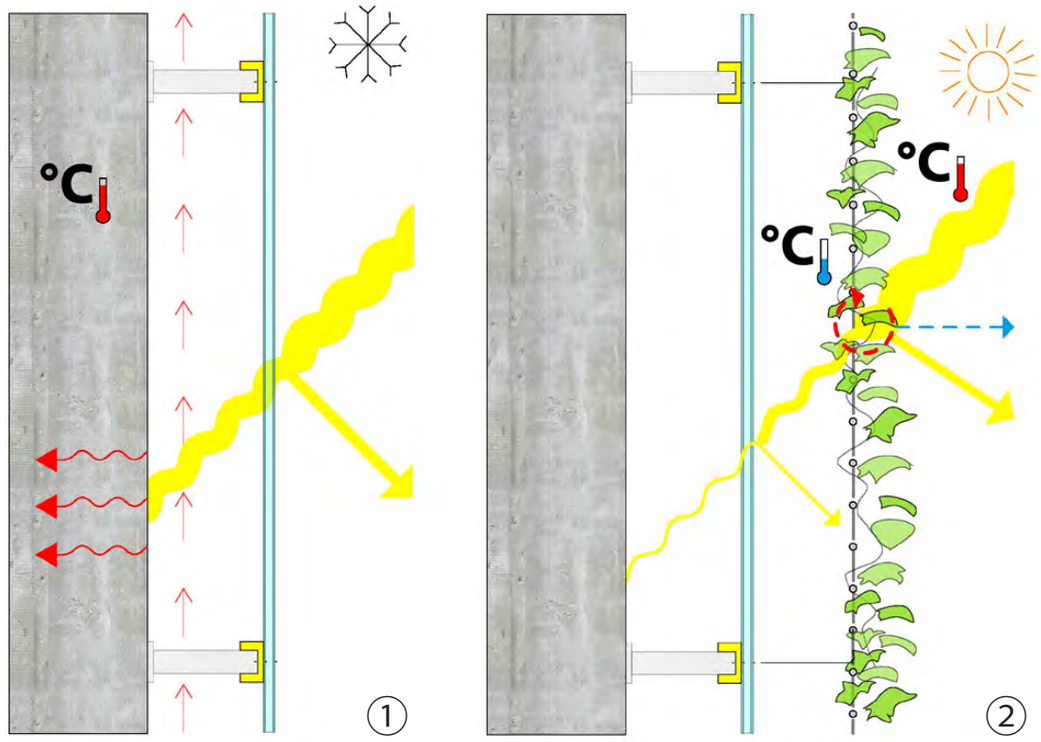
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 118-119

Air collectors and building vegetation

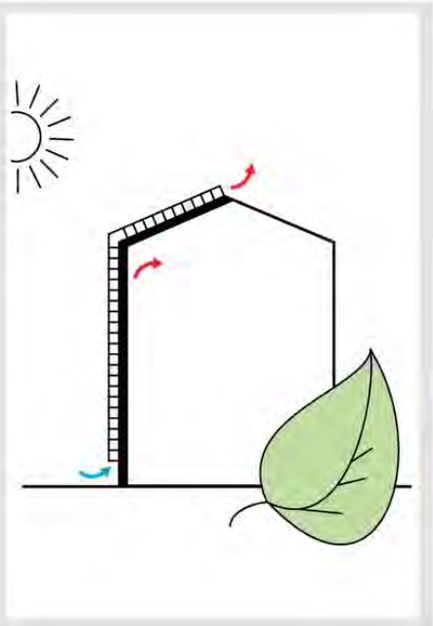
Patchworkhouse, Müllheim
(Pfeifer Kuhn Architects
(photo: Fotostudio Ruedi Walti, Basel)



Monitoring results Patchworkhouse, air interspace of the collector 06/2012 (Prof. Dr. Angèle Tersluisen)



Air collectors without/with trellis and climbers.
Schematic figure of construction as well as functional principles in winter and summer (© Nicole Pfoser, 2013)



Meeting demands

°C

Synergy

- shading and adiabate cooling of absorbers
- avoid overheating of facade and indoor areas in summer

Energetic efficiency

- 85-95 % shading possible through trellis plants [5; 25]
- temperature reduction up to 2-5 K possible [21]
- depends on the planting system

Planting systems

- Facade greening with deciduous trellis plants

Error prevention

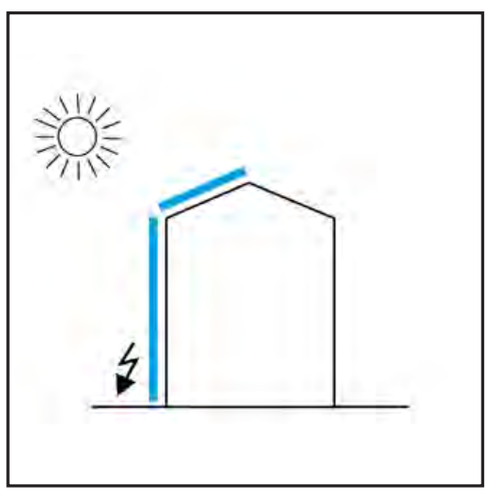
- no shading in winter
- enable backside ventilation
- underlying construction needs to be conceived without thermal bridges
- consider the play of light and shadow in the context of translucent facades

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 120-121

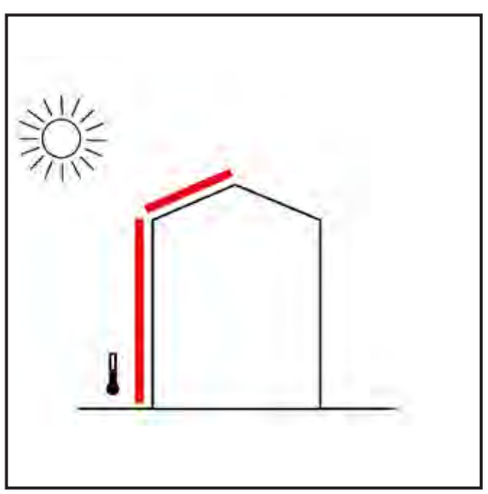
Principles of energy-efficient building

Active systems and measures

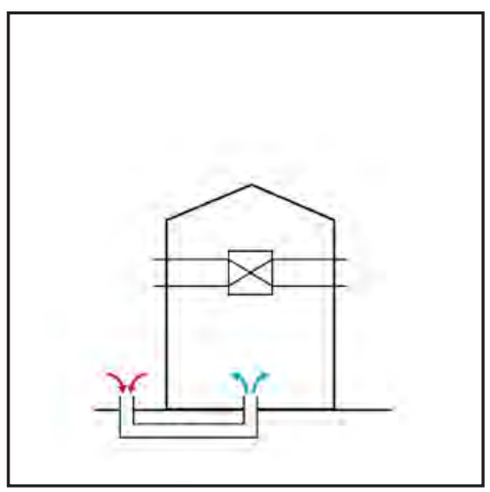
Photovoltaic



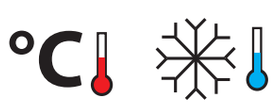
Solar thermal energy



Controlled ventilation



Energy Themes

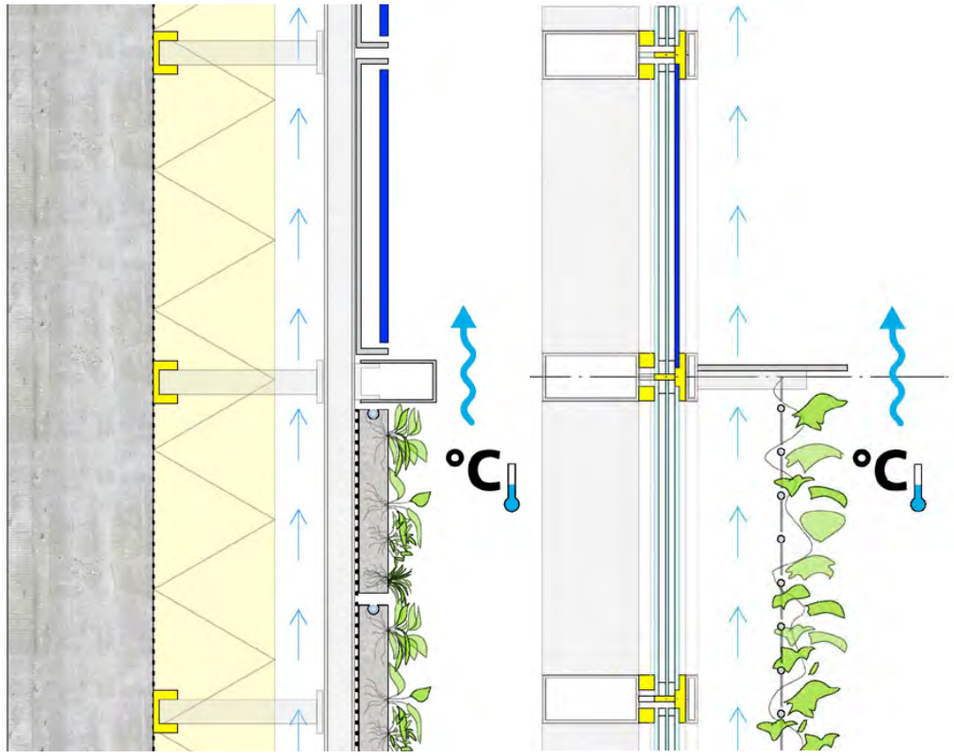


Saving fossile energy for electricity oder heating with solar-aktive energy-producing systems:

- Photovoltaic
- Solar thermal energy
- Controlled ventilation (heat recovery, reduce heat loss, condition – cooling and warming – the air if necessary)

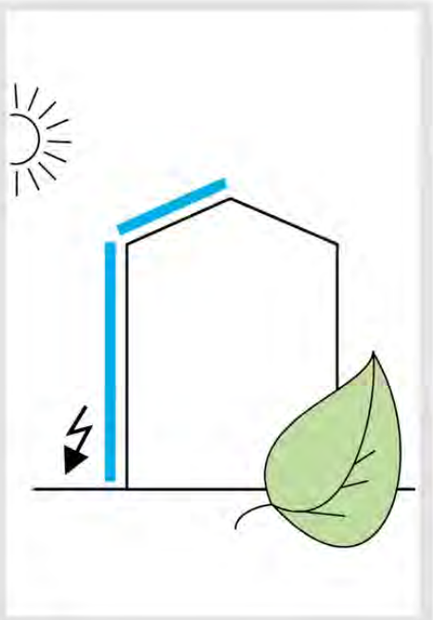
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 93

Photovoltaic and building vegetation



left: photovoltaik on a green roof (source: ZinCo GmbH)
right: Smart is green(photo: © CHRISTIAN HACKER FOTODESIGN for zillerplus)

Constructive combination of PV and facade-/roof-greening (back-ventilated curtain facade with solar-panel facade based greening-system / Curtain-facade with integrated solar-modul and ground based greening (climbers) / extensive roof greening (© Nicole Pfoser, 2013)



Meeting demands

Synergy
- reduction of surface temperatures through adiabate colling (efficiency increas)
- irrigation increases this effect
- substrate replaces ballast (roof-mounted PV-installation)

Energetic efficiency
- efficiency increase of roof-mounted photovoltaic installation about 4-5 % [27]

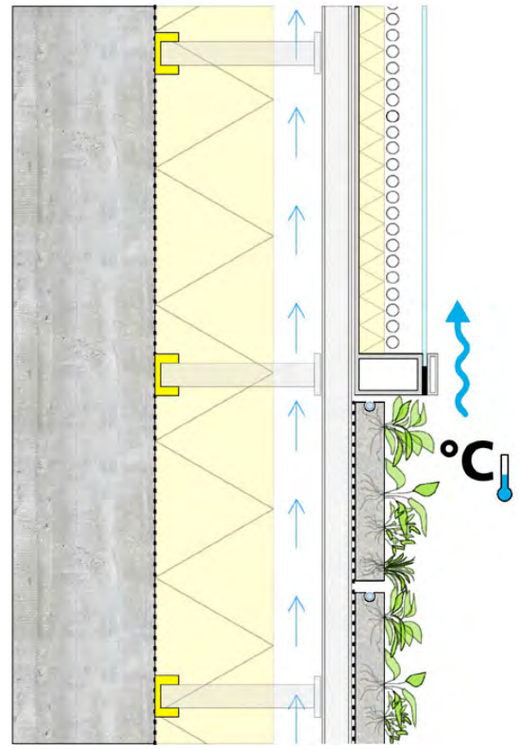
Planting systems
- wall-based facade greening (modular/flat)
- extensive roof greening (moss, shallow-rooting shrubs and small woody plants)

Error prevention
- avoid shading
- avoid permanent pollution

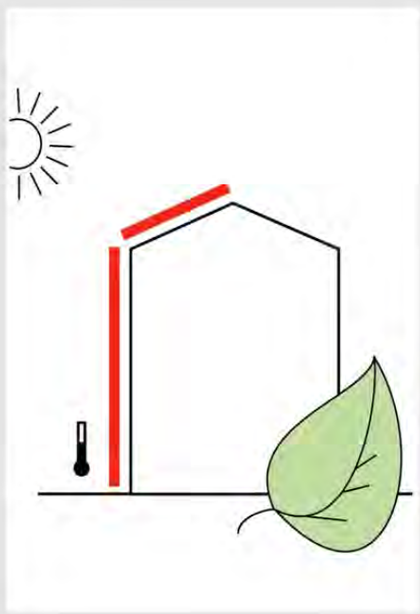
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 123-125

Solar thermal energy and building vegetation

left: collectors in combination with a green roof, south orientated, Passivhaussiedlung Hannover Kronsberg (Feist, W. et al. 2001) / right: Sustainable redevelopment with solar thermal energy (photo: Markus Bachmann, Samba), www.allianz-pro-nachhaltigkeit.de



Constructive combination with building vegetation: back-ventilated curtain facade with a flat-plate collector and a facade based greening-system; (© Nicole Pfoser, 2013)



Meeting demands

°C

Competition

- Efficiency reducation possible because of evapotranspiration cooling and shading

Energetic impact

- Efficiency reducation through adiabate cooling is relatively low: balanced by heat oversupply in summer

Planting systems

- wall-based facade greening (modular/flat)
- extensive roof greening (moss, shallow-rooting shrubs and small woody plants)

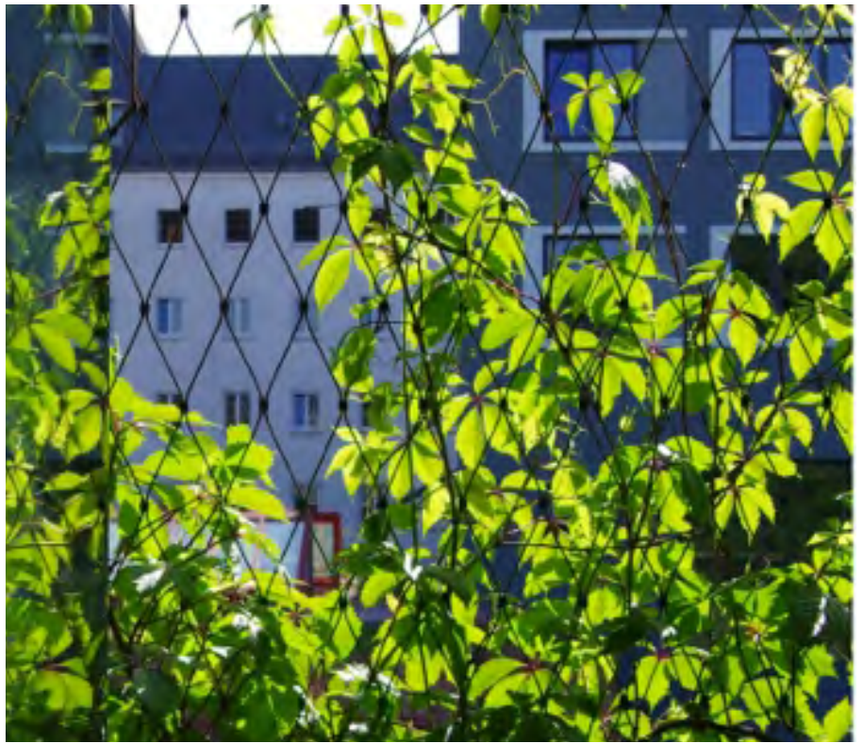
Error prevention

- avoid shawing
- keep distance to distribution and collector lines because of high temperatures

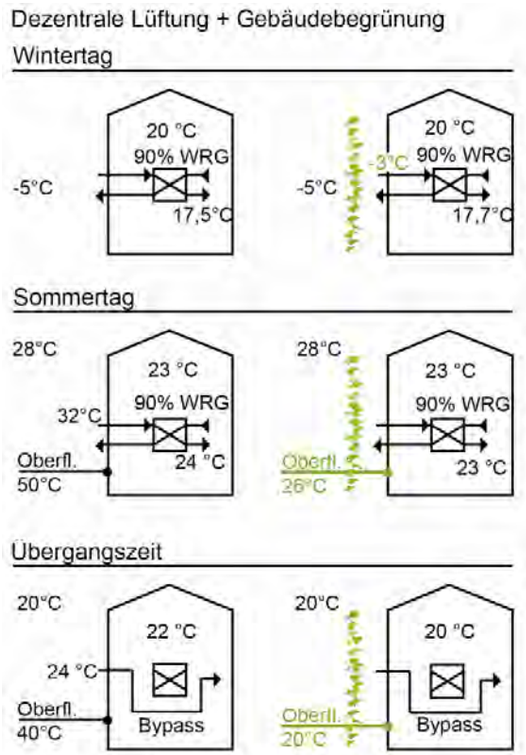
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 126-127

Controlled ventilation and building vegetation

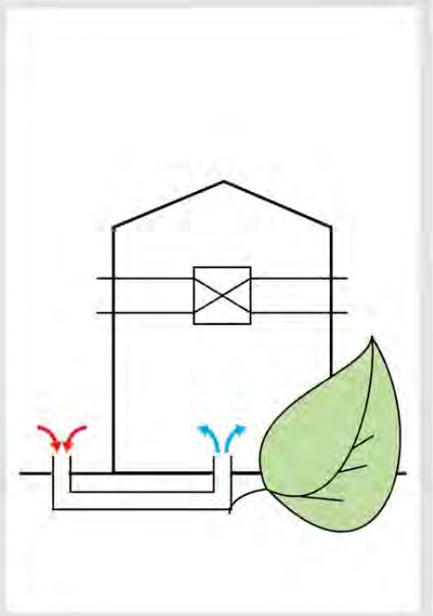
Magasin BHV Homme
(photo: Nicole Pfoser 2011)



PTH St. Georgen, FFM
(photo: Nicole Pfoser 2013)



Decentralized air conditioning with heat recovery, faced with plants
TU Darmstadt, FGee/FG e+f)



Meeting demands

Synergie
- cooling effect through adiabate cooling und shading
- cooler surfaces in summer
- reduction of extreme temperaturs
- dust filtration through greening

Energetic efficiency
- Temperature differences 2-10 K (natural stone facade/summer/ decentral system)
- Temperature difference up to 20 K (compared to bitumen cover/ summer/decentral)
- air humidity (20-40 % higher relative air humidity)

Planting systems
- all facades/roof greening systems

Error prevention
- avoid input of high air humidity on hot days
- keep 1 meter distance to fresh air suction intake
- use filters to avoid intake of pollen/dust/ bacteria

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 128-129

Rainwater utilization and building vegetation

MFO-Park, Zürich/Neu-Oerlikon (photo: Jakob AG 2012)

Green roof for retention and process cooling Kelterei Possmann FFM (photo: Nicole Pfoser 2012)

Meeting demands

Synergy

- cooling effect in summer (adiabate cooling)
- cooling of rain water (treatment for technical cooling functions)
- rain water purification (clearing gray water)
- water retention

Energetic efficiency

- only a few cases show evidence so far
- temerature reduction 2,5-10 K
- water retention: 60-99 % of rain fall [11; 15; 17] (depending on substrates)
- water retention up to 50 l/m²

Planting systems

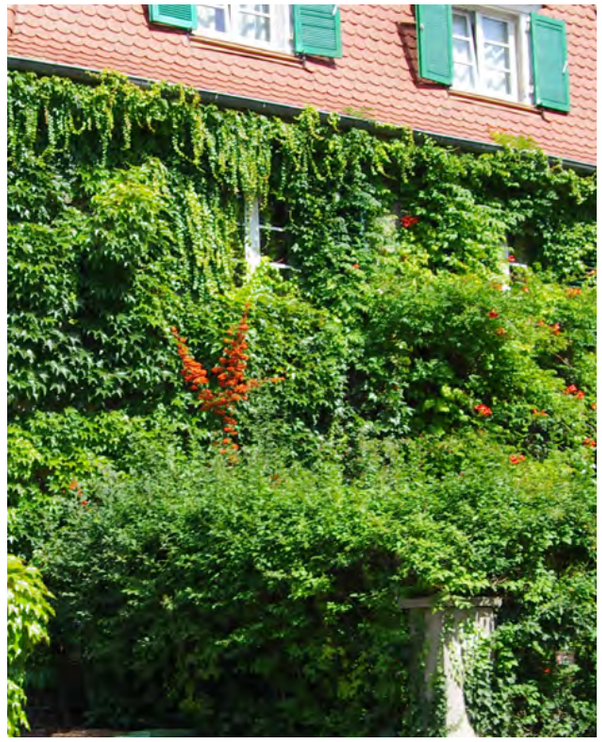
- green roofs: humid roof(regulated water layer underneath/inside or above the substrate)
- roofs as retention area with reposition plants

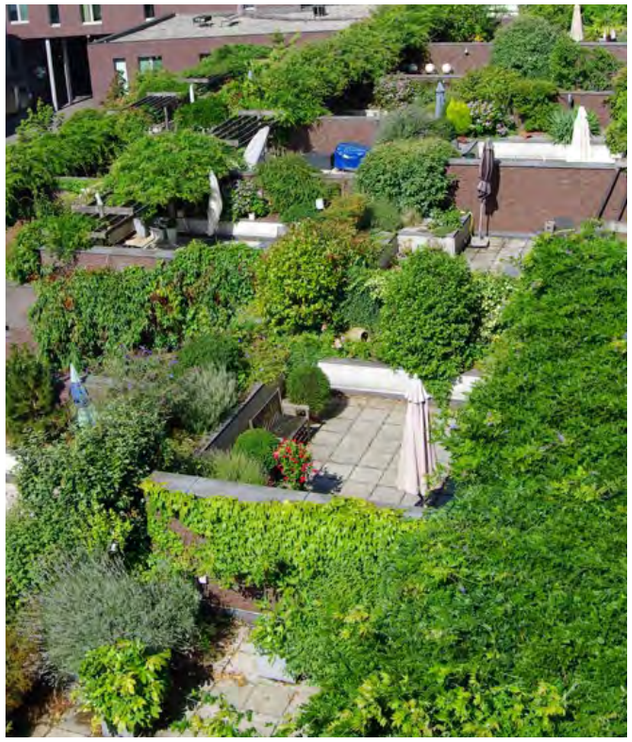
Error prevention

- secure sealing of the roof
- inverted roofs and roofs with subsequent insulation are not suitable

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 130-131

Utilization of biomass and building vegetation



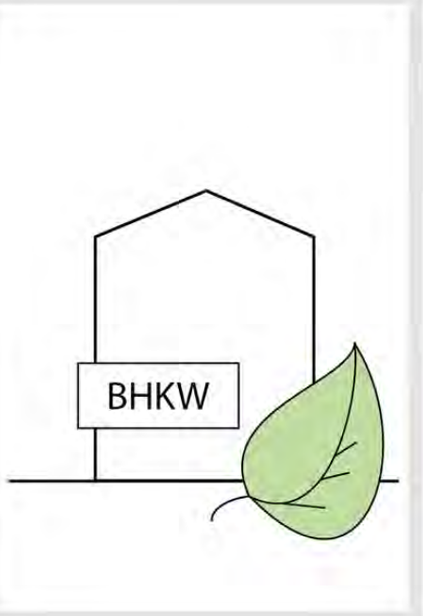


left: facade-greening, Jahnstraße Darmstadt. Maintenance and autumn leaves are able to increase the biomass potential.
(photo: Nicole Pfoser 2011)

middle: intensive green roof, roofgarden Medina Complex, Eindhoven.
(photo: Nicole Pfoser 2013)

right: Fuel briquettes made of leaves, source: http://www.riela.de/html/Aktuell/riela_bibb_1.html

Approximation of a value of energetic biomass potentials as the result of maintenance of roof- and facade greening trough a comparative observation of urban biomass potentials (considering source)



Meeting demands

°C

Synergie
- increasing the amount of biomass in the urban area
- clippings can be used for biogas or other types of energy production (i.e. fuel briquettes made of leaves)

Energetic efficiency
- extensive green roofs: 13 MWh/ha a
- intensive green roofs: 4-23 MWh/ha a
- ground based facade greening: 5-9 MWh/ha a
- wall-based facade greening 13 MWh/ha a
- Fall of leaves: ca. 23 MWh/ha a [3]

Source: Sieber, S. acc. to [8]

Planting systems
- shrubs and woody plants
- deciduous plants

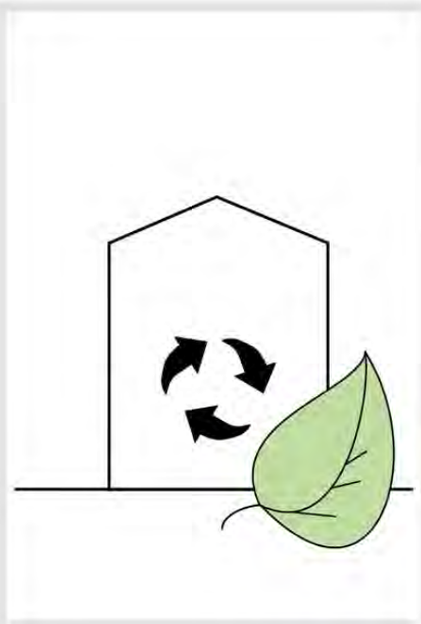
Error prevention
- humid clippings/foliage may cause slagging

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 132-135

Ecology, economy and building vegetation

Viilla Pia (photo: © nonconform architektur vor ort)

Dublin's rooftop Urban Farm (photo: http://jardindesign.org/2013/09/07/grassroots-revolution/)



Meeting demands
- ecological construction materials
- carbon sequestration,
- oxygen production
- Increasing the lifetime of a building: less temperature extremes, mechanical protection, protection from solar radiation, reduced roof humidity [25]
- suppression of fine dust

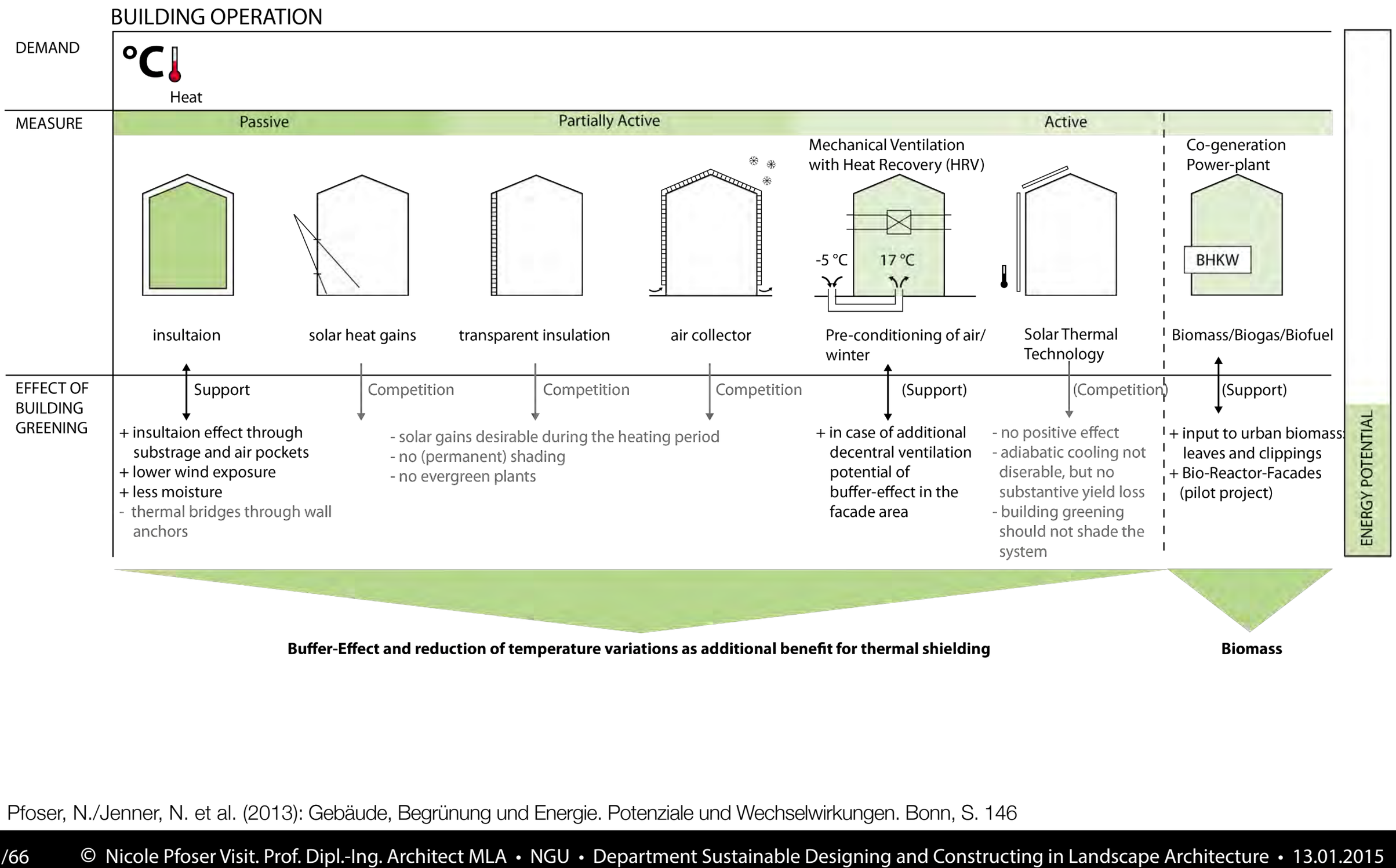
Energetic efficiency
carbon sequestration depends on plan types, surface and climate
- green roo: 0,8 kg CO_2/m² surface mass after three years /facade (20 cm of plant material): 2,3 kgCO_2/m²a [6; 9]
- increasing of the lifetime of building materials
- ecobalance is not considered

Planting systems
- applies to all ofthem
- carbon sequestration needs big amount of biomass

Error prevention
- sufficient maintenance to avoid damages

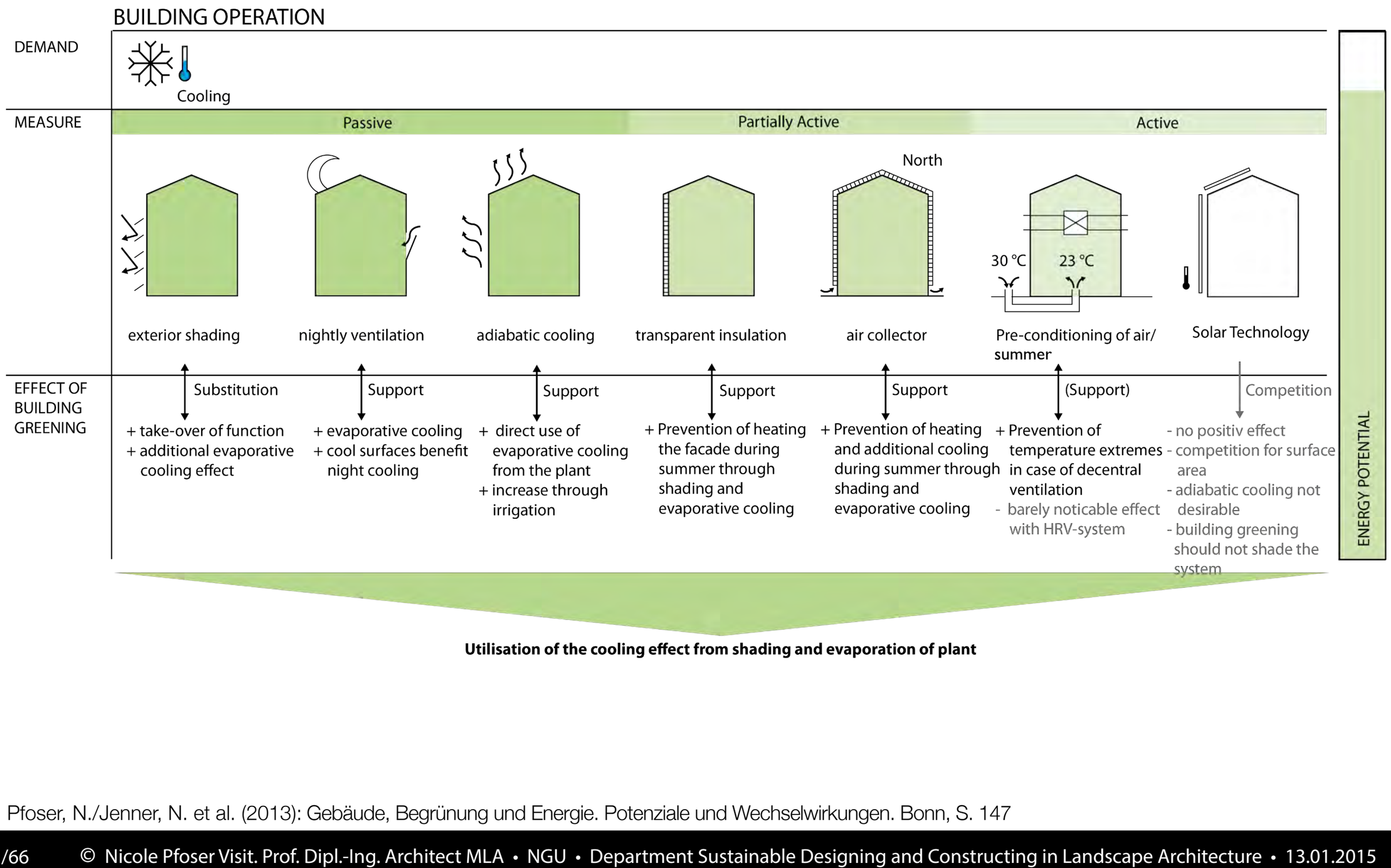
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 136-145

Measures for fulfillment of heating demand.
Synergies and competitions in combination with greening of buildings.



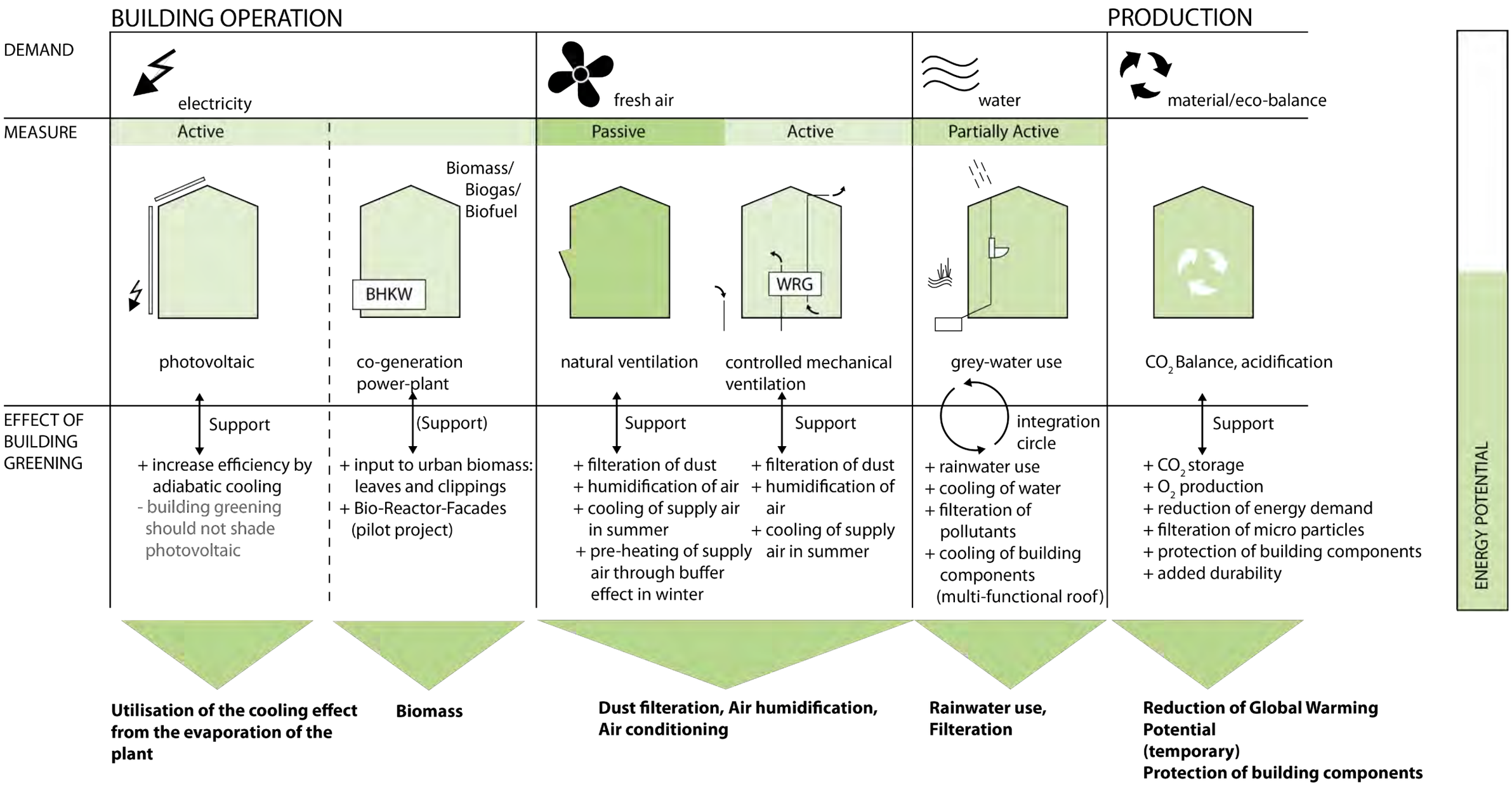
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 146

Measures for fulfillment of cooling demand.
Synergies and competitions in combination with greening of buildings.



Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 147

Measures to fulfill the demands of electricity, fresh air and water in the operation of buildings and eco-balance aspects of material production.

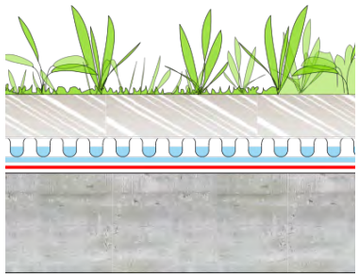
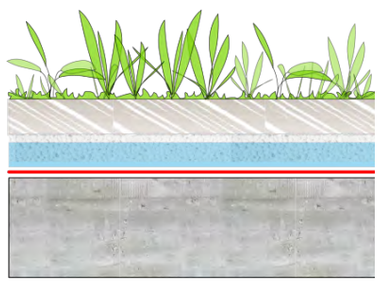
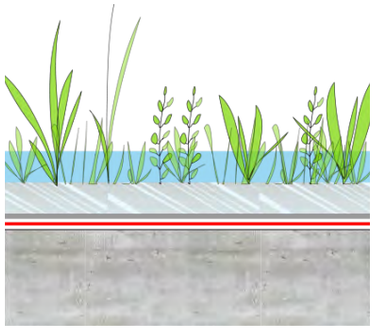


Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 147

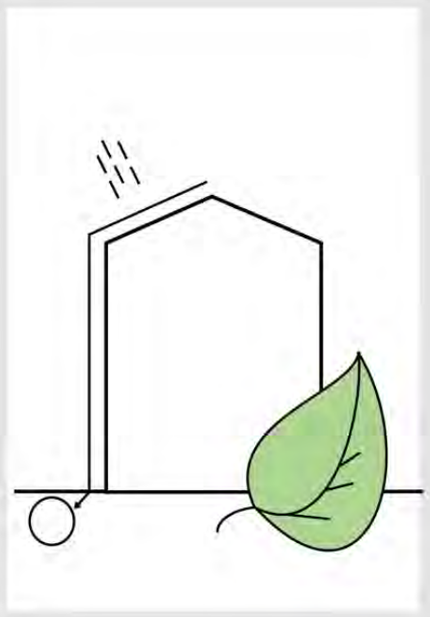
Magasin BHV Homme, Paris - Patrick Blanc (Foto: Nicole Pfoser 2011)

Building vegetation - influence on environment and open space

Surface water and building vegetation

			
Regulierte Wasserführung	**① unter Substrat**	**② im Substrat**	**③ über Substrat**
Schichthöhe des Aufbaus	9 - 12 cm	8 - 12 cm	9 - 12 cm
Aufbau-Gewicht	90 - 120 kg/qm	130 - 210 kg/qm	50 - 150 kg/qm (je nach Wasserstand)
Wasserrückhalt	50 - 90 %	70 %	50 - 90 %
Wasserspeicherung dauerhaft	21 - 38 l/qm	25 - 50 l/qm	bis zu 8 l/qm
Wasserspeicherung temporär	40 - 53 l/qm	kein Messwert	kein Messwert
Abflussbeiwert	0,01 - 0,3	0,3	entfällt, da nur Notüberlauf

Measured data of water retention, water storage and runoff coefficient
of different variants of retention green roofs (market evaluation Nicole Pfoser 2012)



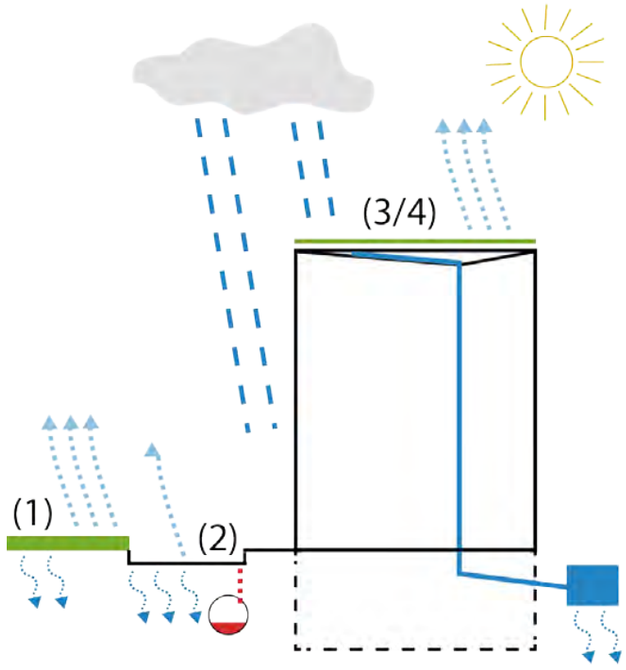
Synergy
- water retention through green buildings
- Release of the sewage system during strong rain events by means of:
  - evaporation
  - retention
  - delayed discharge into the sewage system

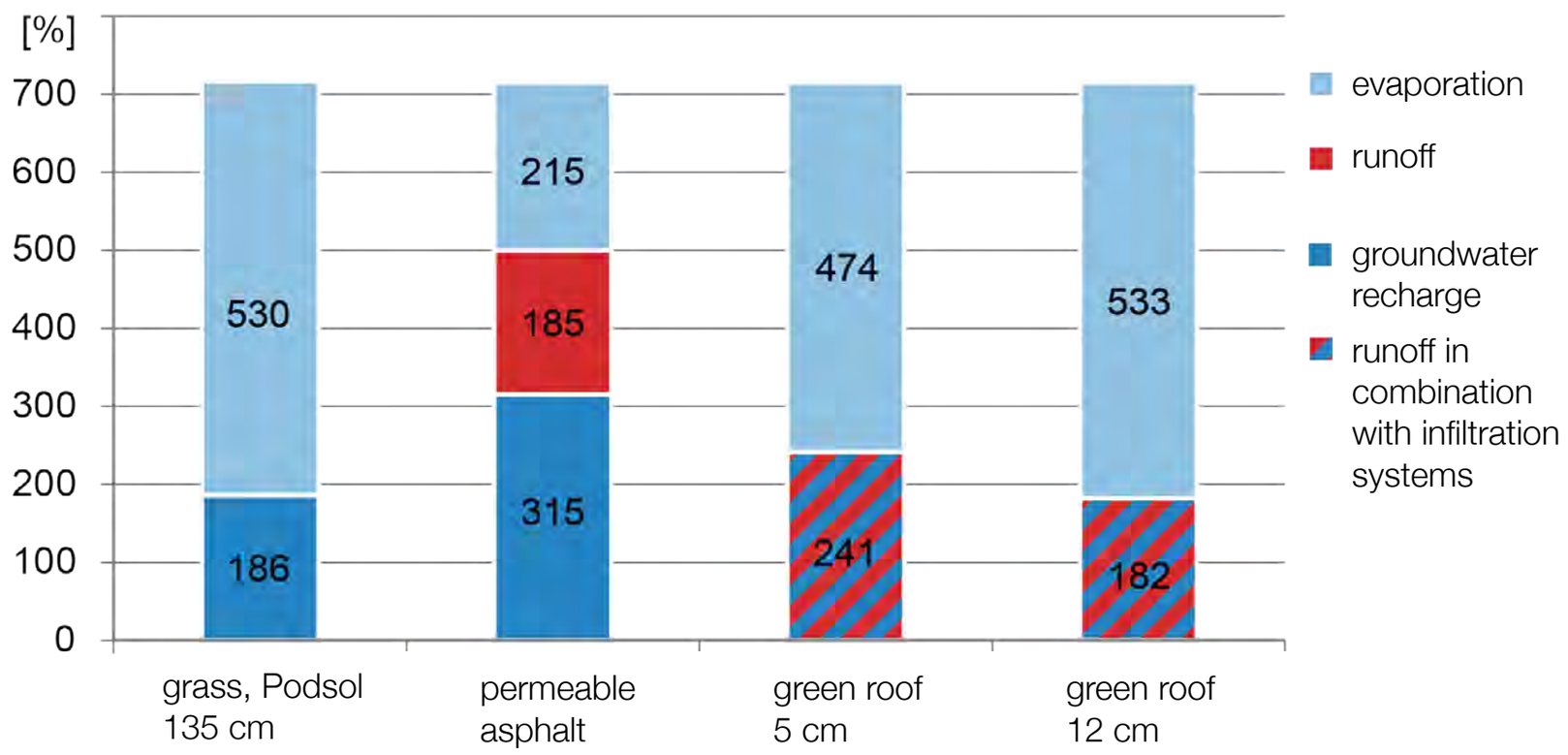
Potential
- water retention potential of green roofs:
  75-90 % of rainfall [11, 15, 17] (depending on construction): intensive planting has strong retention potential (retention potential depends on the depth of the substrate),also applied ot retention roofs

Planting Design
- mainly applies to green roofs
- partly also applies to ground-based and wall-based facade greening.

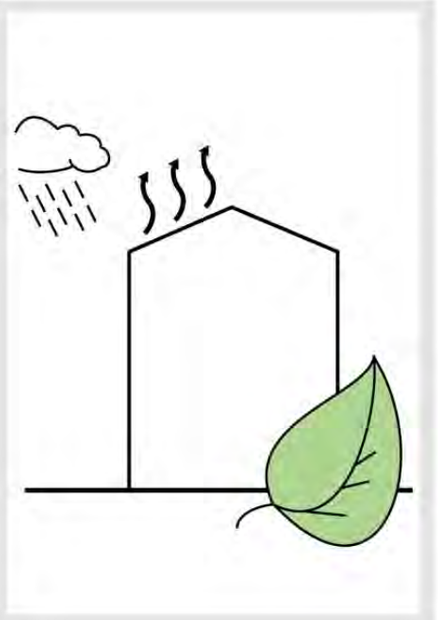
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 151-152

Rainwater evaporation and building vegetation





left: Schematic drawing of water balance of different surfaces (TU Darmstadt, FGee/FGe+f)
right: Measures of water balance of different used surfaces as average annual sum from january 2001 to december 2004 at TU Berlin Wilmersdorf (TU Darmstadt, FGee/FGe+f, nach Schmidt, M. (2010))



Synergy
- reduction of sealed surfaces
- increased evaporation rate
- cooling of the urban space
- contributes to local rainfall

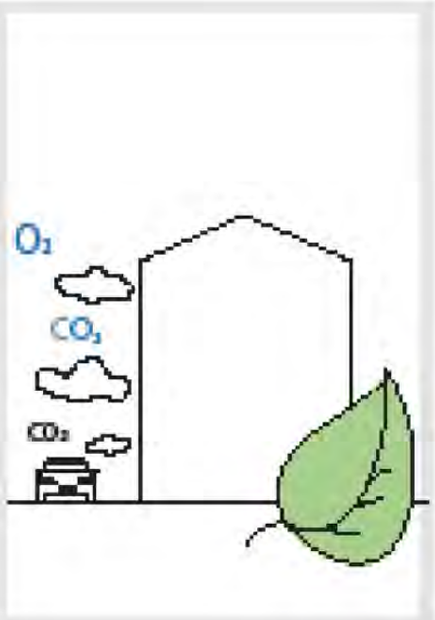
Potential
- Extensive planting designs can evaporated up to 65/75% of annual rainfall [25]

Planting Design
- applies to all planting designs
- intensive planting designs has a higher evaporation rate

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 153-154

Reduction of air pollution

Spontaneous growth on a wall with mosses und lichens
(photo: Nicole Pfoser 2012)



Synergy
- carbon sequestration
- oxygene production
- suppression of fine dusts and metabolism of pollutants

Potential
- Suppression of fine dusts: 4g/m² (Parthenocissus), 6g/m² (Hedera), 71 % of substances with negative effect on lungs
- moss: increased suppression of fine dustrs and up to 75 % meatbolism [6]
- carbon sequestration of mosses up to 2,2 kg/m²
- facade greening (Hedera helix): annual carbon sequestration = 2,3 kg/m², oxygen production = 1,7 kg O_2/m² a [1, 3, 6, 22]

Planting Design
all types of green buildings
- intensive plantings and mosses achieve highest level of fine dust suppression
- Potential depends on plant type, climate and amount of green surface

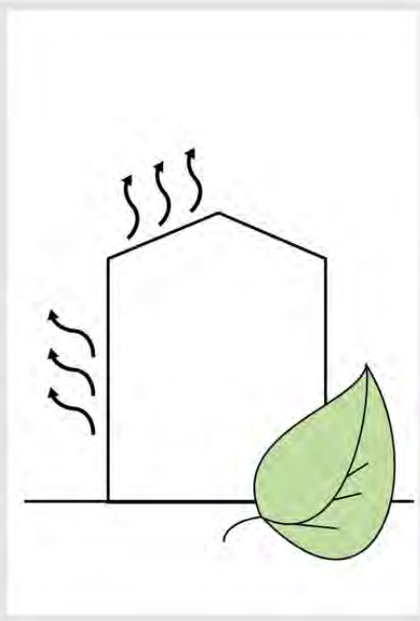
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn

Prevention of overheating and building vegetation

Sommerliche Kühlwirkung an Bauteiloberflächen am Beispiel einer flächigen Wandgebundenen Begrünung:
(Messungen im August 2011 am Musée du Quai Branly, Paris)

Temperatur	
Umgebungstemperatur	29°C
Oberfläche Begrünung	25,5 - 27,7°C
Temperaturdifferenz	1,3 - 3,5 K
relative Luftfeuchte	
Zunahme der Luftfeuchte	11 %

Temperature / Relative humidity:
Example of cooling through a facade based greening on the basis of measures at the facade of Musée du Quai Branly, Paris.
(© Nicole Pfoser 08/2011)



Synergy
cooling effect of evapotranspiration
- reduction of surface temperatures (temperature extremes ΔT) through shading [21, 22, 25, 28]

Potential
- Transformation of 58 % of solar radiation balance into evaporation cooling [25]
- Irrigation increases this effect
- 85-95 % shading with climbers [5; 25], up to 100 % shading with wall-based constructions and green roofs
- strong effect on nearby are

Planting Design
- green roofs and green facades
- deciduous and evergreen plants
- higher evaporation effect of intensive planting designs

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 112-114

Prevention of overheating and building vegetation

Paris

left: Paris - Strategy: Development of green areas (FGee/FGe+f, acc. to www.paris.fr - Plan local d'urbanisme (P.L.U.), Sectorisation végétale de la zone Urbaine Générale

Areas to improve existing green spaces

Areas to build new green spaces

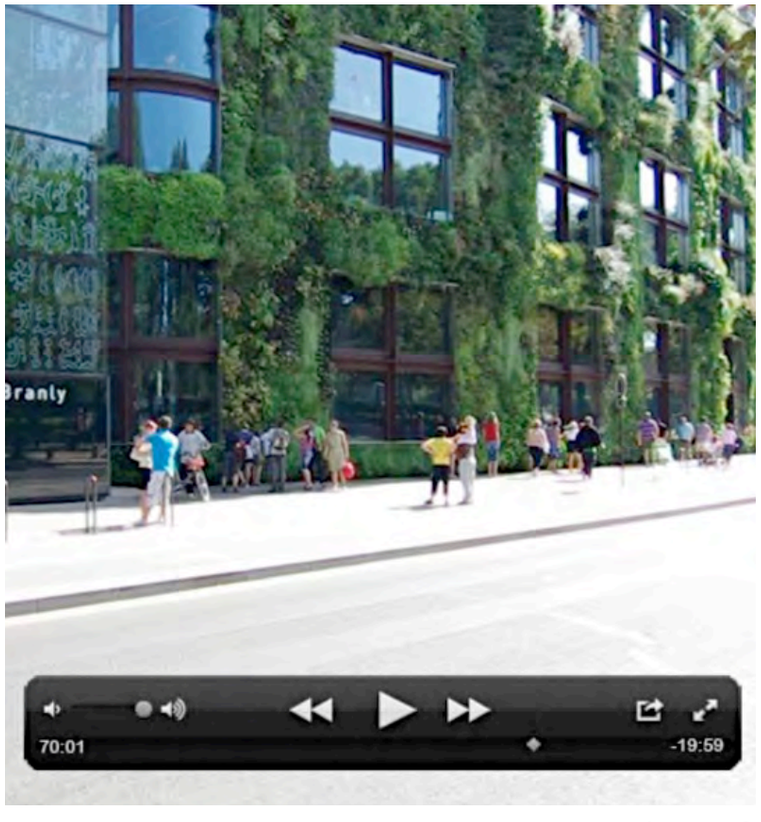
right: : Museé du Quai Branly, Paris (Foto: Nicole Pfoser 2011)

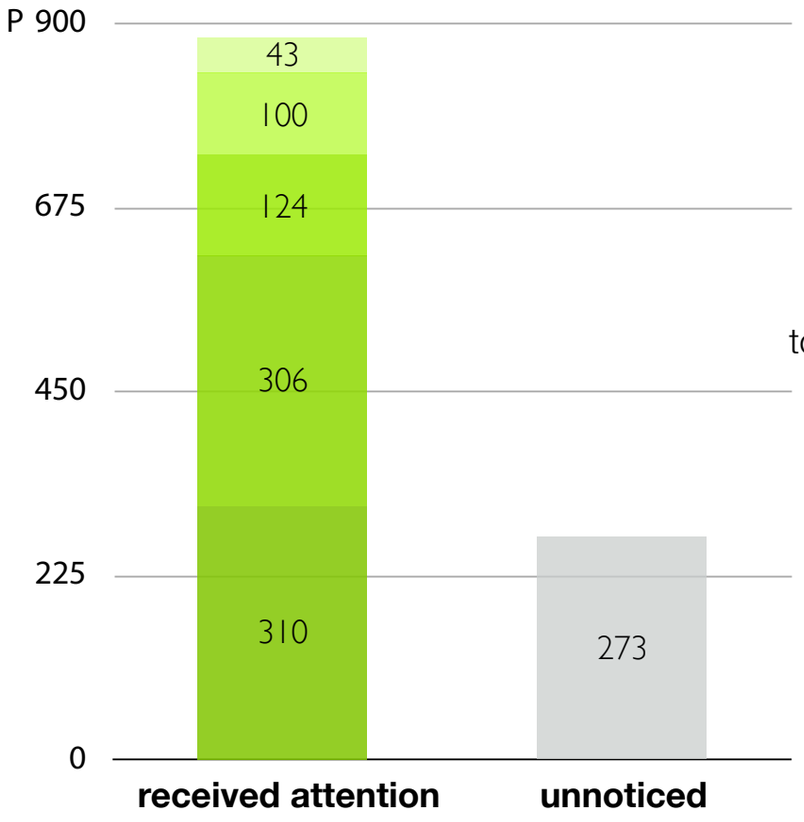
London

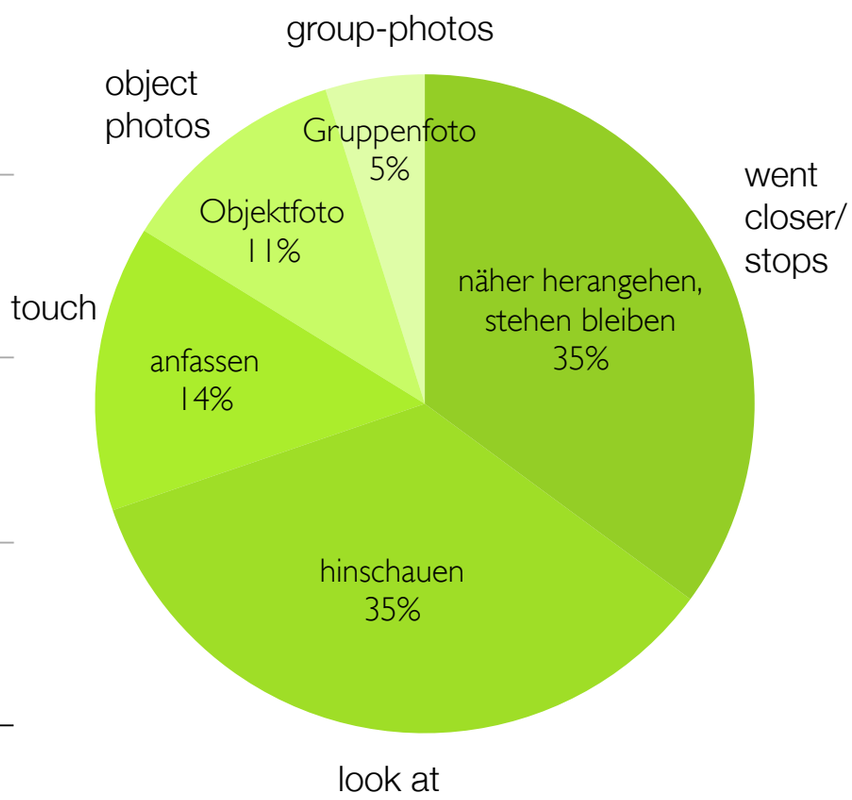
The London Plan Policy: Strategy to improve London's resilience to the impacts of climate change by reducing storm water run-off velocity and volumes, and by increasing the cooling effect during hotter summers.
Brochure „Living Roofs and Walls"
Recommendation:
70 % greening of urban roofs, thereof 25 % usable for habitants.
Water retention through predefined-substrate height

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 226-231

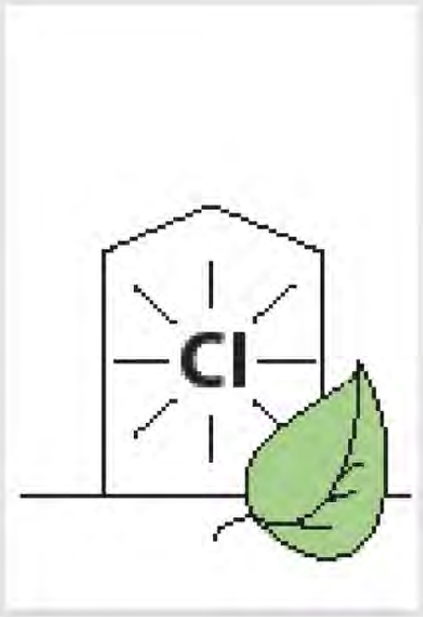
Acceptance of building vegetation







Facade based greened facade at the Musée du Quai Branly, Paris.
Sunday, 21th August 2011, 15-16.30 h, sunny, 35,6 °C. Sum of people passing (P): 1156
Evaluation: 90 minutes analysis of behavior of passers-by (© Nicole Pfoser 09/2011)



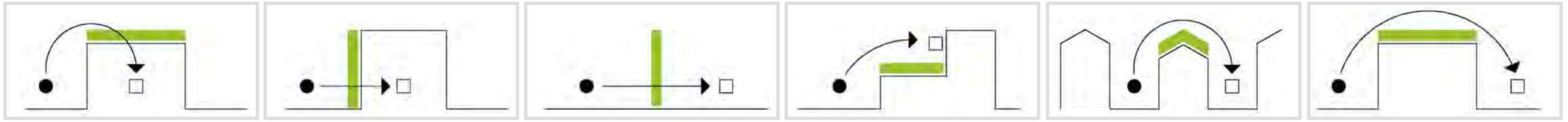
Synergy
Increasing acceptance through:
- improved conditions for people
- Corporate Identity
- improved design quality

Potential
- increasing the value of buildings and open spaces
- create green space without need for additional floor area
- wellbeing caused by better climatic conditions and ventilation
- positive effects on social aspects, mental and physical health
- protect the facade against pollutants and dirt [3; 12; 13|

Planting Design
all types of green roofs and green facades
effect depends on the intesity of green, variety and design quality

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 160

Reduction of noise pollution by building vegetation in open space



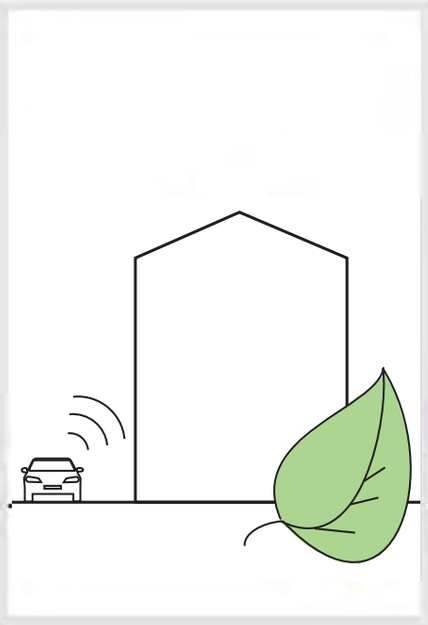
Aussenraum → Innenraum | **Aussenraum → Aussenraum**

Dachbegrünung	Fassadenbegrünung	Lärmschutz / Gehölze	Dachbegrünung
0 25 50 dB	0 25 50 dB	0 25 50 dB	0 25 50 dB

Maximale Lärmminderung

① Substrat trocken 8 dB Substrat feucht 18 dB	⑤ Wilder Wein (bg) 1,7 dB wandgebunden 2,7 dB (bei 500-1000 Hz)	⑨ Lärmschutzwand begrünt wg/bg (bei Verkehrs-Frequenzbereich) 17-43 dB	⑫ Gestaffelte Fassade mit Flachdachbegrünung eines 5 m Rücksprungs, Substratstärke 20 cm Verkehr 30 km/h 2 dB Verkehr 130 km/h 5,5 dB maximale Lärmminderung (abhängig von Bepflanzung) 4,7-6,4 dB	⑫ Begrüntes Satteldach, Schallquelle Nachbarstraße - maximale Lärmminderung bei Verkehr 30 km/h 1,1 dB bei Verkehr 130 km/h 3,3 dB
② 1400 Hz 5 dB 750 Hz 20 dB	⑥ Wilder Wein (bg) 4 dB (bei 500-1000 Hz)	⑩ nachträgliche Begrünung Efeu d=80 cm 2-27 dB Efeu d=25 cm 0-16 dB (bei 50-8000 Hz)		⑫ Begrüntes Flachdach, Schallquelle Nachbarstraße - maximale Lärmminderung bei 1000 Hz 6 dB
③ 50-2000 Hz 5-13 dB > 2000 Hz 2-8 dB	⑦ wandgebunden, abhängig von Hz, Aufbau- und Substratstärke 4-9,9 dB	⑪ Lärmschutz-Baumreihe (15 Jahre alt) 9 dB		
④ abhängig von Schichtenhöhe (Auflast) und Dachneigung 5-46 dB	⑧ wandgebunden 5 dB			

Maximum of noise mitigation by greening (Nicole Pfoser 2013, according to Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 156)



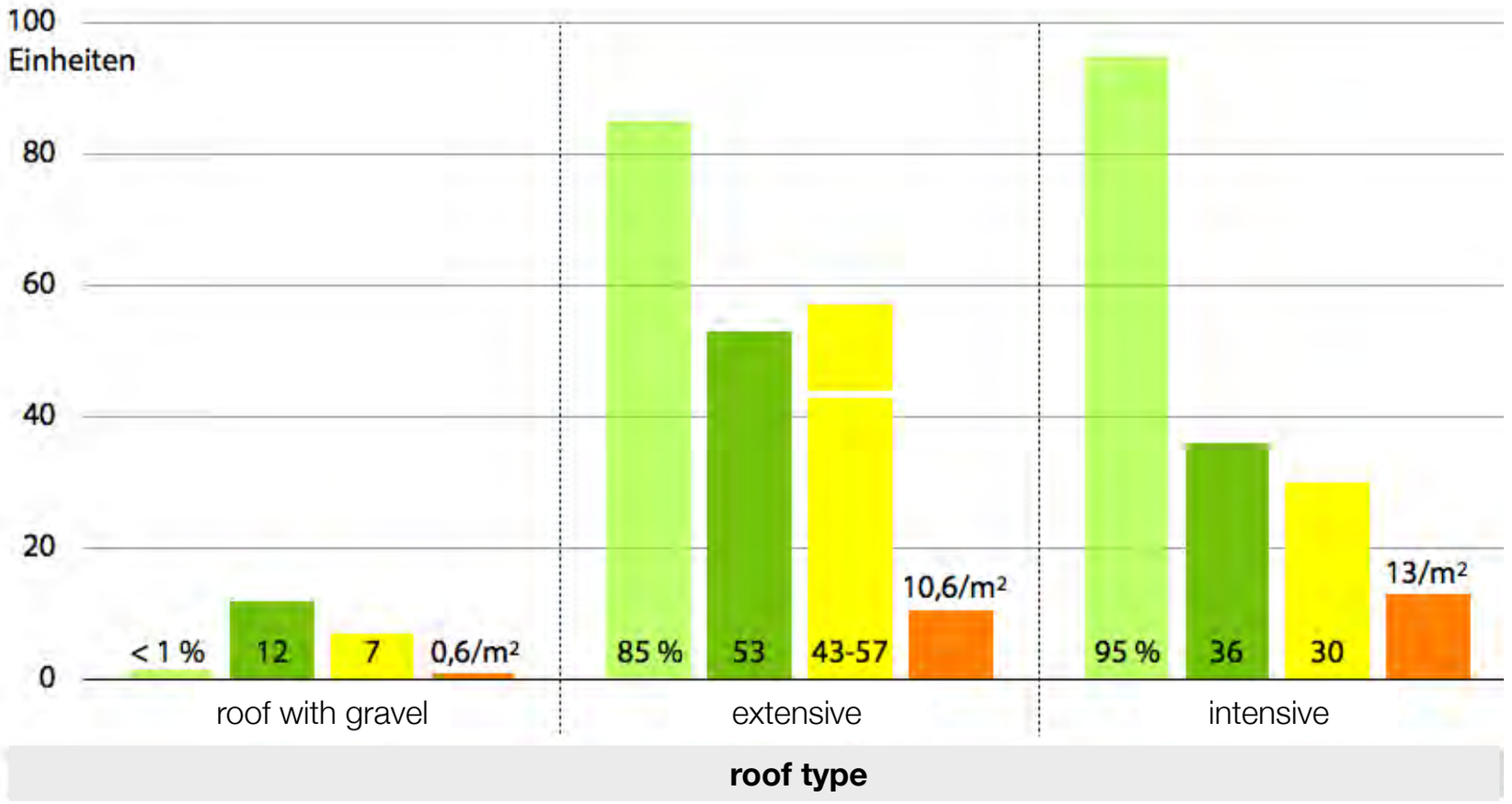
Synergy
Noise reduction factor results from the sum of internal/extrnal reflection of leaves and the absobtion effect of the substrate

Potential
- noise reduction through ab sorbtion and reflection, reduction of noise reflection depends on the level of layers and the inclination of the roof 5-46 dB [18]
- reduction of transmission of the building

Planting design
all types of green roofs and green facades with suitable plant types
Reducing factors are:
- leave volume (amount, size, depth)
- substrate (volumene, weight)

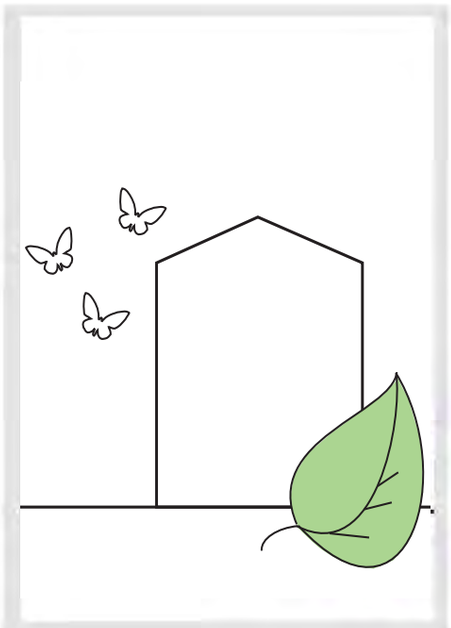
Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 155-157

Biodiversity and building vegetation



coverage rate Flora (%)
species diversity Flora
species diversity Fauna
population density Fauna (number/m2)

Quantitative measures of Flora and Fauna of green roofs (Nicole Pfoser 2013, according to: Zimmermann, P. (1987): Dachbegrünung, In: Veröffentlichungen für Naturschutz und Landschaftspflege in Baden-Württemberg (62). Karlsruhe, S. 545-547)



Synergy
The diversity of urban fauna is an indicator for the liveability of a city: water retention, air quality, biodiversity, buffering of temperature extremes are common needs

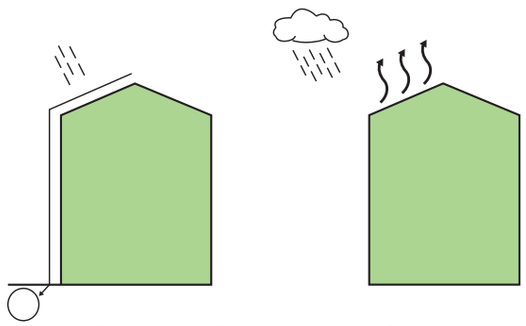
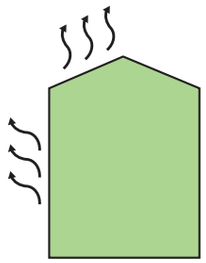
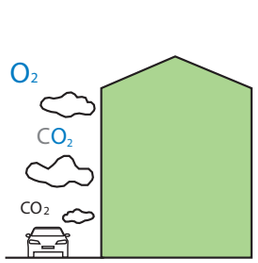
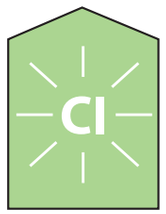
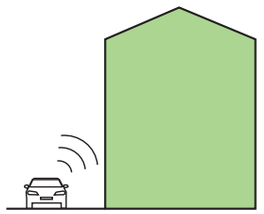
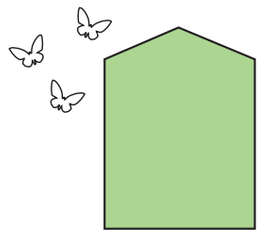
Potential
Urban areas are largely sealed. Roofs and facades can provided alternative habitats for animals. The potential for delivering this function depends on:
- location (exposure, silence...)
- size
- varied vegetation (Krupka 1992). The biodiversity level of green roofs can be 23-94% higher compared to a normal roof) [21; 22; 23]

Planting Design
shrubs, plants providing food for insects/animals, plant societies providing protection and shelter

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 158-159

Synergies in the building's environment in regard of surface water management, rain water evaporation, noise protection measures and biodiversity in connection with the greening of buildings.

ENVIRONMENT

DEMAND	Water	Prevention of overheating	Reduction of air pollution	Acceptance	Reduction of noise pollution	Biodiversity
MEASURE	 surface water in sewer system rainwater evaporation	 adiabatic cooling and shading	 Photosythesis and dust suppression	 Increasing the value of buildings and open spaces	 Acoustic reflections and absorption	 Expansion of flora and fauna habitat
EFFECT OF BUILDING GREENING	Support + water retention trough retention systems + prevention of strain of sewer system Support + supports evaporation of rain water + supports local precipitation	Support + direct use of evaporative colling and shading + reduce urban heat islands	Support + carbon sequestration + oxygene production + suppression of fine dusts and metabolism of pollutants	Support + improve conditions for people + increasing acceptance + Corporate Identity + improved design quality	Support + noise reduction of urban spaces trough absorption and reflection + reduction of transmission of the building	Support + improvement of the local diversity of species + create habitats for insects and birds
	Water retention, Water evaporation	**shading, evaporative cooling**	**improving air quality**	**Design, wellbeeing**	**noise reduction**	**raises biodiversity**

Pfoser, N./Jenner, N. et al. (2013): Gebäude, Begrünung und Energie. Potenziale und Wechselwirkungen. Bonn, S. 161, supplemented 05.2014

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