Guideline for the calculation of extensive green roofs

Within the research project

> „Ermittlung von Materialeigenschaften und effektiven Übergangsparametern von Dachbegrünungen zur zuverlässigen Simulation der hygrothermischen Verhältnisse in und unter Gründächern bei beliebigen Nutzungen und unterschiedlichen Standorten“ [1]
>
> (Funded by the research program "Zukunft Bau" of the Bundesinstitut für Bau-, Stadt- und Raumforschung (German Federal Ministery of Transport, Building and Urban development); file number: SF-10.08.18.7-11.18 / II 3-F20-10-1-100)

one generic and different product-specific models were developed in order to calculate and plan green roofs – especially on wooden constructions – reliably by the help of the software tool WUFI®.

The generic green roof model was developed on the basis of field studies in Holzkirchen, Leipzig [2], Vienna [3] and Kassel [4]. The climate data available for the test period don’t contain any data for the atmospheric counter radiation, so it was necessary to consider their influence in a simplified way by the other climate data and appropriate surface transfer coefficients. Therefore this model is suitable especially for locations in Central Europe respectively locations with a comparable climate and can be used if no measured data for the atmospheric counter radiation or no detailed information about the applied substrate type are available.

On the basis of the generic model, product-specific approaches for five green roof systems of the company Optigreen were developed by means of additional laboratory and field tests in Holzkirchen. Hereby the influence of the measured atmospheric counter radiation was considered explicitly, so these approaches are in principle also suitable for other climate regions. Validations have already been performed for Holzkirchen and Milan [5].

In the following the procedure as well as the required material data, moisture sources and boundary conditions and also application limits for the developed green roof models are described.

[1] PDF (26.8 MB), Summary, Catalog entry at IRB-Verlag
[2] Winter, S.; Fülle, C.; Werther, N.: Forschungsprojekt MFPA Leipzig und TU München (Z 6 – 10.08.18.7-07.18). „Flachdächer in Holzbauweise“. 2007-2010.
[3] Teibinger, M.; Nusser, B.: Ergebnisse experimenteller Untersuchungen an flachgeneigten Hölzernen Dachkonstruktionen. Herausgegeben von Holzforschung Austria, Wien. (Forschungsbericht, HFA-Nr.: P412), 2010.
[4] Minke, G.; Otto, F.; Gross, R.: Ermittlung des Wärmedämmverhaltens von Gründächern. Abschlussbericht, AZ 24242-25. ZUB Kassel. Juli 2009.
[5] Fiori, M.; Paolini, R.: Politecnico di Milano, Dipartimento di Architettura, Ingegneria delle costruzioni e Ambiente costruito. The green roof monitoring is funded by the Italian Ministry of Research, project PRIN SENSE „Smart Building Envelope for Sustainable Urban Environment“.

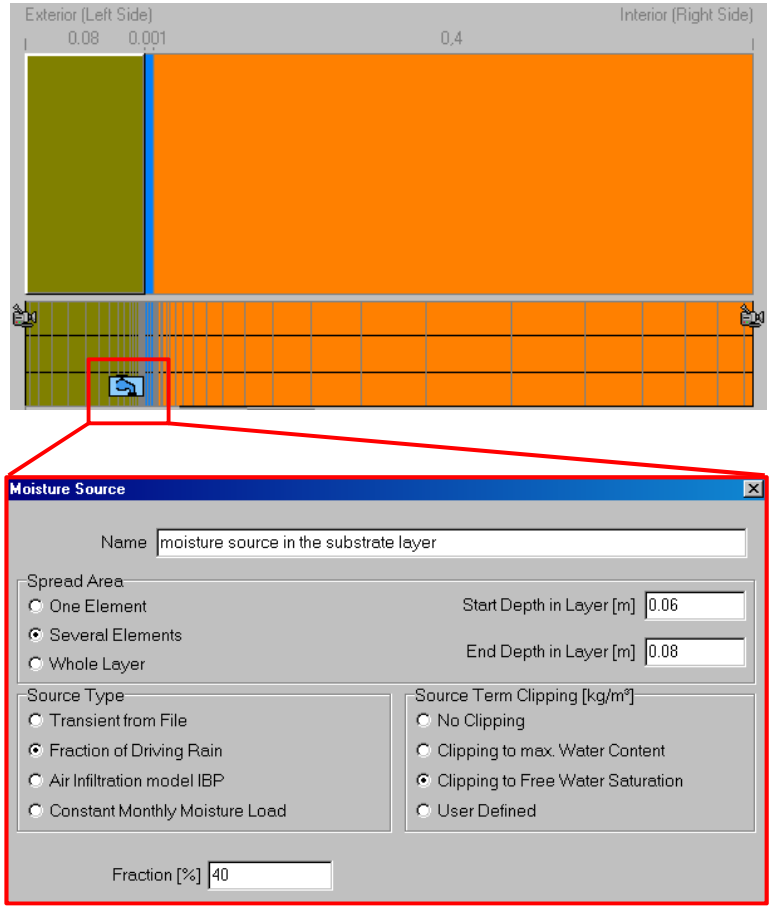
Generic green roof model

The generic green roof model should be used if no detailed information about the substrate type or no measured data for the atmospheric counter radiation are available. In this model the long-wave radiation is considered in a simplified way by the reduced short-wave radiation absorptivity. This is acceptable if the radiation conditions are comparable to the one at the examined locations. Other radiation conditions (especially due to clearly different clouding) should be considered by a detailed calculation of the long-wave radiation losses.

Assembly:

- generic substrate with required thickness
  (material data set: „generic substrate.xml“, directly available in WUFI® since database-version 24.77 (12/2013)
  → Source: Fraunhofer-IBP, Catalog: Green und Gravel Roofs)

Note: The models were developed for extensive green roofs with a substrate thickness up to 15 cm.



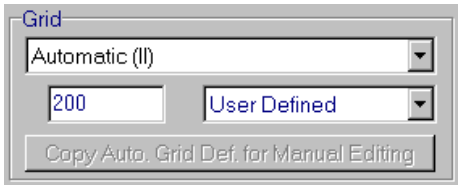
Moisture source:

In the lowest 2 cm of the generic substrate:

- spread area: several elements
  example: 8 cm substrate layer
  start depth in layer: 0.06 m / end depth in layer: 0.08 m
- source type: fraction of diving rain
- fraction: 40 %
- clipping of the source term to the free water saturation

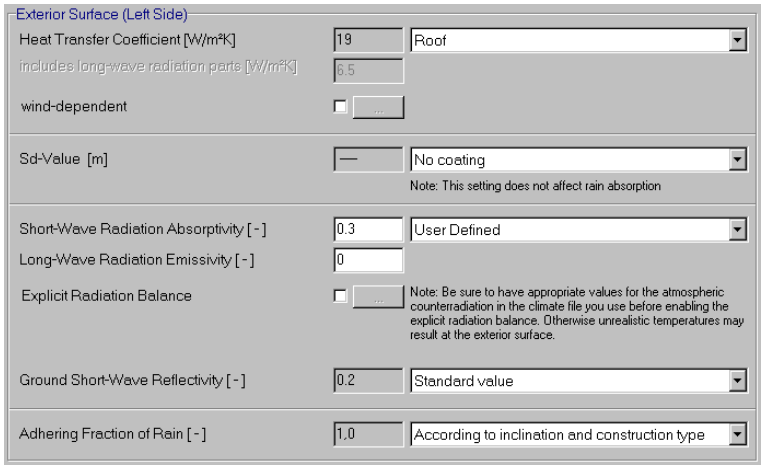
Suggested grid resolution:

Automatic (II) with 200 elements



Surface transfer parameters on the exterior surface:

- heat transfer coefficient: 19 W/m²K
  resp. heat resistance: 0.0526 m²K/W
  (depending on the settings in WUFI®)
- short-wave radiation absorptivity: 0.3
- long-wave radiation emissivity: 0
- explicit radiation balance: not used



Note: After start of calculation the warning “Explicit radiation balance disabled but inclination is (e.g.) 2°” appears → this warning can be ignored for the calculation of a green roof with the generic model!

Exterior climate data set:

Required climate data for the calculation with the generic green roof model:

- temperature
- relative humidity of the air
- global radiation (resp. diffuse and direct radiation for pitched roofs)
- precipitation

Specific green roof models

Due to the fact that the product-specific approaches also consider the long-wave counter radiation and thus all relevant climate elements, these approaches are in principle also suitable for other climate regions. Prerequisite is the availability of data for the atmospheric counter radiation. Validations have already been performed for the European locations Holzkirchen and Milan.

Within the research project all necessary input data for the hygrothermal simulation of the five Optigreen-Systems were developed in collaboration with the company.

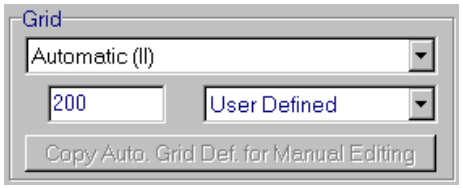
Optigreen-Systems according the product names of the manufacturer:

- Light-weight Roof Solution 1
- Economy Roof Solution 1
- Economy Roof Solution 2
- Pitched Roof 5-45°
- Nature Roof Solution 1

First the input data which are identical for the five approaches are given. Then each of the systems is described briefly and the procedure for the calculation with WUFI® is explained. Additional information is given in the info-text of each material.

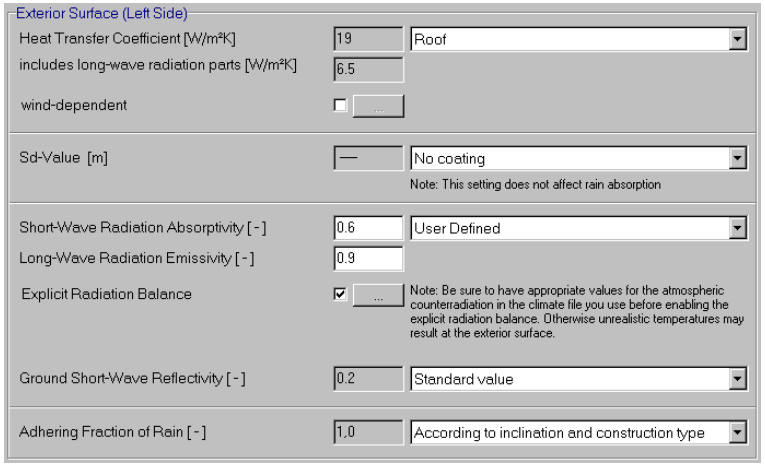
Suggested grid resolution:

Automatic (II) with 200 elements



Surface transfer parameters on the exterior surface:

- heat transfer coefficient: 19 W/m²K
  resp. heat resistance: 0.0526 m²K/W
  (depending on the settings in WUFI®)
- short-wave radiation absorptivity: 0.6
- long-wave radiation emissivity: 0.9
- explicit radiation balance: used



Exterior climate data set:

Required climate data for the calculation
with the specific green roof model:

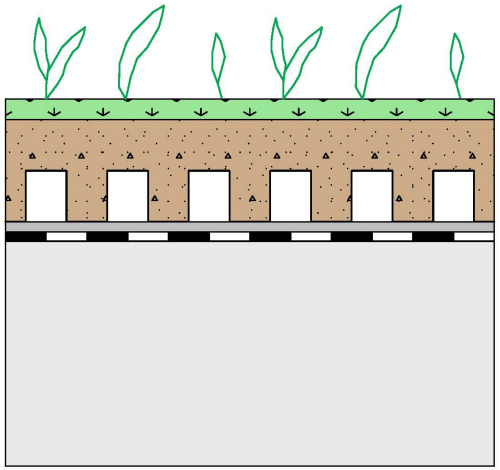
- temperature
- relative humidity of the air
- global radiation (resp. diffuse and direct radiation for pitched roofs)
- atmospheric counter radiation
- precipitation

Optigreen-System Light-weight Roof Solution 1:

Description according to the manufacturer:

- double layer, extensive roof greening (from 0-5° roof pitch)
- low layer height (approx. 60 mm)
- low weight (approx. 55 kg/m²)
- drought-compatible sedum plants (approx. 6-8 species)
- low maintenance (1 time per year)

System drawing:

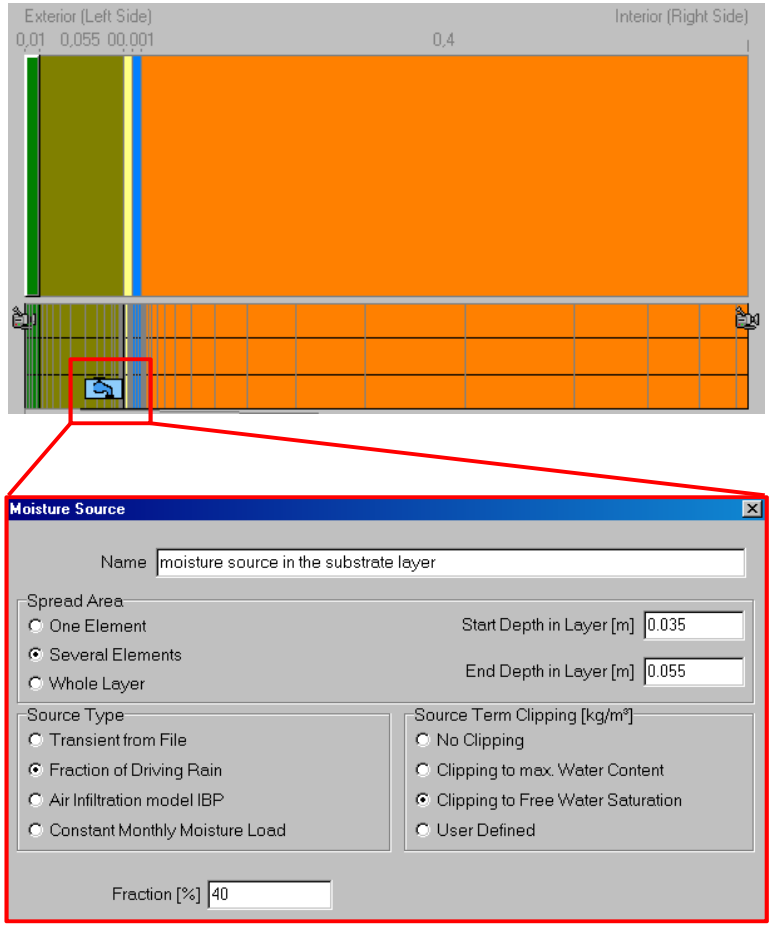


sedum planting
substrate type L incl.
drainage board FKD 25
protection mat

Assembly in WUFI®:

- 1 cm sedum planting
  (material data set: „Optigreen Light-weight Roof 1 (sedum planting) 1-3.xml“)
- 5.5 cm substrate type L incl. FKD
  (material data set: „ Optigreen Light-weight Roof 1 (substrate type L incl. FKD) 2-3.xml“)
- 0.4 cm protection mat
  (material data set: „ Optigreen Light-weight Roof 1 (protection mat) 3-3.xml“)

Materials directly available in WUFI® since database-version 24.77 (12/2013)
→ Source: Fraunhofer-IBP, Catalog: Green und Gravel Roofs



Note:

The assembly is included into the WUFI® “construction-database” since WUFI® Pro 5.3 (DB 24.77). To insert click the button “example cases” below the component assembly and choose „Optigreen-System Light-weight Roof Solution 1” in Fraunhofer-IBP source, catalog “Roofs”. After inserting you have to add the substructure to your roof assembly. Before calculation you also need to set the boundary conditions and the moisture source according to this guideline.

Moisture source:

In the lowest 2 cm of the layer „substrate type L incl. FKD“

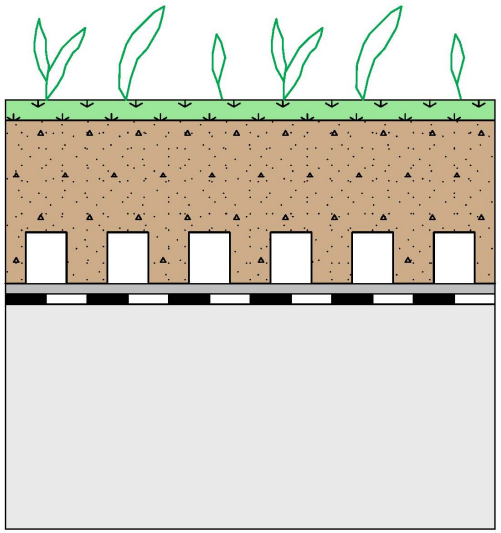
- spread area: several elements
  start depth in layer: 0.035 m / end depth in layer: 0.055 m
- source type: fraction of diving rain
- fraction: 40 %
- clipping of the source term to the free water saturation

Optigreen-System Economy Roof Solution 1:

Description according to the manufacturer:

- double layer, extensive roof greening (from 0-5° roof pitch)
- low layer height (approx. 85 mm)
- low weight (approx. 95 kg/m²)
- drought-compatible sedum plants (approx. 6-8 species)
- low maintenance (1 - 2 times per year)

System drawing:



sedum planting

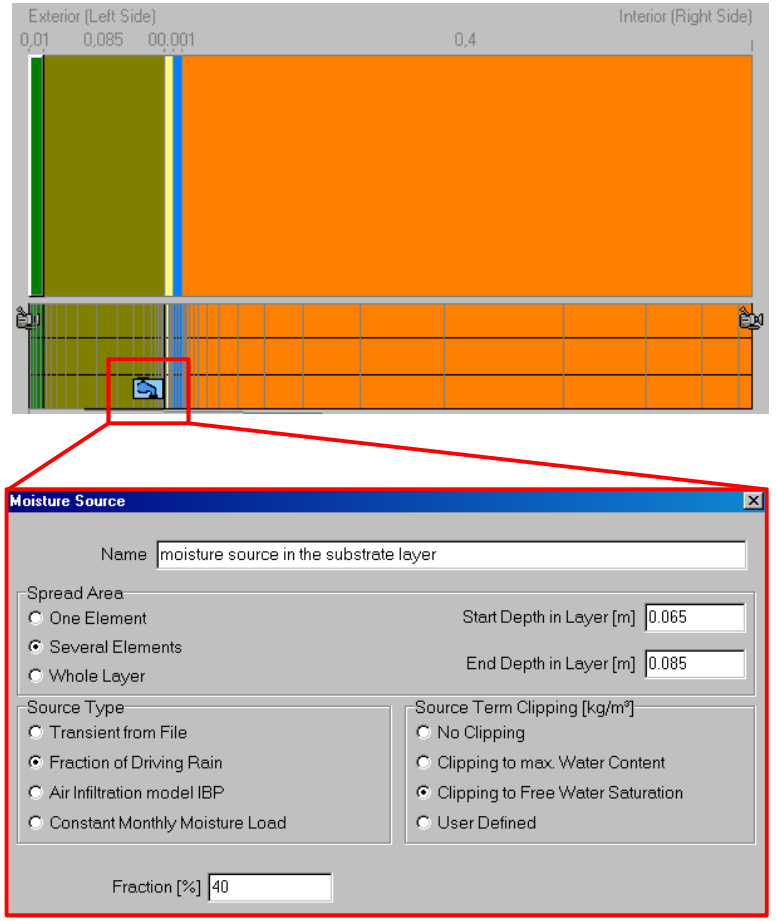
substrate type M incl.
drainage board FKD 25

protection mat

Assembly in WUFI®:

- 1 cm sedum planting
  (material data set: „Optigreen Economy Roof 1 (sedum planting) 1-3.xml“)
- 8.5 cm substrate type M incl. FKD
  (material data set: „Optigreen Economy Roof 1 (substrate type M incl. FKD) 2-3.xml“)
- 0.4 cm protection mat
  (material data set: „Optigreen Economy Roof 1 (protection mat) 3-3.xml“)

Materials directly available in WUFI® since database-version 24.77 (12/2013)
→ Source: Fraunhofer-IBP, Catalog: Green und Gravel Roofs



Note:

The assembly is included into the WUFI® “construction-database” since WUFI® Pro 5.3 (DB 24.77). To insert click the button “example cases” below the component assembly and choose „Optigreen-System Economy Roof Solution 1” in Fraunhofer-IBP source, catalog “Roofs”. After inserting you have to add the substructure to your roof assembly. Before calculation you also need to set the boundary conditions and the moisture source according to this guideline.

Moisture source:

In the lowest 2 cm of the layer „substrate type M incl. FKD“

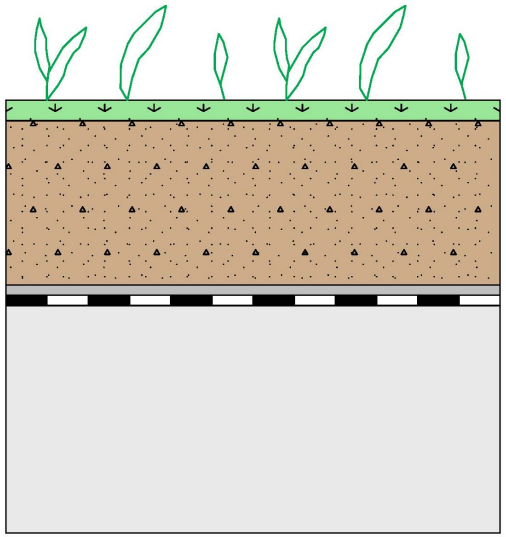
- spread area: several elements
  start depth in layer: 0.065 m / end depth in layer: 0.085 m
- source type: fraction of diving rain
- fraction: 40 %
- clipping of the source term to the free water saturation

Optigreen-System Economy Roof Solution 2:

Description according to the manufacturer:

- single layer, extensive roof greening (from 0-5° roof pitch)
- low layer height (approx. 80 mm)
- low weight (approx. 100 kg/m²)
- drought-compatible sedum plants (approx. 6-8 species)
- low maintenance (1 - 2 times per year)

System drawing:



sedum planting

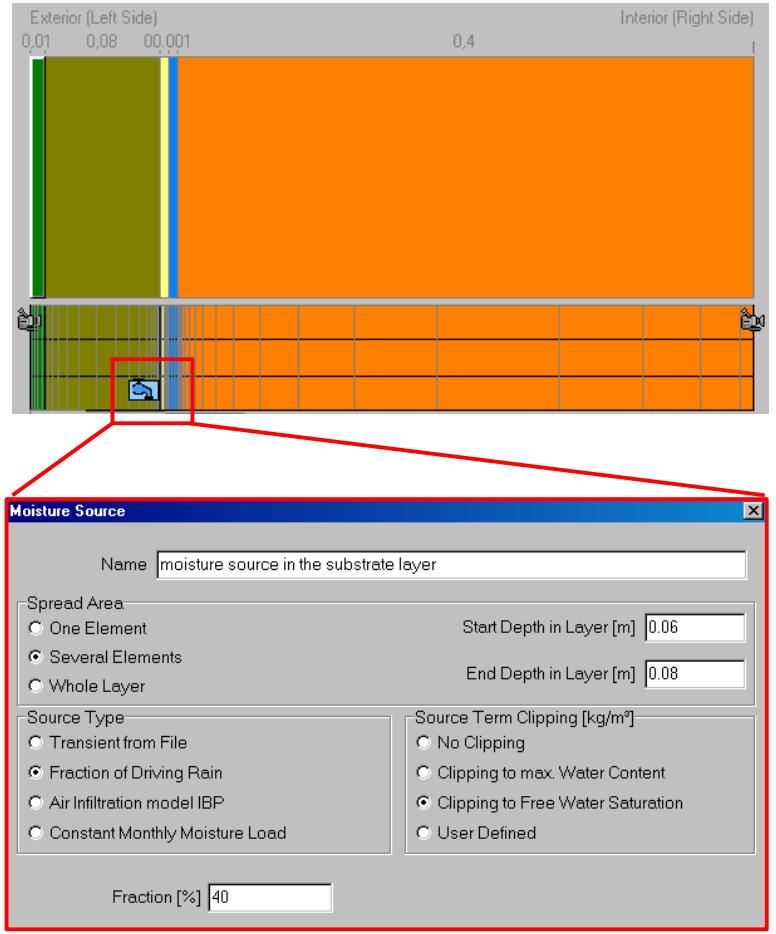
substrate type M

protection mat

Assembly in WUFI®:

- 1 cm sedum planting
  (material data set: „Optigreen Economy Roof 2 (sedum planting) 1-3.xml“)
- 8 cm substrate type M
  (material data set: „Optigreen Economy Roof 2 (substrate type M) 2-3.xml“)
- 0.4 cm protection mat
  (material data set: „Optigreen Economy Roof 2 (protection mat) 3-3.xml“)

Materials directly available in WUFI® since database-version 24.77 (12/2013)
→ Source: Fraunhofer-IBP, Catalog: Green und Gravel Roofs



Note:

The assembly is included into the WUFI® “construction-database” since WUFI® Pro 5.3 (DB 24.77). To insert click the button “example cases” below the component assembly and choose „Optigreen-System Economy Roof Solution 2” in Fraunhofer-IBP source, catalog “Roofs”. After inserting you have to add the substructure to your roof assembly. Before calculation you also need to set the boundary conditions and the moisture source according to this guideline.

Moisture source:

In the lowest 2 cm of the layer „substrate type M“

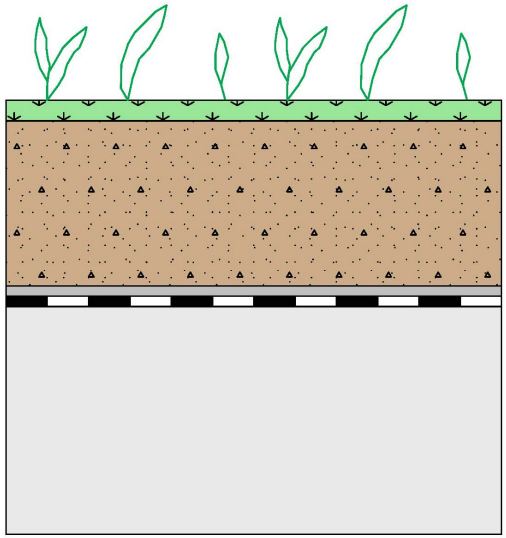
- spread area: several elements
  start depth in layer: 0.06 m / end depth in layer: 0.08 m
- source type: fraction of diving rain
- fraction: 40 %
- clipping of the source term to the free water saturation

Optigreen-System Pitched Roof 5-45°:

Description according to the manufacturer:

- double layer, extensive pitched roof greening (from 5-45° roof pitch)
- low layer height (approx. 90 mm)
- low weight (approx. 110 kg/m²)
- drought-compatible sedum plants (approx. 6-8 species)
- low maintenance (1 time per year)

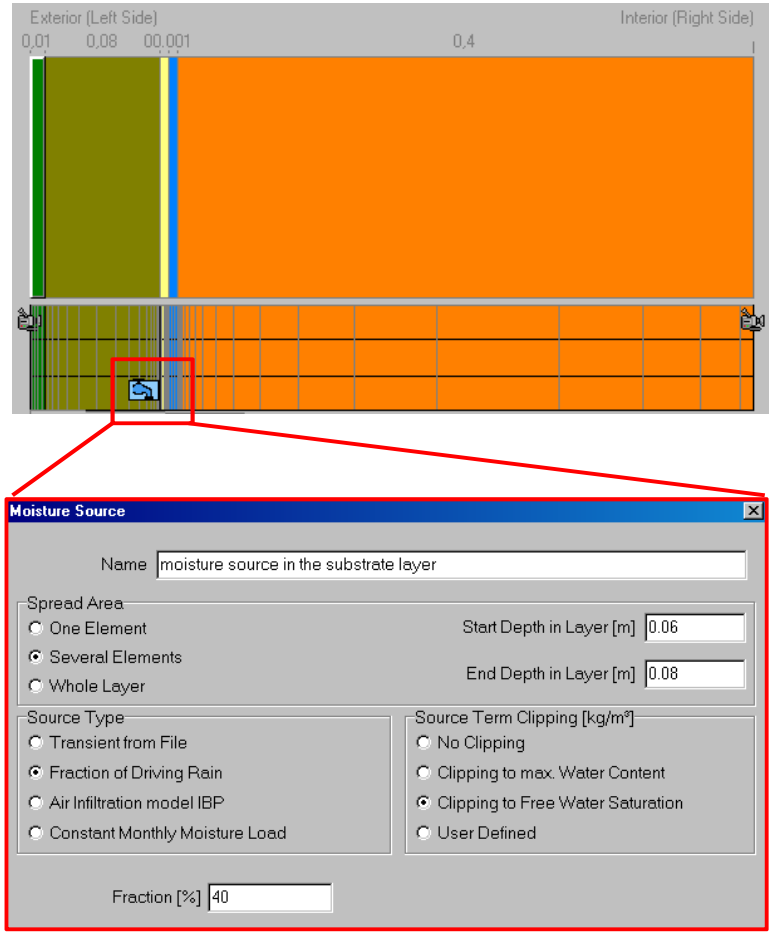
System drawing:



Assembly in WUFI®:

- 1 cm sedum planting
  (material data set: „Optigreen Pitched Roof 5-45° (sedum planting) 1-3.xml“)
- 8 cm substrate type E
  (material data set: „Optigreen Pitched Roof 5-45° (substrate type E) 2-3.xml“)
- 0.4 cm protection mat
  (material data set: „Optigreen Pitched Roof 5-45° (protection mat) 3-3.xml“)

Materials directly available in WUFI® since database-version 24.77 (12/2013)
→ Source: Fraunhofer-IBP, Catalog: Green und Gravel Roofs



Note:

The assembly is included into the WUFI® “construction-database” since WUFI® Pro 5.3 (DB 24.77). To insert click the button “example cases” below the component assembly and choose „Optigreen-System Pitched Roof 5-45°” in Fraunhofer-IBP source, catalog “Roofs”. After inserting you have to add the substructure to your roof assembly. Before calculation you also need to set the boundary conditions and the moisture source according to this guideline.

Moisture source:

In the lowest 2 cm of the layer „substrate type E“

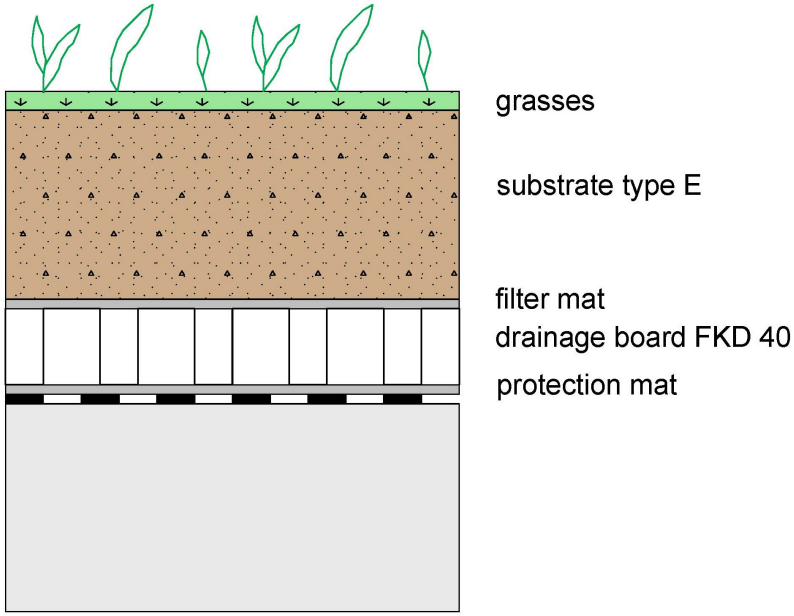
- spread area: several elements
  start depth in layer: 0.06 m / end depth in layer: 0.08 m
- source type: fraction of diving rain
- fraction: 40 %
- clipping of the source term to the free water saturation

Optigreen-System Nature Roof Solution 1:

Description according to the manufacturer:

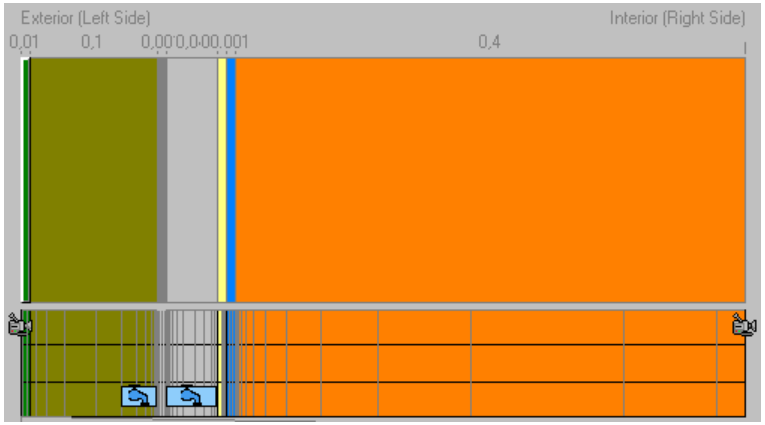
- multi-layer, extensive roof greening (from 0-5° roof pitch)
- medium layer height (approx. 100 mm)
- middle weight (approx. 120 kg/m²)
- drought-compatible sedum plants, grasses, herbs (approx. 25 species)
- medium maintenance (2 - 3 times per year)

System drawing:



Assembly in WUFI®:

- 1 cm grasses
  (material data set: „Optigreen Nature Roof 1 (grasses) 1-5.xml“)
- 10 cm substrate type E
  (material data set: „Optigreen Nature Roof 1 (substrate type E) 2-5.xml“)
- 0.1 cm filter mat
  (material data set: „Optigreen Nature Roof 1 (filter mat) 3-5.xml“)
- 4 cm drainage board
  (material data set: „Optigreen Nature Roof 1 (drainage board) 4-5.xml“)
- 0.4 cm protection mat
  (material data set: „Optigreen Nature Roof 1 (protection mat) 5-5.xml“)



Materials directly available in WUFI® since database-version 24.77 (12/2013)
→ Source: Fraunhofer-IBP, Catalog: Green und Gravel Roofs

Note:

The assembly is included into the WUFI® “construction-database” since WUFI® Pro 5.3 (DB 24.77). To insert click the button “example cases” below the component assembly and choose „Optigreen-System Nature Roof Solution 1” in Fraunhofer-IBP source, catalog “Roofs”. After inserting you have to add the substructure to your roof assembly. Before calculation you also need to set the boundary conditions and the moisture sources according to this guideline.

Moisture source:

In the lowest 2 cm of the layer „substrate type E“

- spread area: several elements
  start depth in layer: 0.08 m / end depth in layer: 0.1 m
- source type: fraction of diving rain
- fraction: 40 %
- clipping of the source term to the free water saturation

In the whole layer „drainage board“

- spread area: whole layer
- source type: fraction of diving rain
- fraction: 40 %
- clipping of the source term to the maximal filling volume
  of the drainage board ((8.7 kg/m²) / (0.04 m) = 217.5 kg/m³)