

Federal Ministry  
for Economic Affairs  
and Climate Action



Beratungsstelle  
Energieeffizienz und  
Nachhaltigkeit

Bayerische  
Architektenkammer



# U-green

## BUILDING PHYSICS ASSESSMENT OF GREEN FACADES AND ROOFS

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Bayerische Landesanstalt für Wein- und Gartenbau

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Technische Universität Berlin

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Center for Applied Energy Research

# CAE | Center for Applied Energy Research

- 50 Employees
- 3700 qm Research Area
- Climate-Research-Facility
- Info-Center (public access)
- Green Box



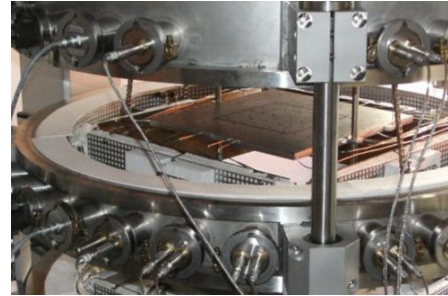
## Workgroups



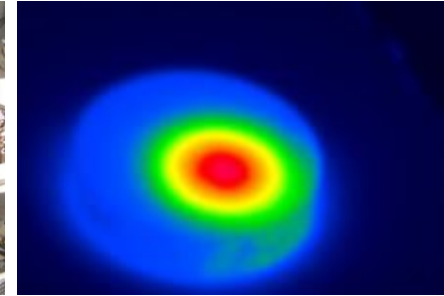
**Climate Neutral Buildings and Cities**



**Smart Functional Materials**



**Advanced Thermal Management**



**Sensors for Energy and Hydrogen Technology**



**Energy System Management and Technology Integration**



## Centre of Competence for Landscaping, Viticulture and Horticulture

41 Employees

**teaching,  
investigating  
and advising**

- Business of Horticulture and Landscaping
- Landscape Architects
- Governmental and communal facilities of Horticulture and Landscaping in Bavaria.

Institute  
for  
**Urban Green  
Space and  
Landscaping**





### Trees for the climate change



### Biodiversity



### Urban Gardening on roofs and facades

Urban Gardening  
Klimaforschung in Bayern



### Climate change adaptations with Building Greening



# TUB | Technische Universität Berlin

- one of Germany's largest universities
- dates back to 1770
- 35,470 students in winter term 22/23
- 7,243 employees (incl. 61 Professors emeritus)
- public funds from regional government:  
366.1 million euros (2022)
- additional third-party expenditures:  
204.4 million euros (2021)

## Faculties

- I Humanities & Educational Sciences
- II Mathematics & Natural Sciences
- III Process Sciences

- IV Electrical Engineering and Computer Science
- V Mechanical Engineering and Transport Systems
- VI Planning Building Environment**
- VII Economics and Management



## Outline

- Goals of the project
- Expert Committee
- Methods & Results
- Outlook



## Outline

- **GOALS OF THE PROJECT**
- Expert Committee
- Methods & Results
- Outlook



## Goals of the project

- **Cataloguing** commercially available façade and roof greening systems
- **Thermal characterization** of greening systems (roof and façade) in field and laboratory measurements:
  - Winter thermal protection
  - Summer overheating protection
- **Development** of appropriate **measurement parameters** for the integration of greening systems into standards for energy balancing of buildings
- Creation of a **freely accessible data catalogue** for greening systems
- Programming of a **calculation tool** for the energetic calculation of greening systems





## Outline

- Goals of the project
- **EXPERT COMMITTEE**
- Methods & Results
- Outlook



## Expert Committee



### EXPERT COMMITTEE CONSISTING OF:

- Bayerische Architektenkammer
- BBSR
- BuGG
- Bund Deutscher Architektinnen und Architekten (BDA)
- Bundesanstalt für Immobilienaufgaben
- CAE
- FLL
- LWG
- Normenausschuss Bauwesen (NABau) im DIN
- TU Berlin

Other relevant stakeholders will be identified through contact with the DIN Standards Committee for Construction (NABau). Research needs and data formats are to be clarified and an overview list of relevant standards, guidelines, etc. soon to be revised is to be compiled.

## Outline

- Goals of the project
- Expert Committee
- **METHODS & RESULTS**
- Outlook



## Methods & Results | Thermal Characterization



- Macro DSC for the determination of the heat capacity of substrates
- Needle-Probe method for determining the thermal conductivity of substrates
- Climate chamber for determining the specific evapotranspiration capacity of plants
- Hot box for determining the thermal resistance of greening systems



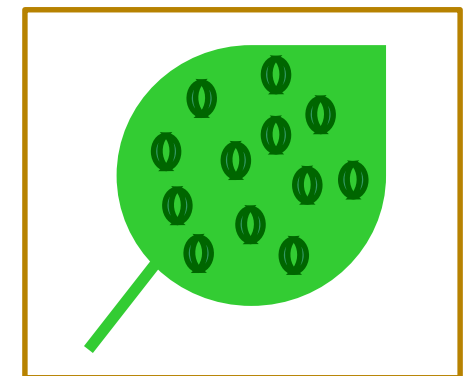
# Methods & Results | Plants Catalogue



- Heat protection (summer) and damping (winter) by

Opacity
<ul style="list-style-type: none"><li>- Leaf position</li><li>- Leaf size</li></ul>

Transpiration
<ul style="list-style-type: none"><li>- Leaf position</li><li>- Leaf size</li><li>- Hairiness of leaf</li><li>- Amount of stomata</li></ul>



# Methods & Results | Plants Catalogue



## SELECTIVE CRITERIA

Living walls	Green facades	Green roofs
<ul style="list-style-type: none"><li>• Dry soil conditions</li><li>• Fresh soil conditions</li><li>➤ sunny/shadowy</li></ul>	<ul style="list-style-type: none"><li>• Direct or indirect greening</li><li>➤ sunny/shadowy</li></ul>	<ul style="list-style-type: none"><li>• Extensive</li><li>• Intensive</li><li>➤ sunny/shadowy</li></ul>

# Methods & Results | Plants Catalogue



**44 plant species**  
= Representatives of

- facade greening
- living walls
- green roofs



focus on different locational factors and morphological differences



*Humulus lupulus*



*Wisteria floribunda*



*Heuchera villosa*  
var. *macrorrhiza*



*Bergenia cordifolia*



*Stachys monnieri*  
'Hummelo'



*Sedum floriferum*  
'Weihenstephaner Gold'

⇒ Complete range of the ability of transpiration and shading

# Methods & Results | Evapotranspiration



## MEASUREMENT OF PLANT EVAPOTRANSPIRATION RATE

- Measurement setup in climate chamber
- Three plants of each species
- Measurement of the evapotranspiration amount by weighing
- Temperature = 25°C, humidity = 50%, illumination intensity  $\approx$  70 kLux (center area)
- Measurement under water saturation
- Separate measurement of the evapotranspiration amount of plant and substrate
- First results of winter measurements with greenhouse plants





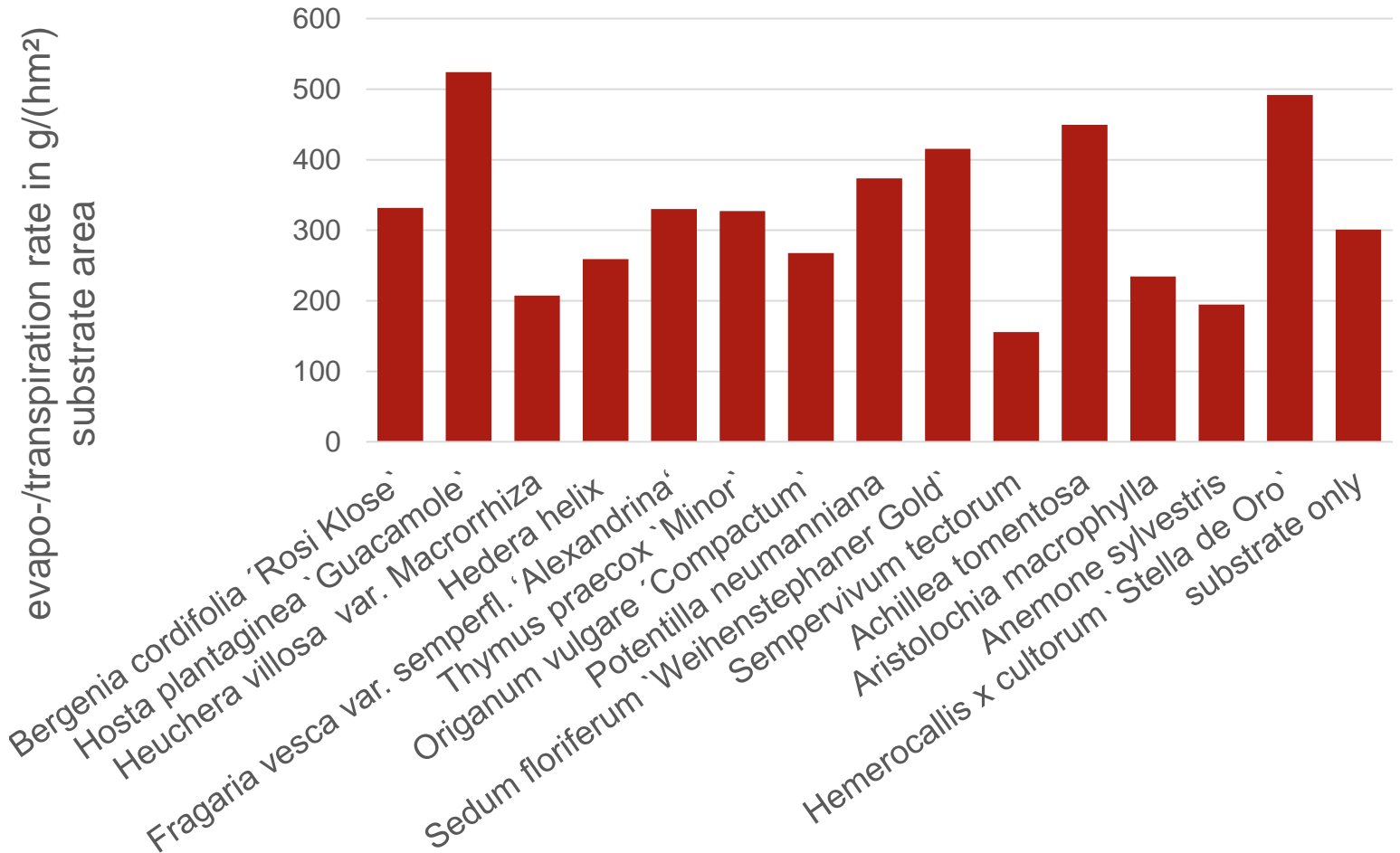
# Methods & Results | Evapotranspiration



## MEASUREMENT OF PLANT EVAPOTRANSPIRATION RATE

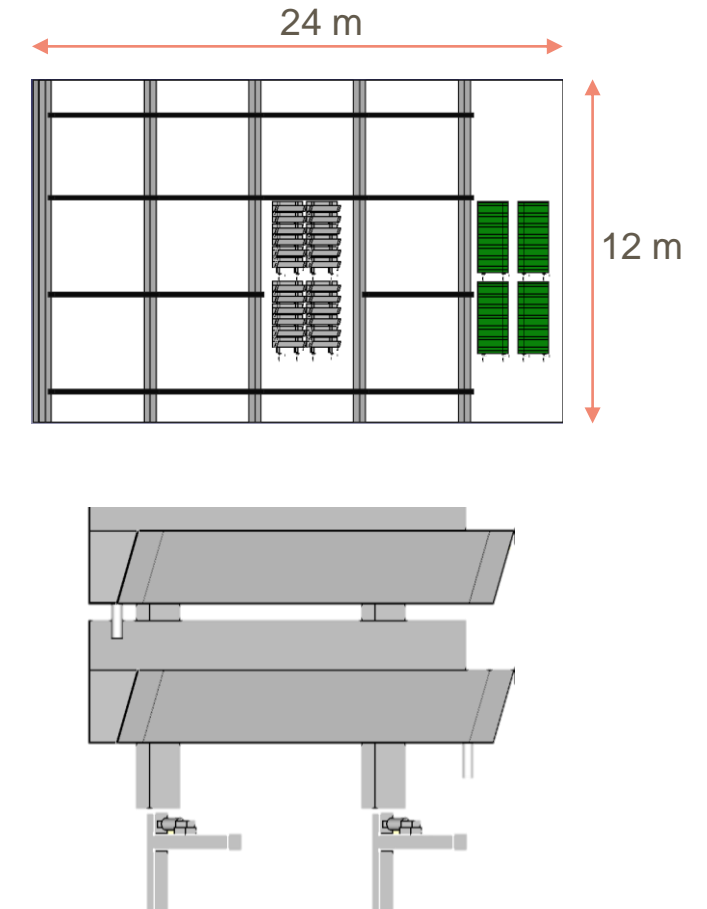
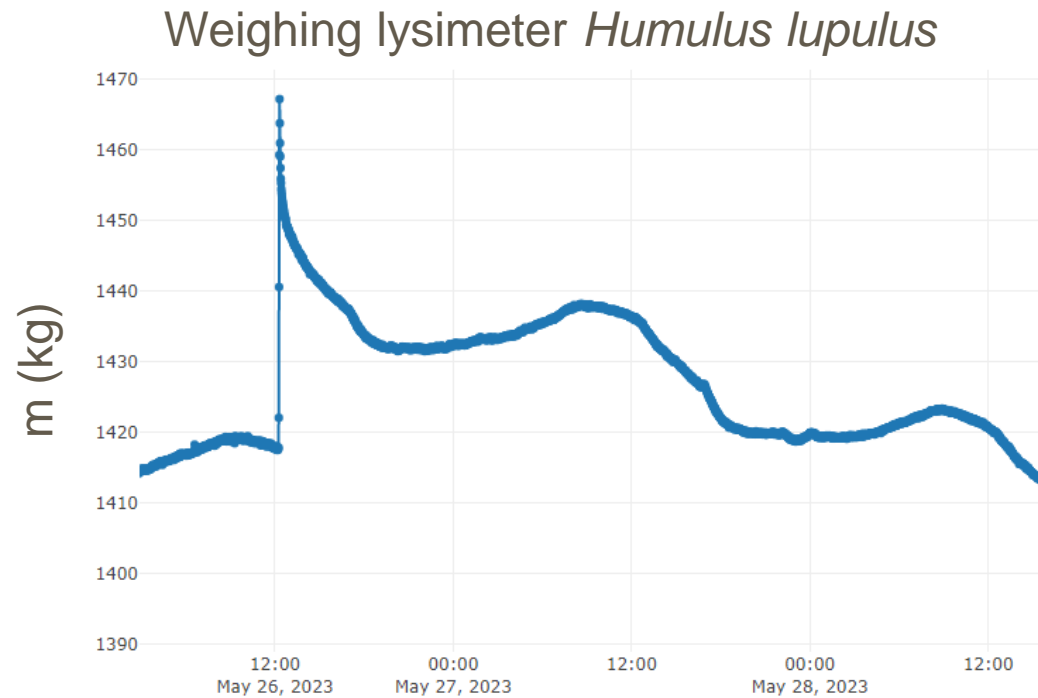
- Data for plant transpiration without substrate evaporation
- large differences between species
- Substrate evaporation in the same order of magnitude
- Total cooling power of 200 – 550 W/m<sup>2</sup> (plant & substrate)

→ **SUBSTANTIAL COOLING EFFECT!**



# Methods & Results | Evapotranspiration

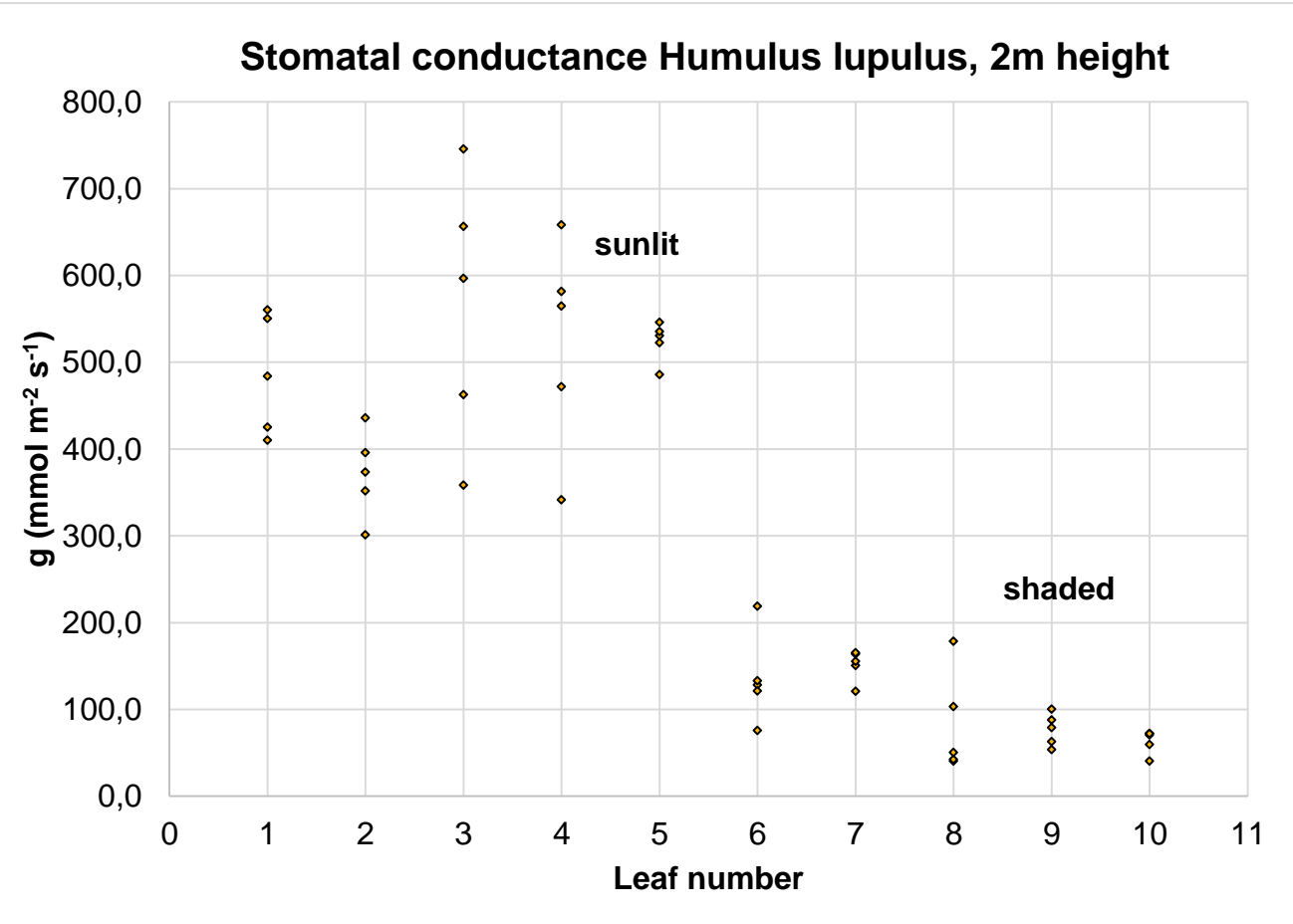
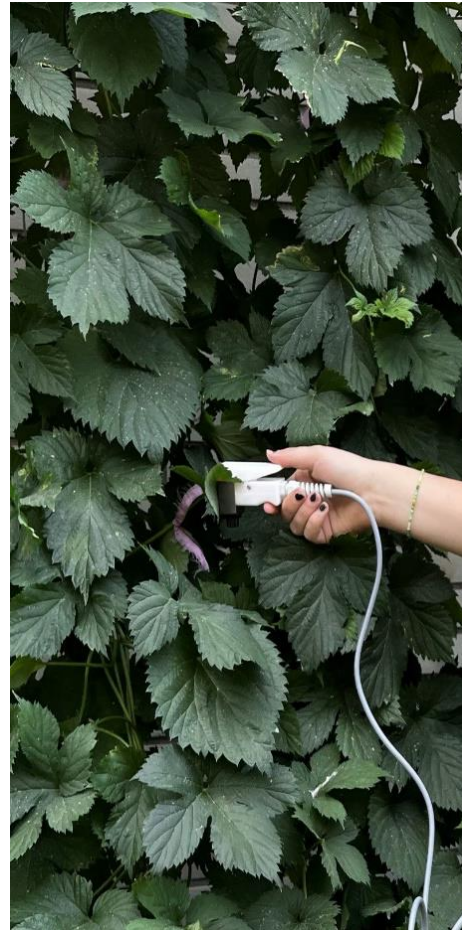
## MEASUREMENT OF PLANT EVAPOTRANSPIRATION RATE



# Methods & Results | Evapotranspiration

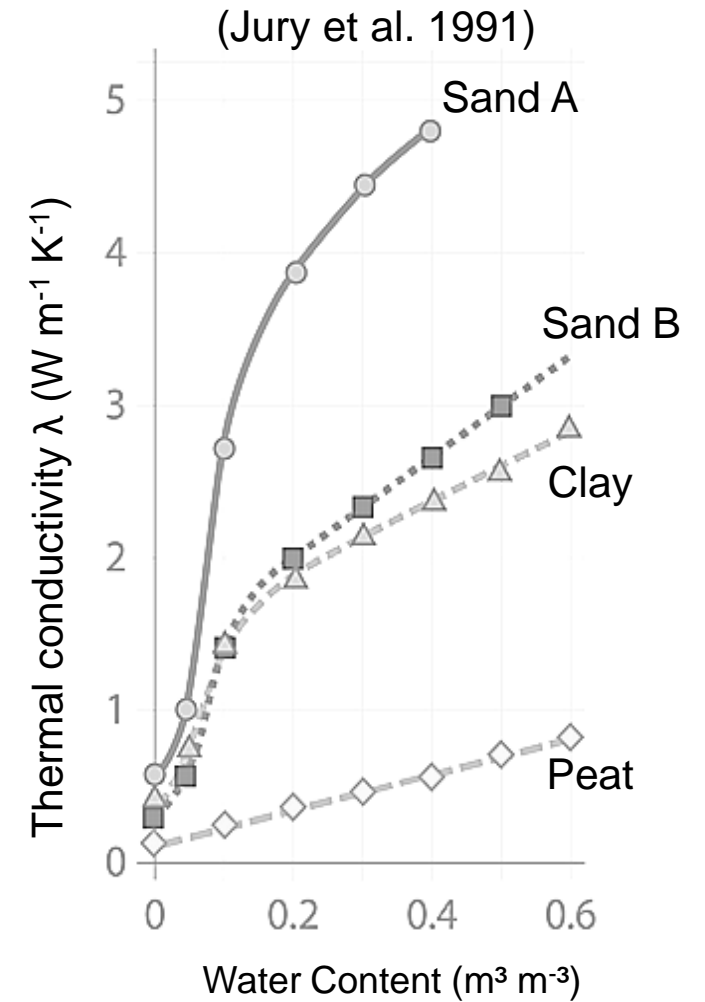
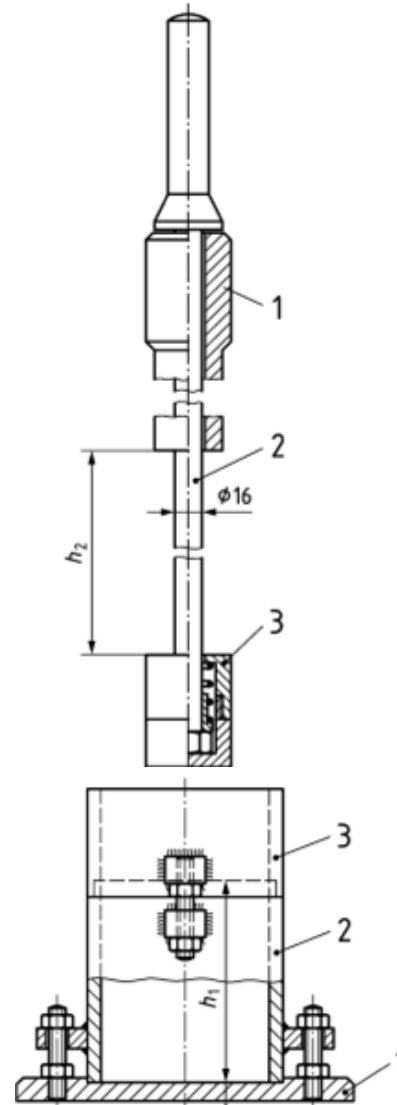
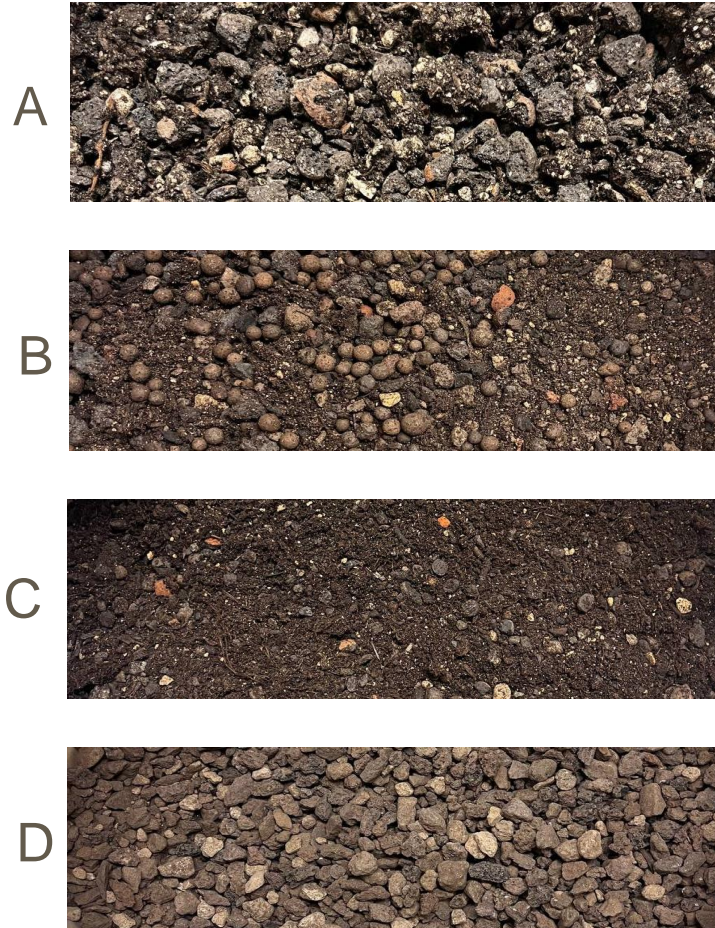
## MEASUREMENT OF PLANT EVAPOTRANSPIRATION RATE

- Stomatal conductance of selected plants
- Evaluation of height-dependencies
- Continuous quantification over vegetation period



# Methods & Results | Thermal Characterization

## THERMAL CONDUCTIVITY OF SUBSTRATES

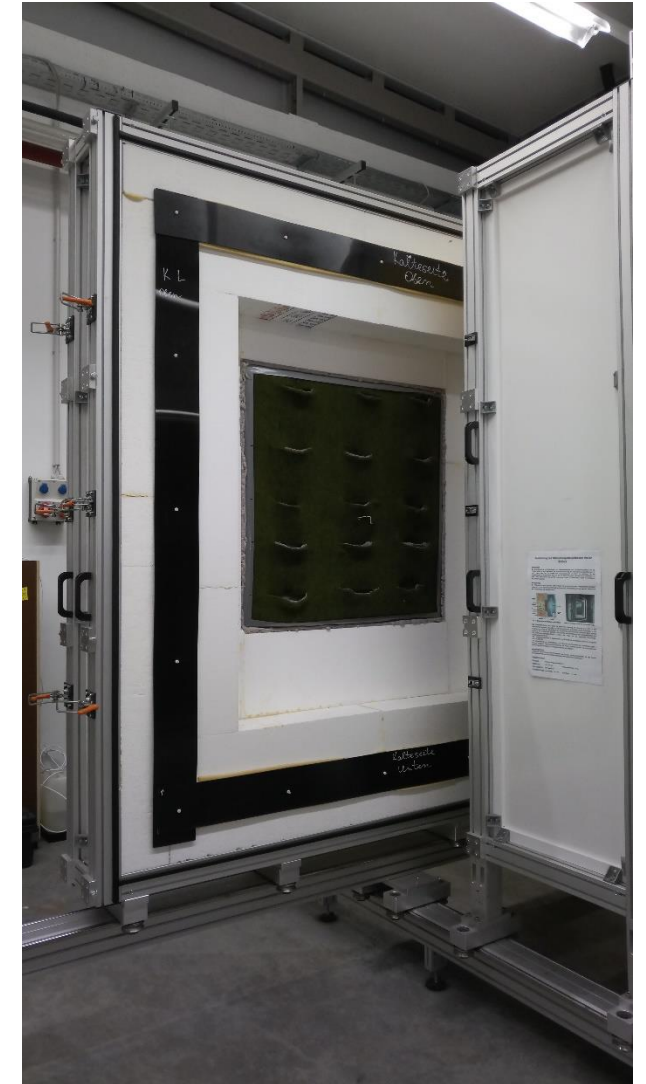
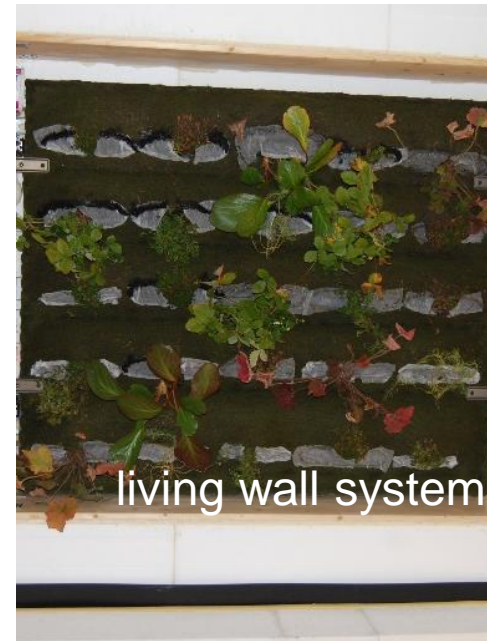


# Methods & Results | Thermal Characterization



## MEASUREMENT OF THERMAL RESISTANCE

- Measurement of three façade systems in Hot-Box
- Determination of thermal resistance by comparison with reference wall
- Measurement with and without rear ventilation

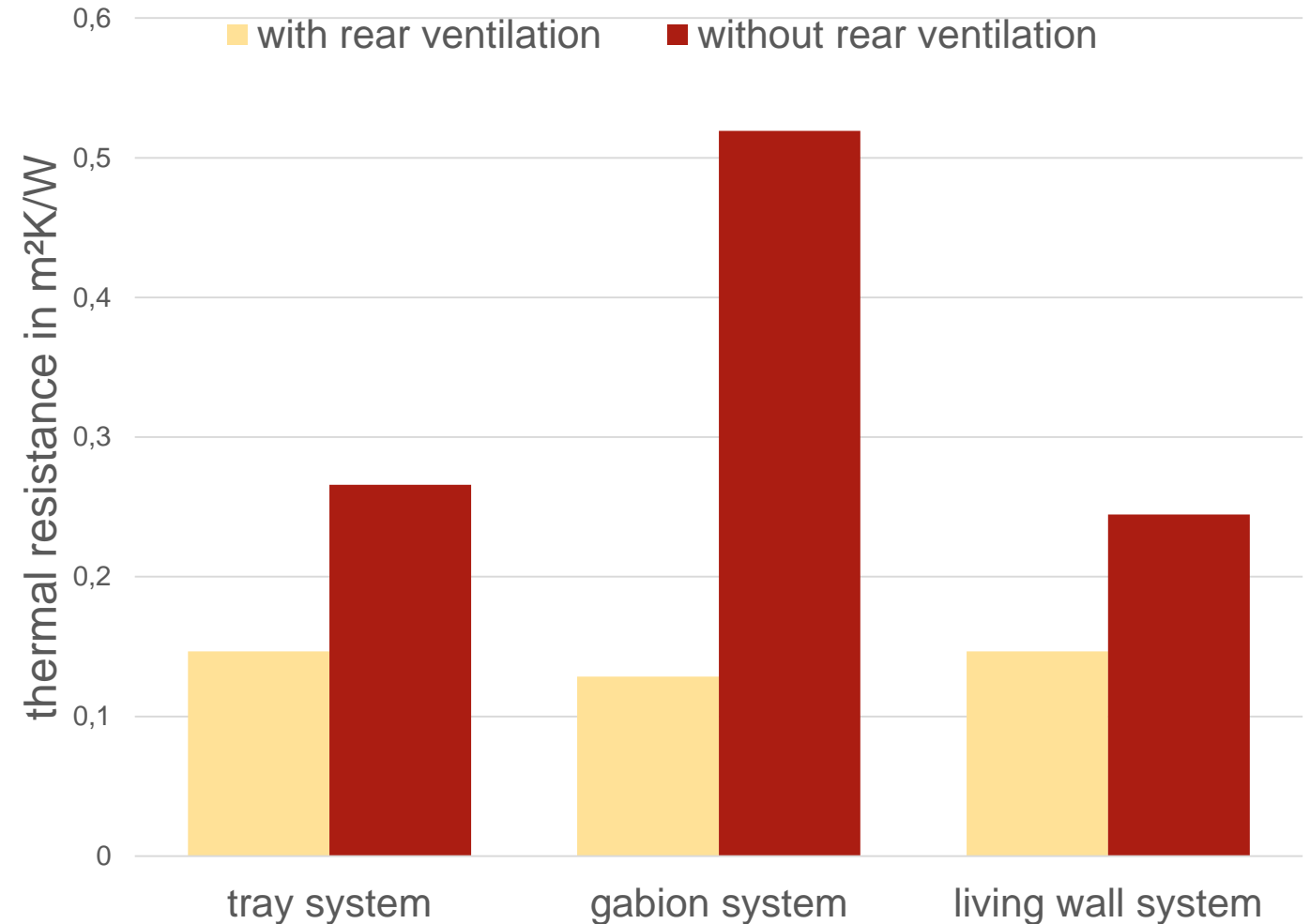


# Methods & Results | Thermal Characterization



## MEASUREMENT OF THERMAL RESISTANCE

- Similar thermal resistances when rear ventilated
- Big differences without rear ventilation
- All data without thermal influence of the support system  
→ ideal mounting



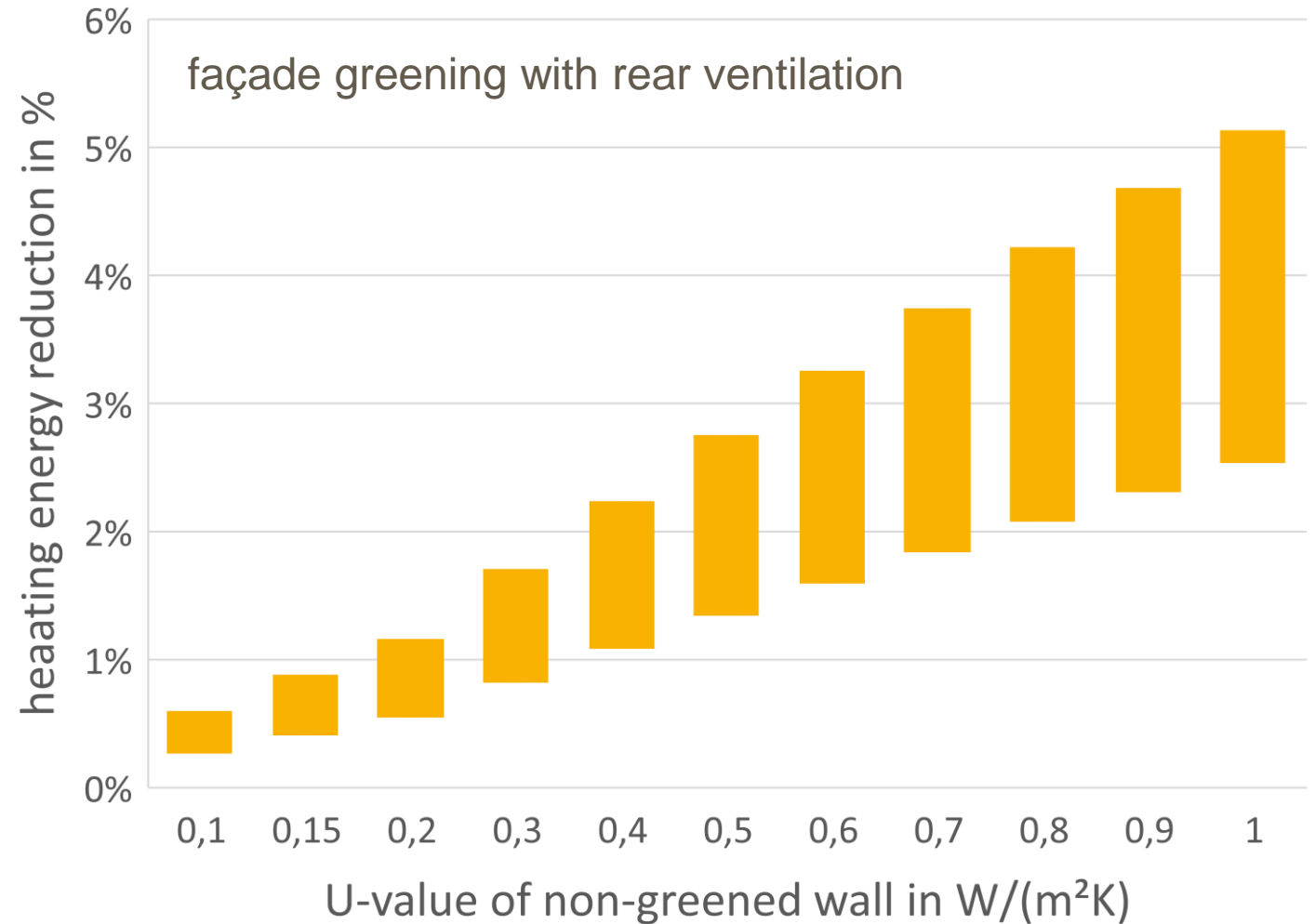
# Methods & Results | Thermal Characterization



## EFFECT ON HEATING REQUIREMENT OF ENTIRE BUILDING

- Façade greening on complete wall area with ideal mounting
- Walls contribute with 20-40% to the total heating demand (typical range for residential buildings)
- Less effect with better insulated walls

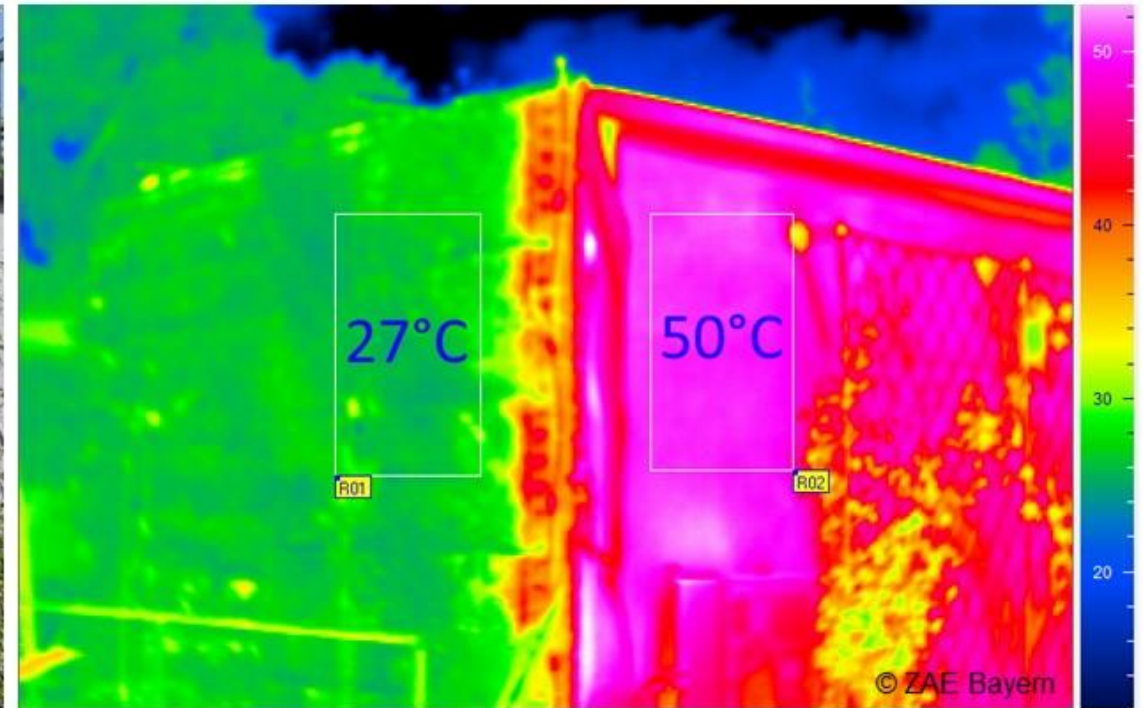
**→ IMPROVEMENT OF WINTER THERMAL INSULATION THROUGH FAÇADE GREENING FOR NEW BUILDS IS NEGLIGIBLE!**



## Methods & Results | Thermal Characterization



- Climate house with test façades to determine the thermal behavior of green façades
- Test set-ups to determine the thermal behavior of green roofs
- Measurement of heat flows and temperatures under real conditions, comparison with reference system for summer and winter cases

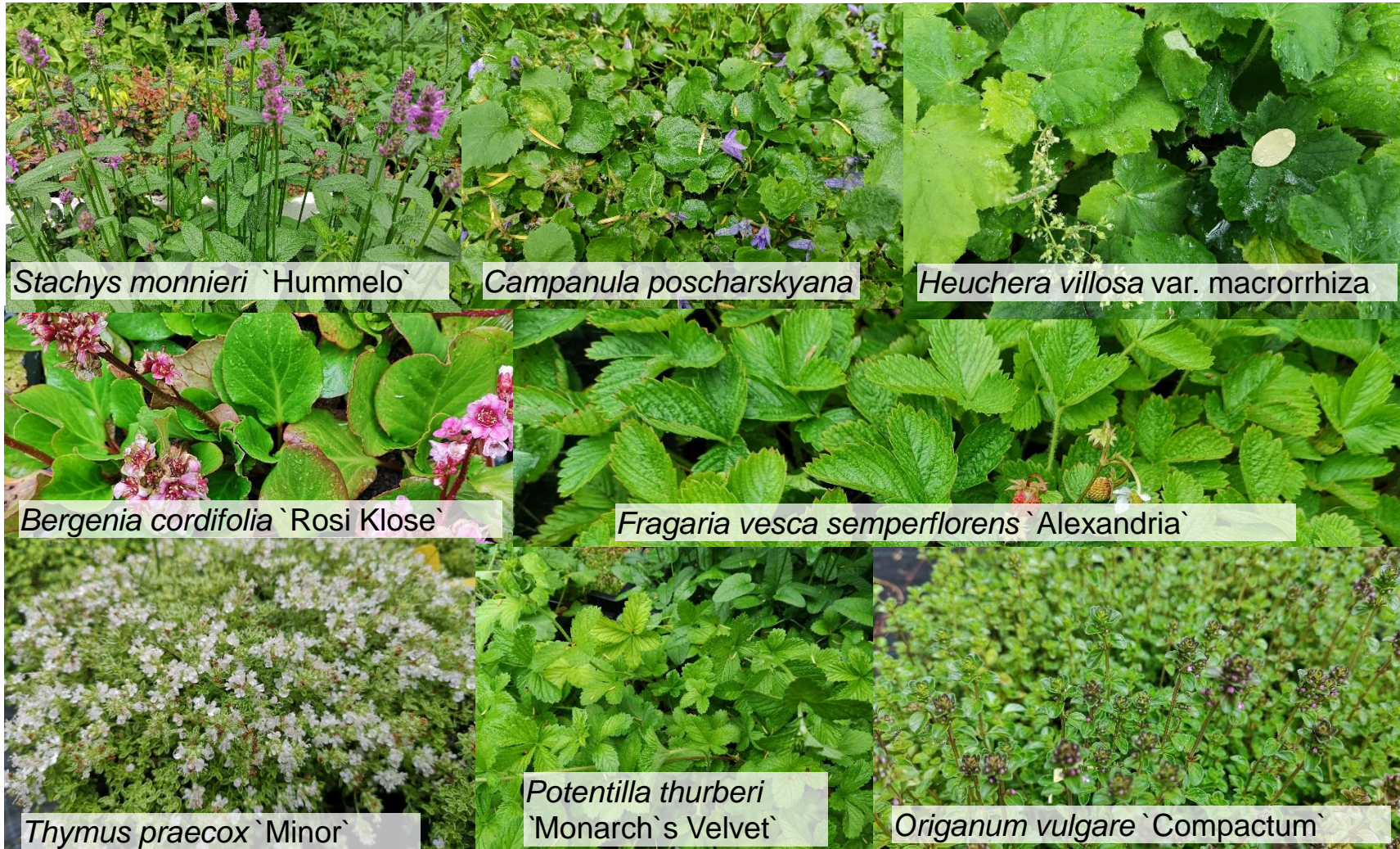




# Planting scheme for Thermal Characterization .... under real conditions



## Plants for the sunny facade



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# Outlook



**Thank you for your attention**



**... and the Federal Ministry for Economical Affairs and Climate Action for funding this project!**

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Gefördert durch:



aufgrund eines Beschlusses  
des Deutschen Bundestages



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Energieeffizienz und  
Nachhaltigkeit  
Bayerische  
Architektenkammer

