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Hydrological and thermal response of green roofs in different climatic conditions

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Green roofs

Green roofs

- are the most developed and established green building envelopes technology
- are becoming a predominant solution in urban planning
- and increasingly used alternative at building envelope retrofitting

Extensive green roofs

- low additional structural load
- low cost
- low maintenance

Key advantage in urban environment

- stormwater retention

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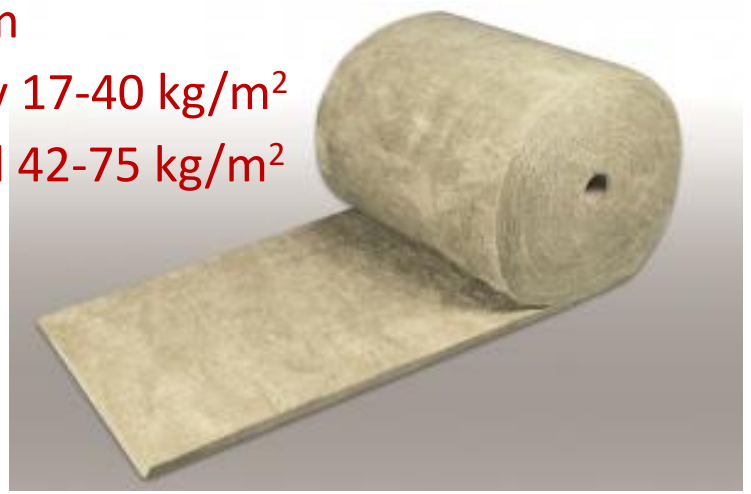
Lightweight extensive green roofs:

- simple installation, lower thickness and weight
- mineral wool growing media

  high (>80% volume) water retention capacity
- thickness: 2 – 10 cm
- overall weight: dry 17-40 kg/m^2

  saturated 42-75 kg/m^2



Green roof model

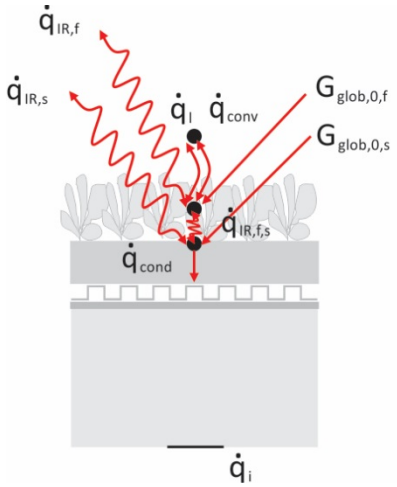
1D transient heat transfer model

coupled eq. on 2 outer boundary planes: foliage and growing media

- absorbed global solar radiation
- long-wave radiation exchange
- convective heat fluxes on 2 planes

  considers LAI, ΔT, aerodynamic resistance (including stability correction factors at $T_f > T_a$)
- latent heat flux by ET
- conduction heat flux
- heat accumulation in substrate and loadbearing construction

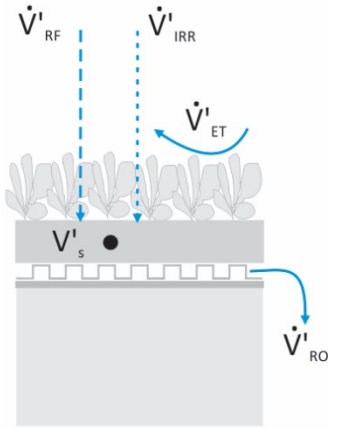
  water content dependent material properties; latent heat at freezing temperature conditions



Water balance

- rainfall
- irrigation
- evapotranspiration

  empirical expression for reduced ET at water stress conditions
- water content in growing media
- outflow



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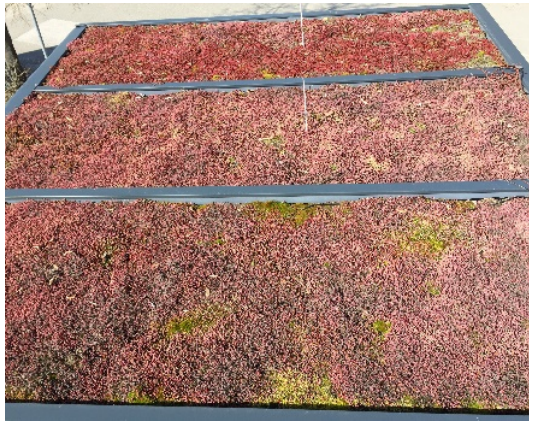
Green roof model validation

Laboratory test building with green roofs modules

- experimental research since 2013
- lightweight extensive green roofs with rock mineral wool growing media



Sedum-mix plants

Green roof model validation

Laboratory test building with green roofs modules

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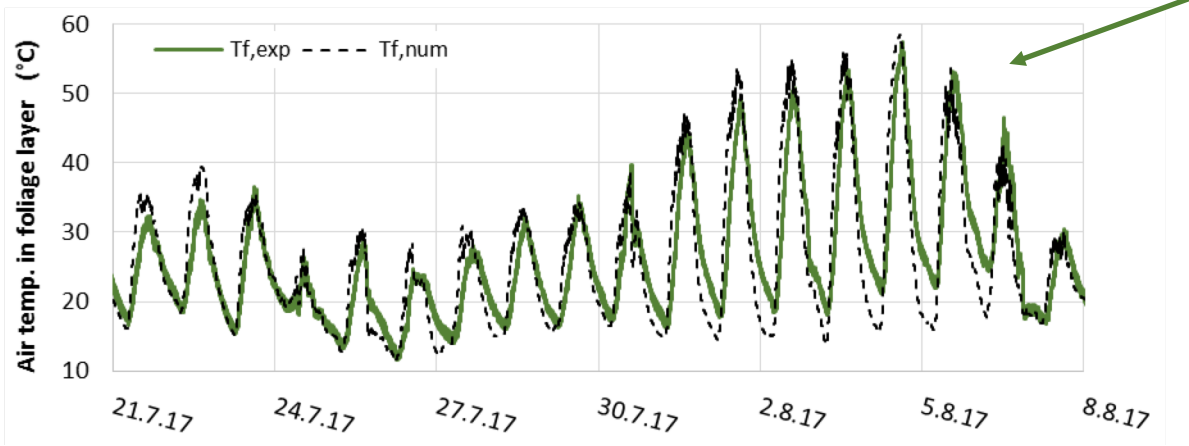
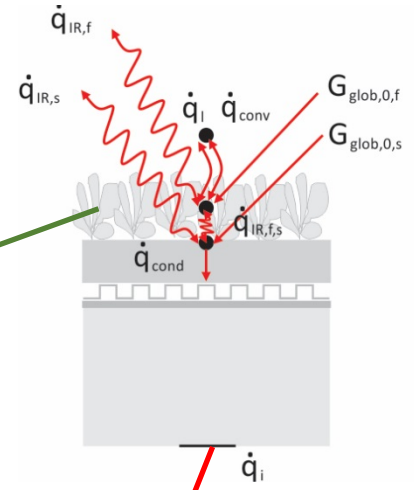
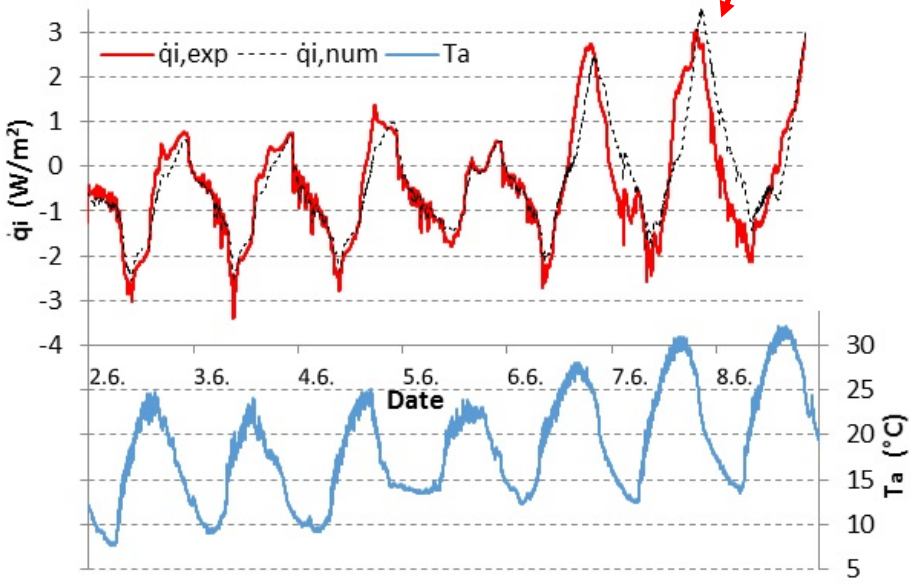
Validation of green roof thermal response

- inner surface heat flux
- air temperature in foliage layer







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Green roof model validation

Laboratory test building with green roofs modules

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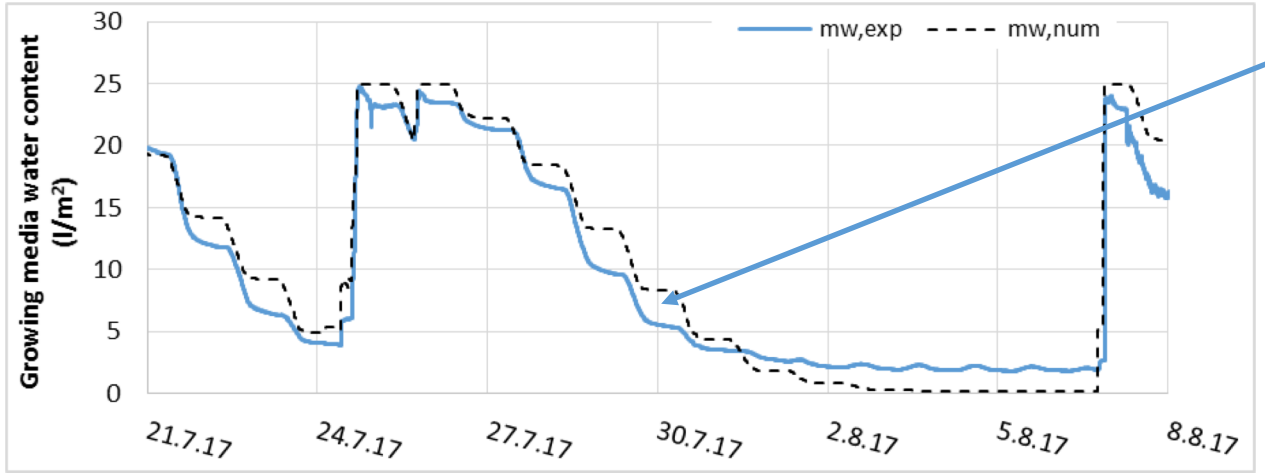
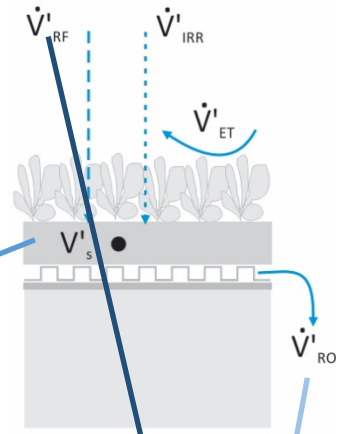
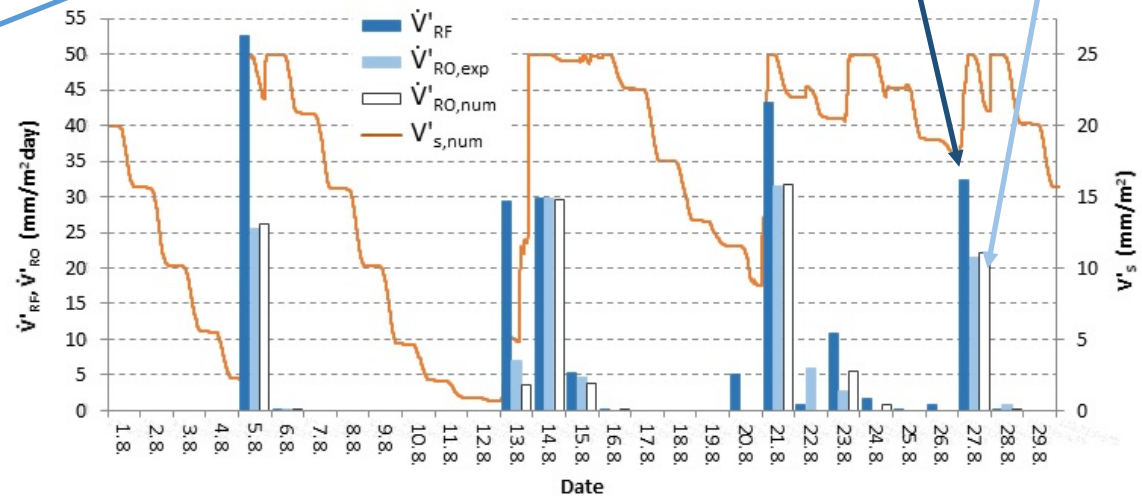
Validation of green roof hydrological response

- mineral wool growing media water content
- daily run-off (outflow)





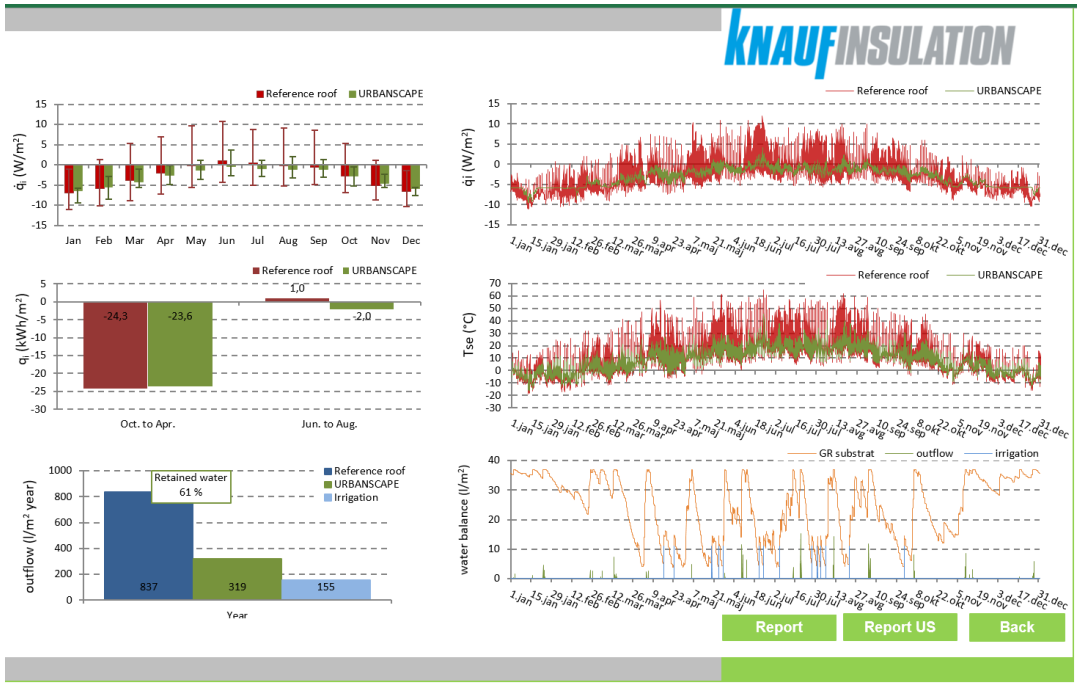


Green roof software

Software tool for performance analysis

adapted to lightweight extensive green roofs with mineral wool growing media

comparison with non-vegetated roof



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Green roof performance analysis

Analysis

- heat losses in heating season Nov. – Apr.
- heat gains in summer June – Sept.

  compared to reference non-vegetated roof: lightweight; U=0.34 W/m²K (10 cm TI); dark (α_s=0.7)
- retained water
- irrigation

Lightweight extensive green roofs

- thickness of mineral wool growing media: 2, 4, 6, 8 cm

  max. water content: 25, 37, 54, 66 l/m²
- irrigation scenarios: no irrigation

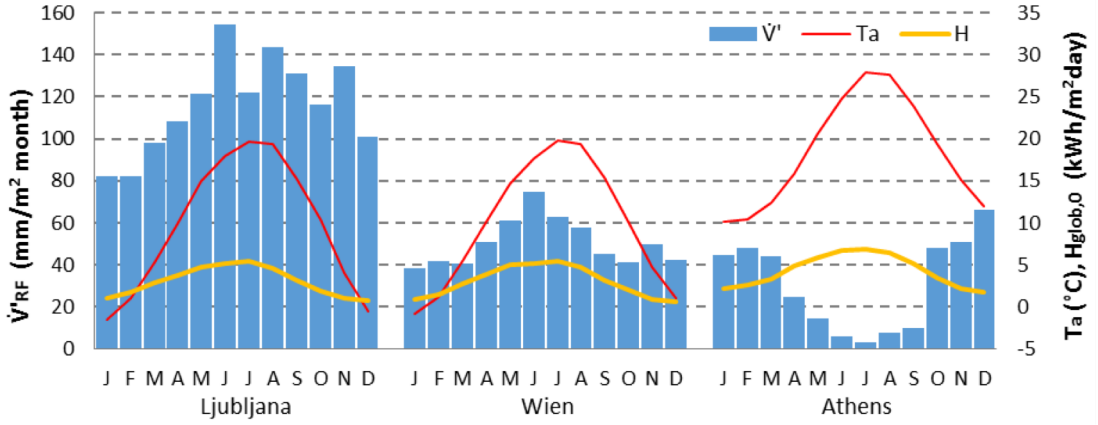
  irrigation if VWC < 20% (to 50%)

  irrigation based on weather forecast (5 days)

Cities

Continental and Mediterranean climate conditions

high, medium and low rainfall



	Ljubljana	Wien	Athens
ambient temperature (°C)	10	10	18
solar irradiation (kWh/m²a)	1100	1100	1560 (+40%)
rainfall (mm/m²a)	1400	600 (44%)	370 (26%)

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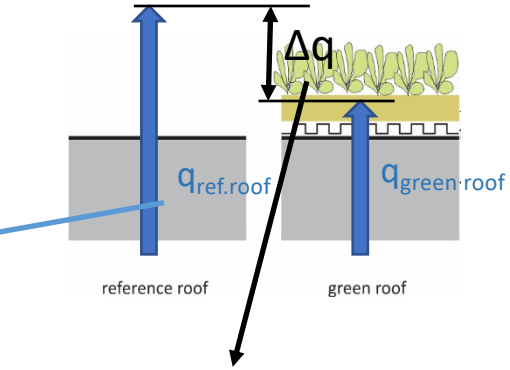

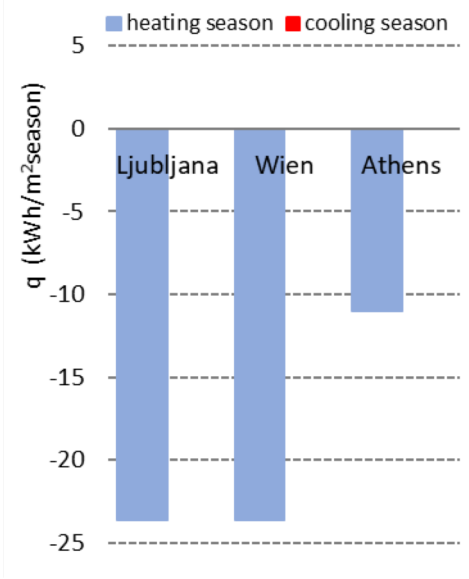

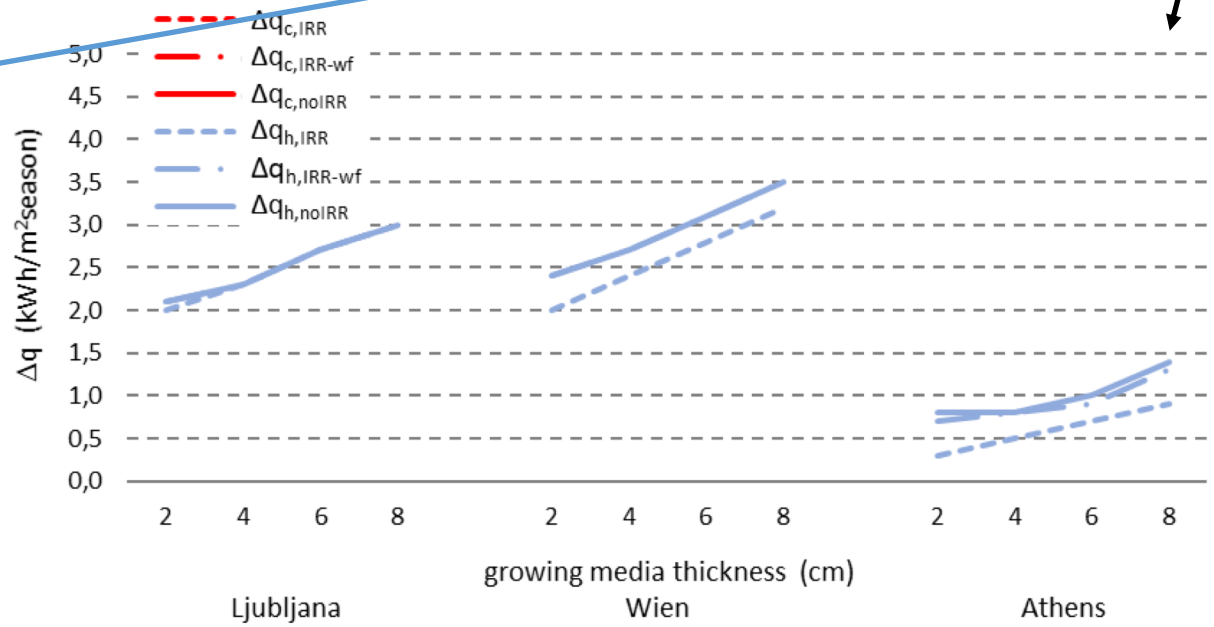

- 7% to 15% heat losses reduction in case of noIRR

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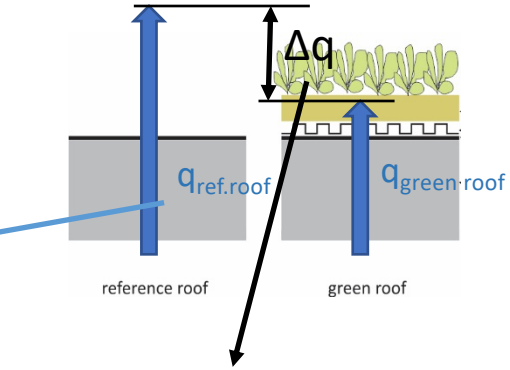
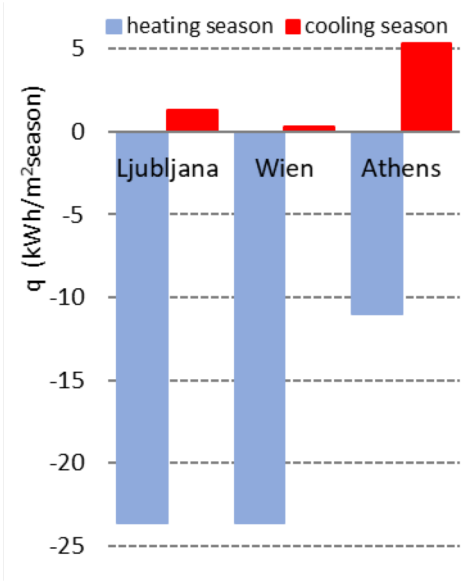
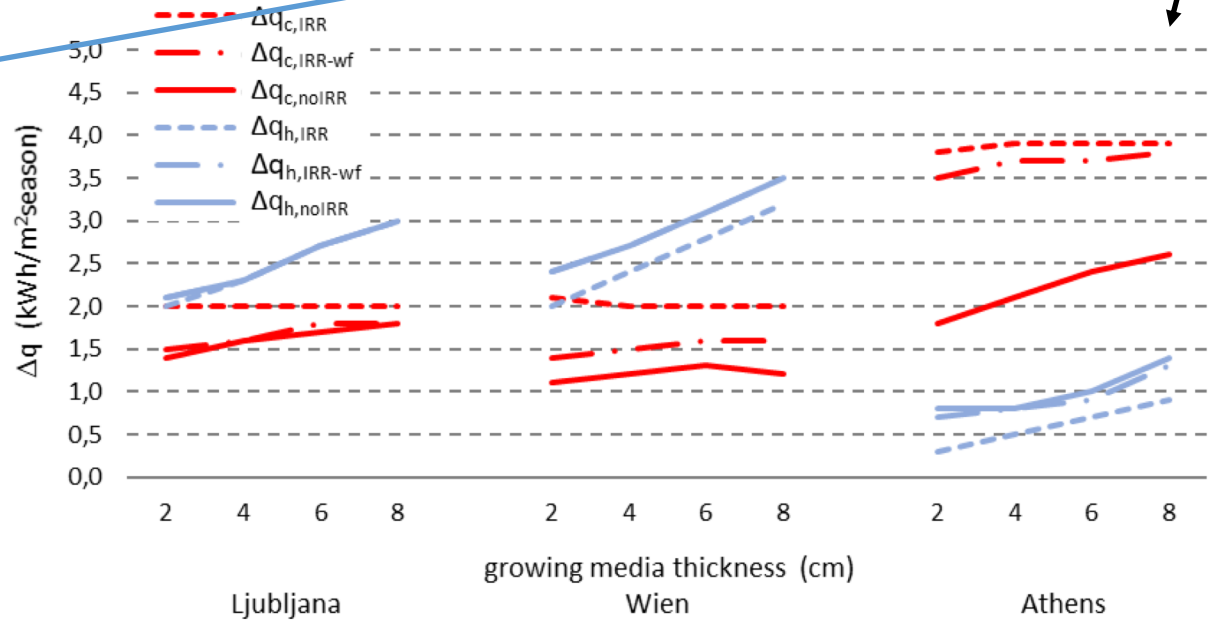




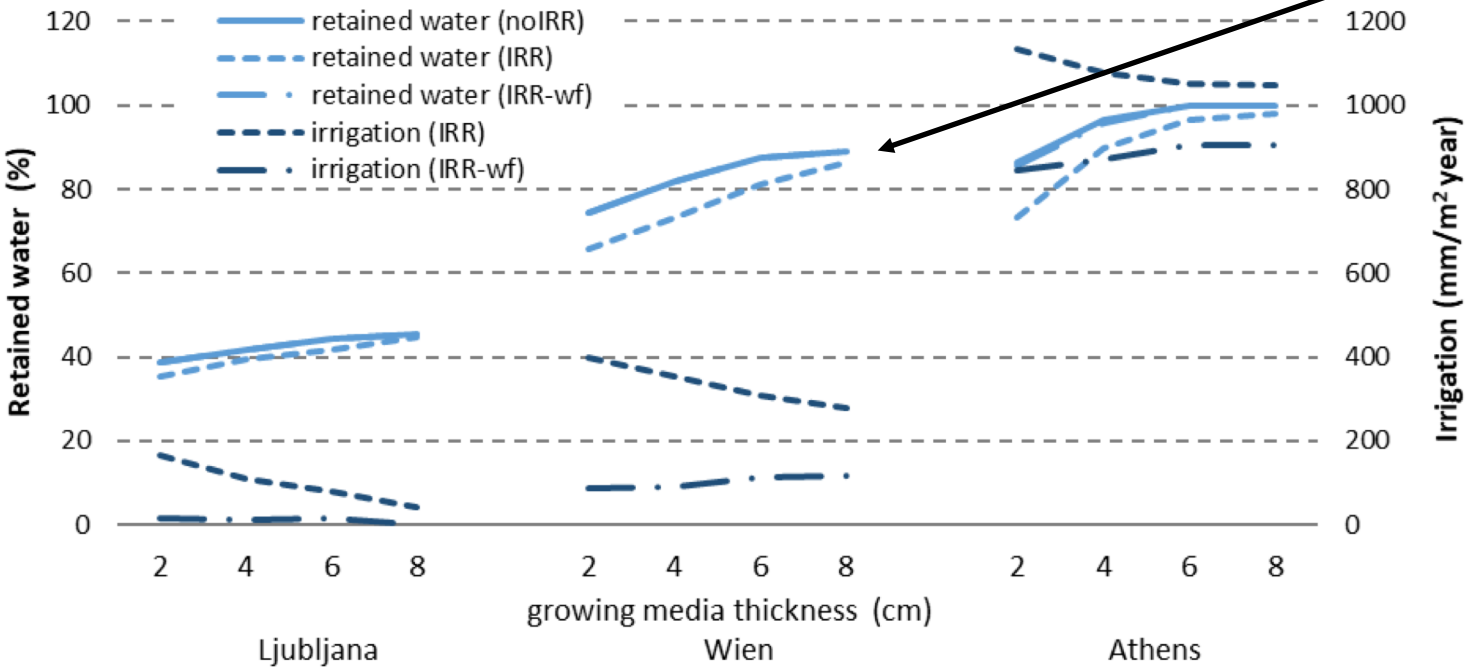


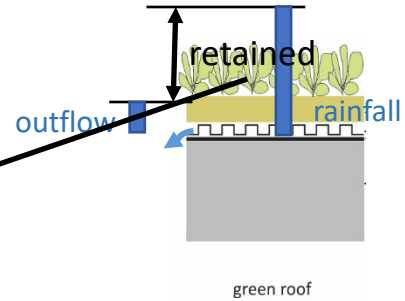
- 7% to 15% heat losses reduction in case of noIRR
- heat gains to heat losses in Ljubljana and Wien (Continental)
- in Athens heat gains reduced for up to 75%

Green roof performance analysis

Analysis

- retained water (% rainfall)
- irrigation (l/m²y)





- highest water retention in case of no irrigation
- the same for weather forecast irrigation; no risk of plant withering; considerably reduced irrigation water
- 4 cm or 6 cm for optimal retention

Conclusions

- Optimal green roof composition (growing media thickness) can only be determined taking into account local climate conditions
- Weather forecast based irrigation can provide the best green roof performance

Thank you for your attention !