Urban Microclimate and Building Interactions

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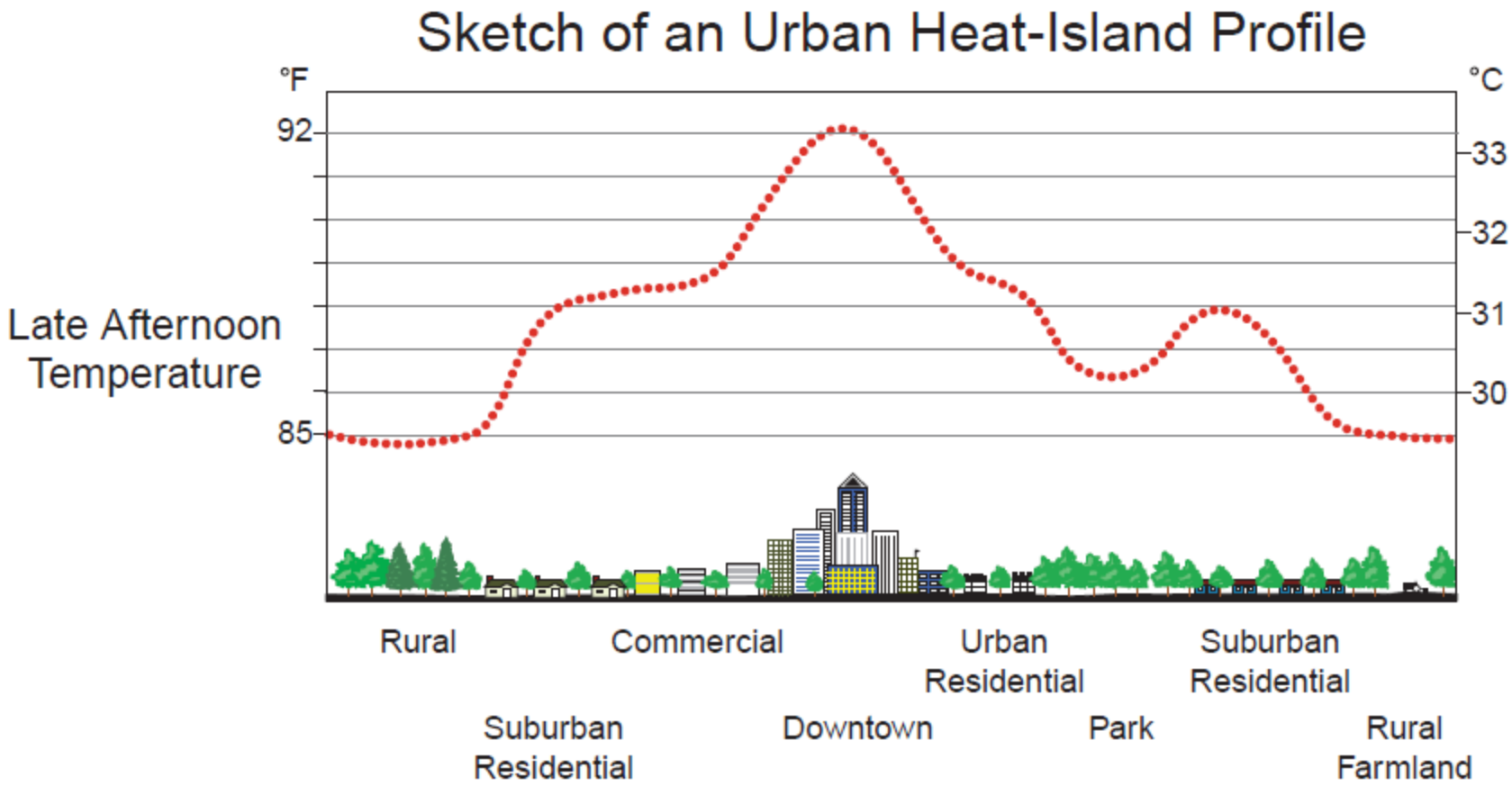
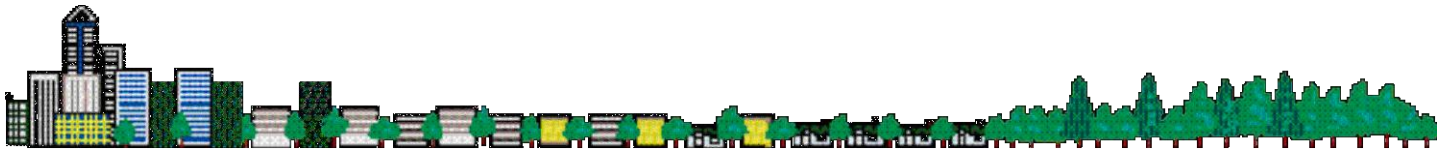
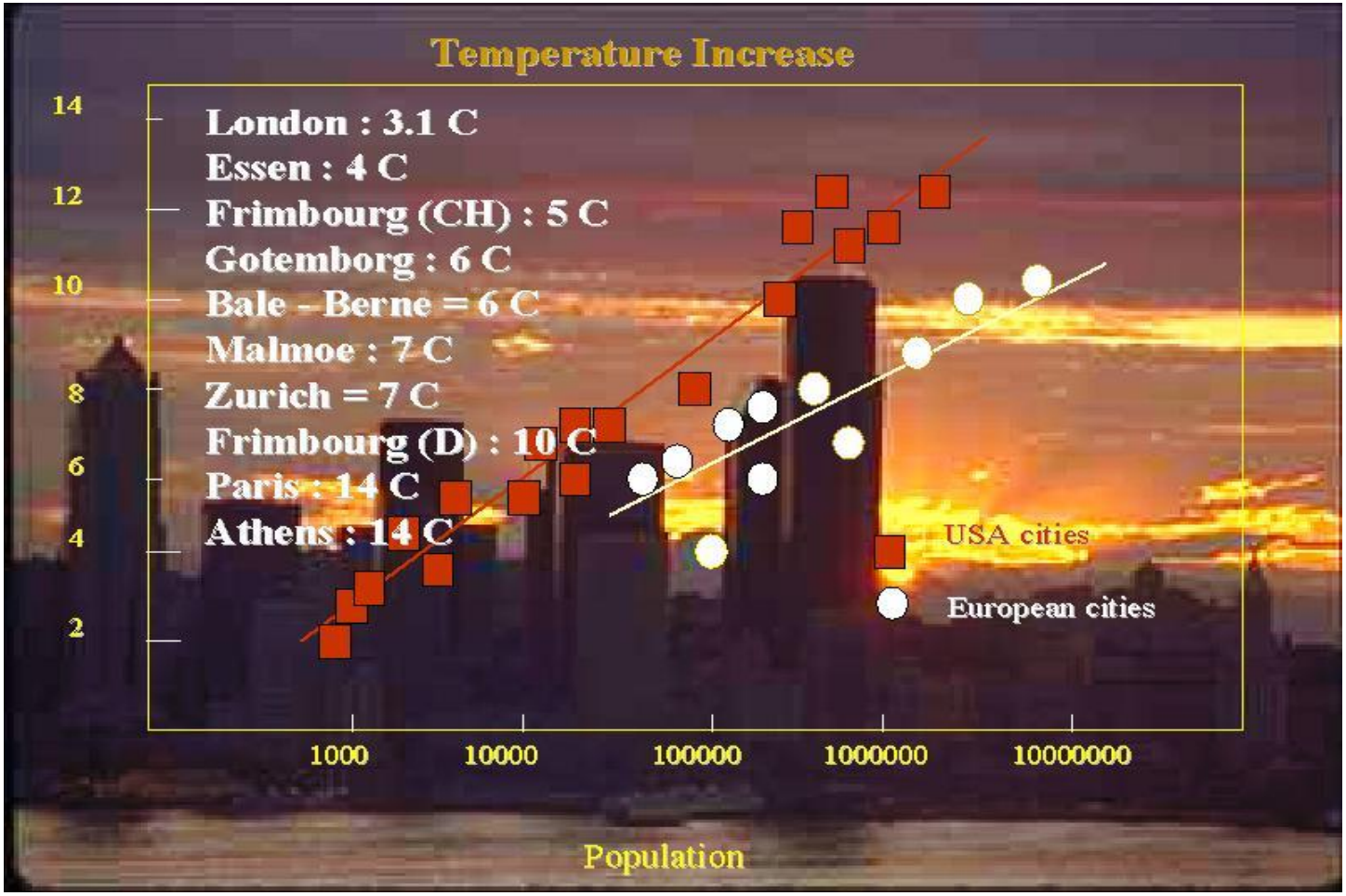
Urban Heat Island phenomenon



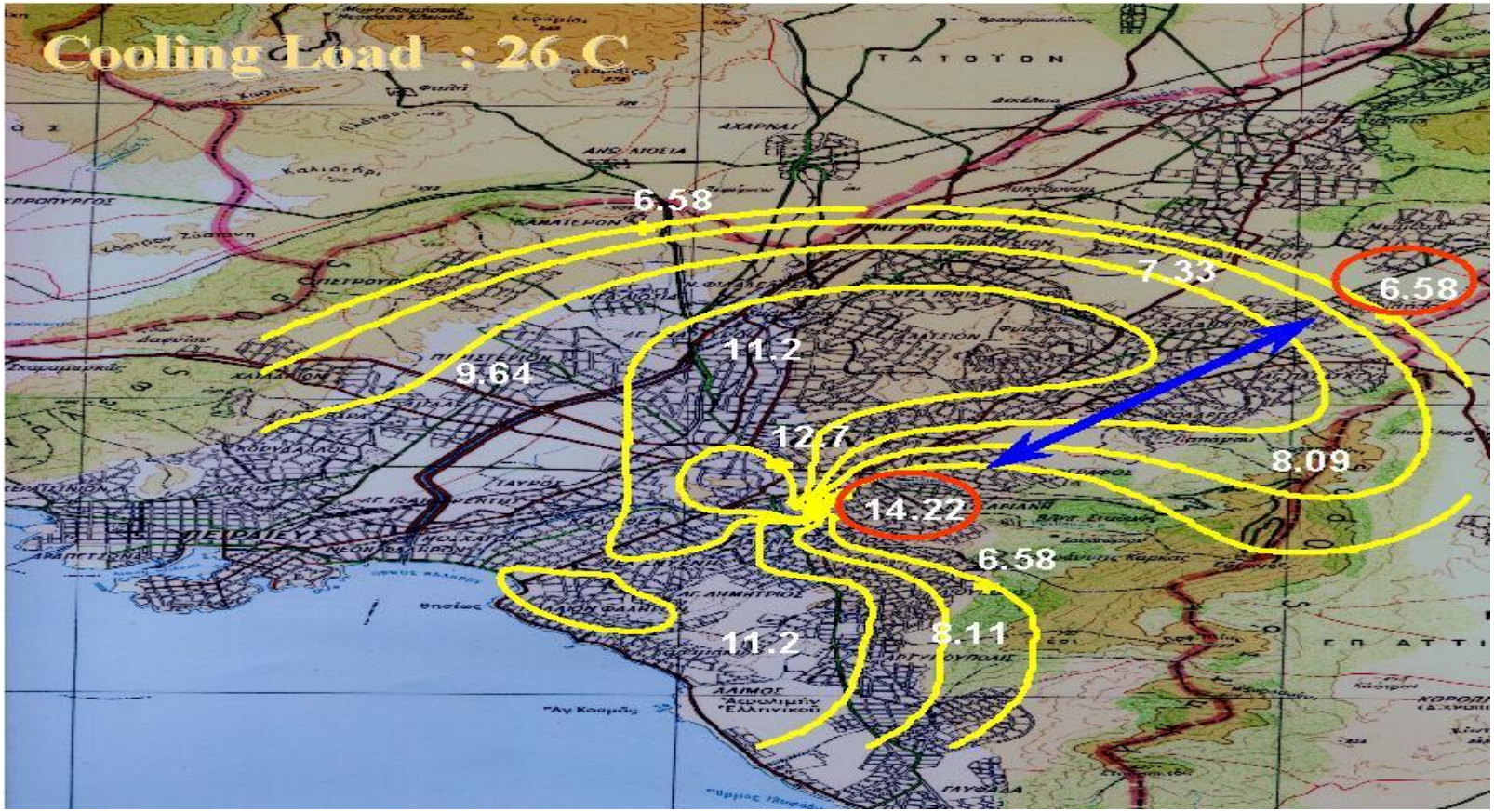


Evolution of urban temperatures



Maximum difference in urban and rural temperature for US and European cities. From [Littlefair, 2000], data from (Oke 1982).

Urban Heat Island and cooling loads

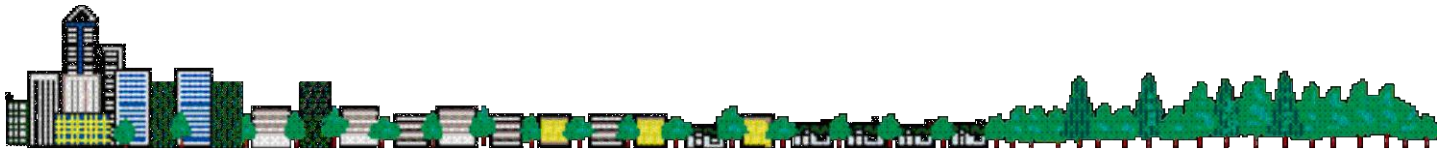


Distribution of cooling load [kWh/m^3] in Athens 2004, for a set point of 26 C, (Santamouris et al, 2004)

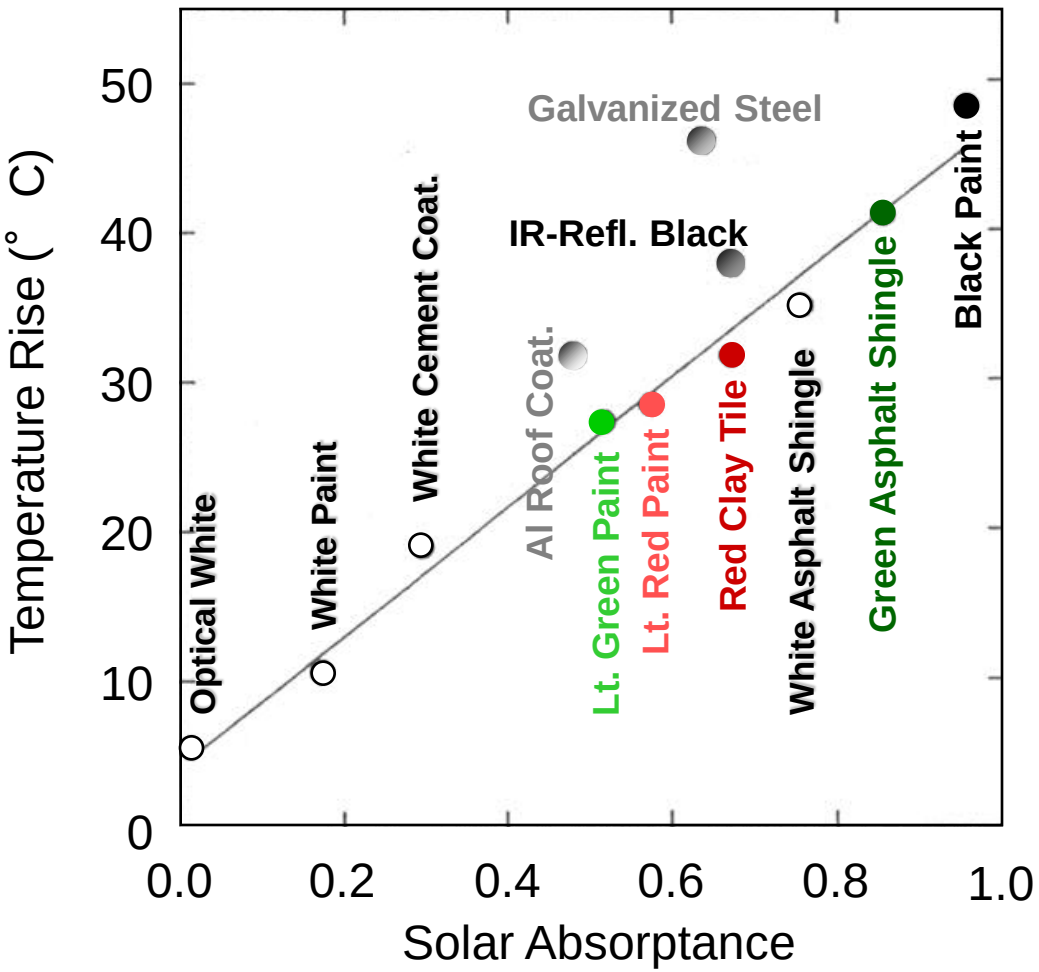
Main causes of Urban Heat Island

- Low surface albedo
- Low evapotranspiration rate
- Geometry and orientation
- Anthropogenic heat
- Urban greenhouse effect

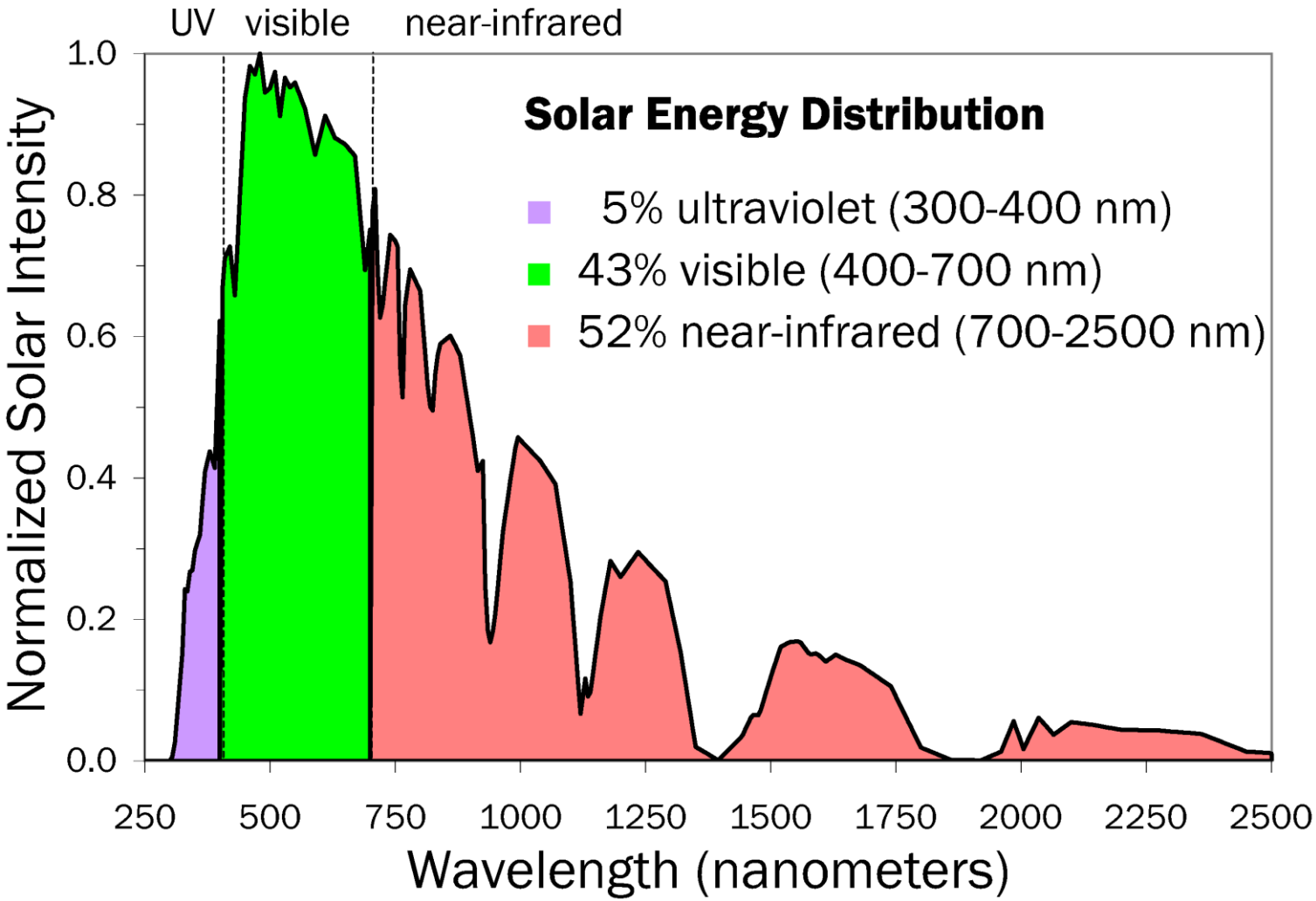
- Cool surfaces
- Greenery



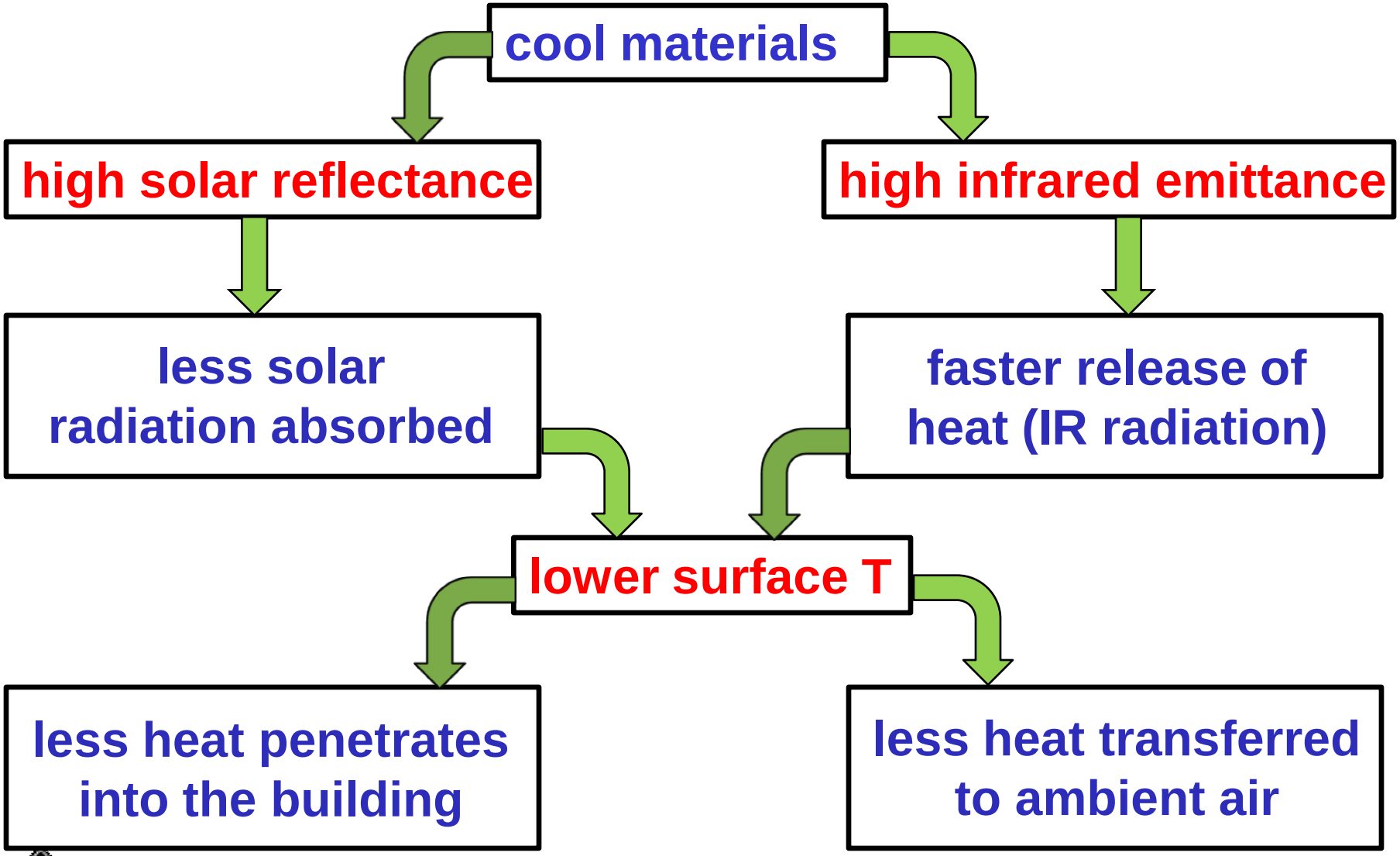
Temperature rise of various materials in sunlight

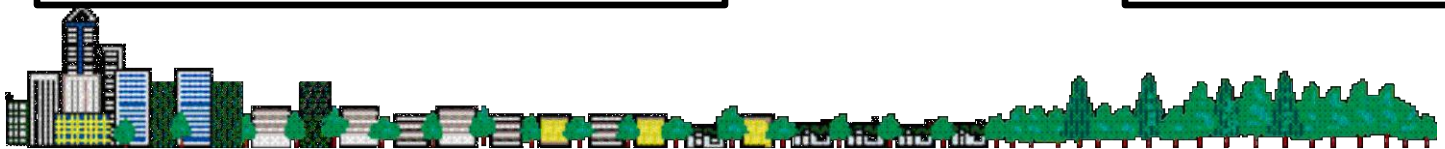


Cool colors reflect invisible near-infrared sunlight



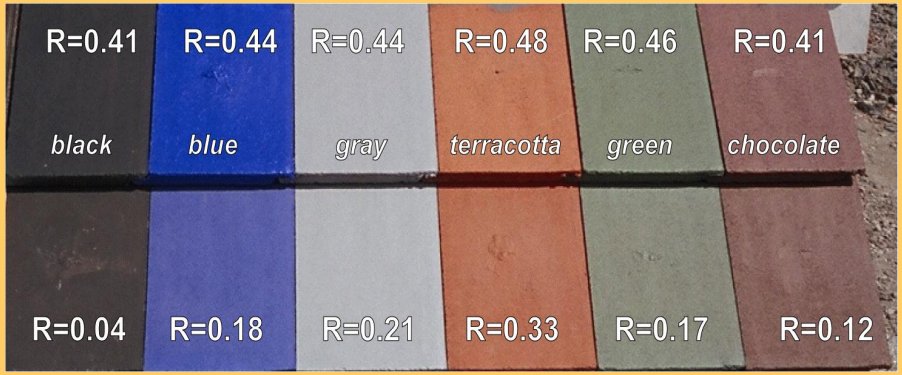
Principle of cool materials





Cool roof technologies

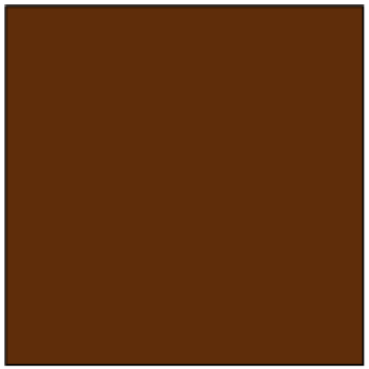
cool concrete tile R ≥0.40	R=0.41 black	R=0.44 blue	R=0.44 gray	R=0.48 terracotta	R=0.46 green	R=0.41 chocolate
standard concrete tile (same color)	R=0.04	R=0.18	R=0.21	R=0.33	R=0.17	R=0.12
solar reflectance gain =	+0.37	+0.26	+0.23	+0.15	+0.29	+0.29



Courtesy American Rooftile Coatings

Courtoisie de BASF Coatings

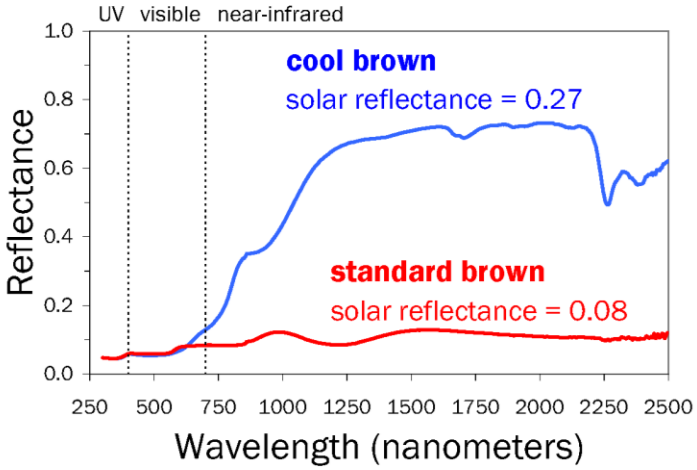
cool



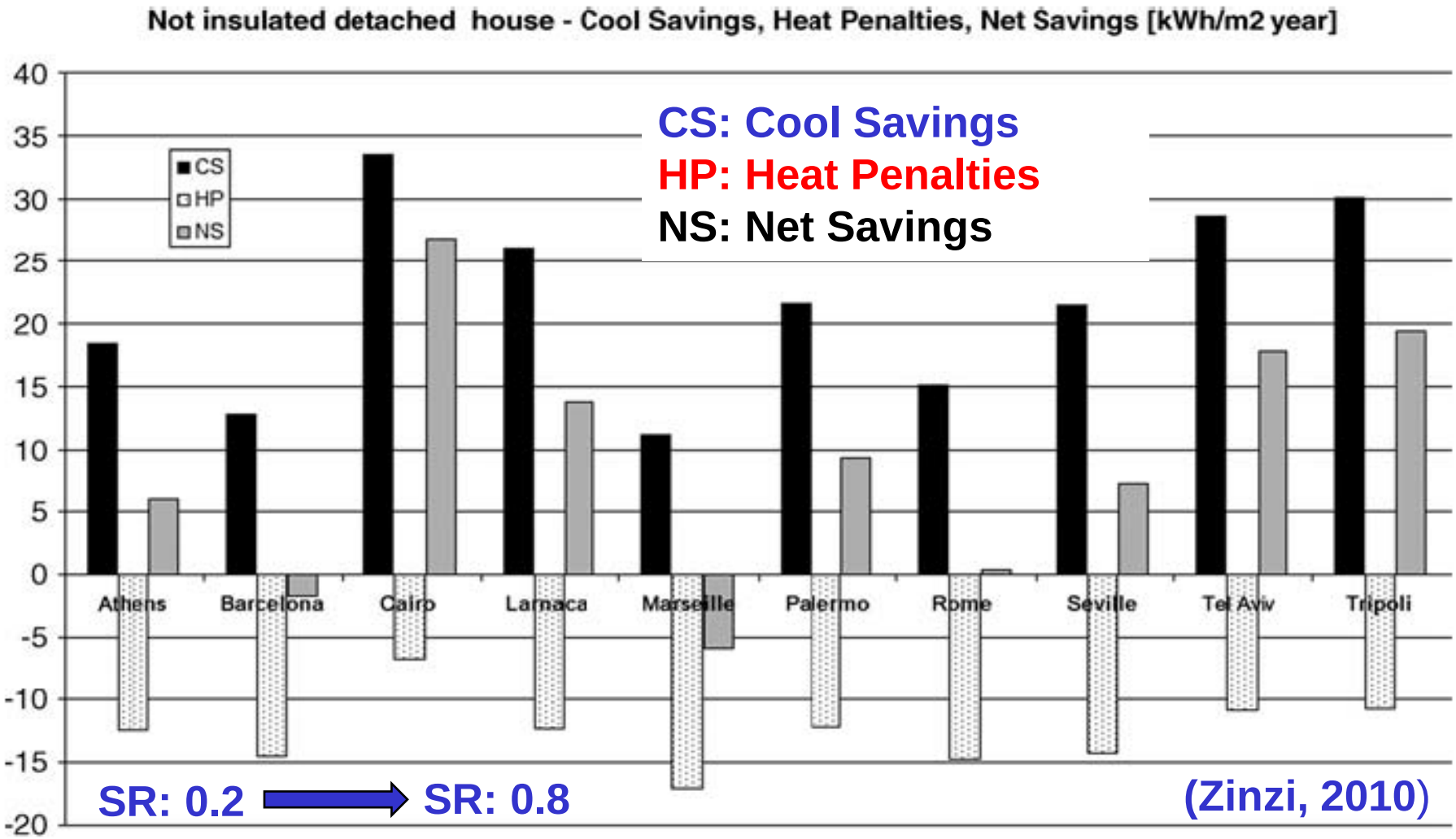
solar reflectance = 0.27
thermal emittance = 0.85
roof temp – air temp = 36°C (65°F)

standard

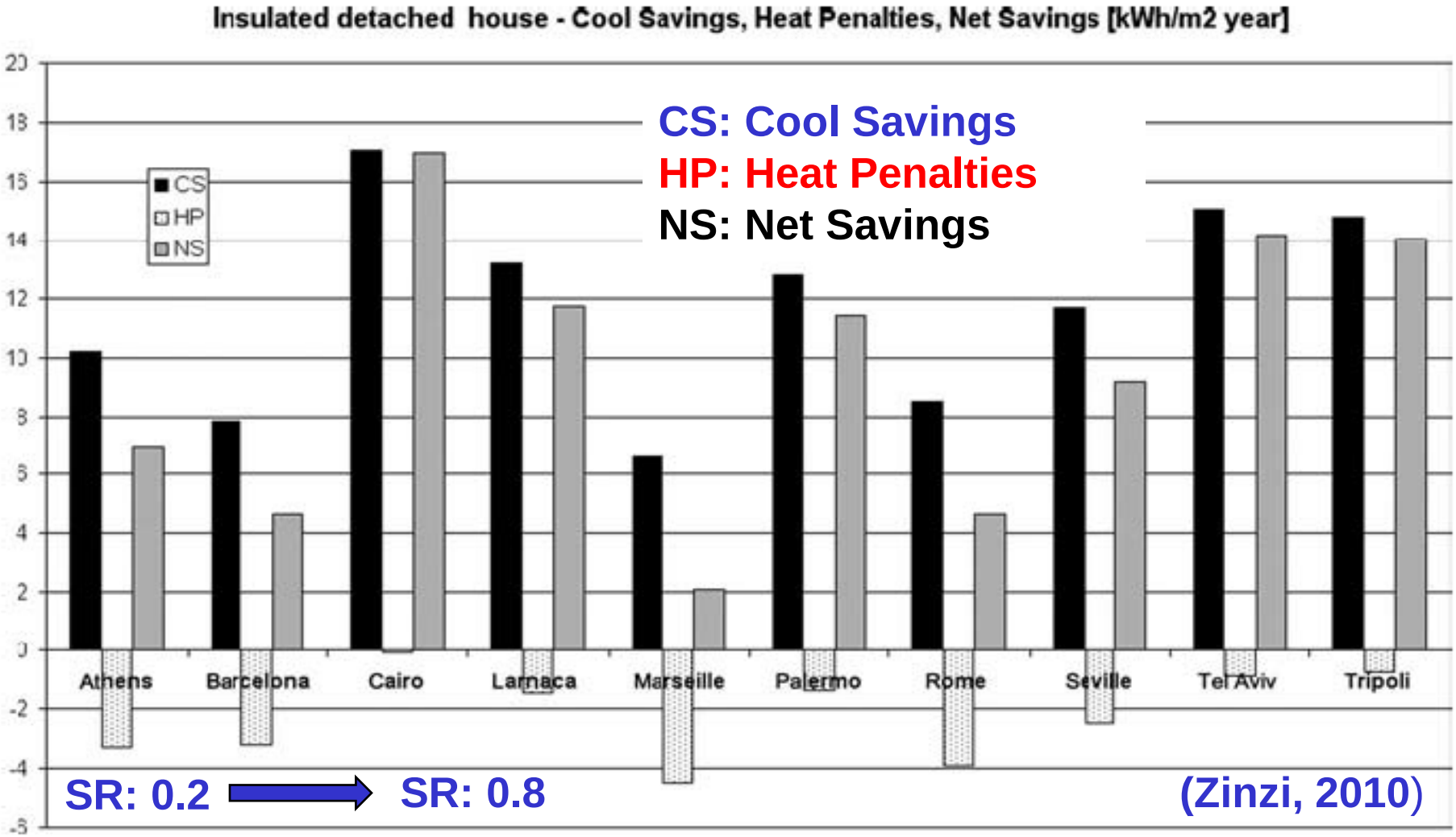
solar reflectance = 0.08
thermal emittance = 0.85
roof temp – air temp = 45°C (81°F)



Effect of roof spectral reflectance SR on building energy consumption

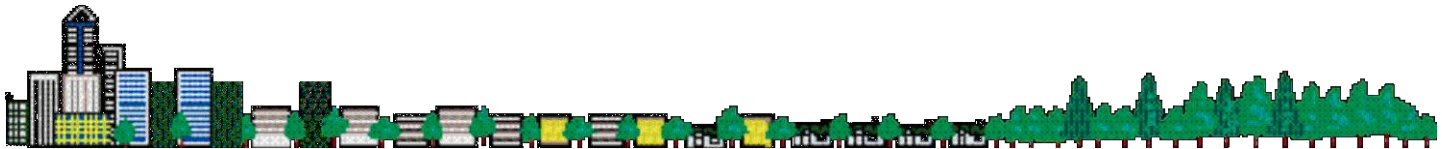


Effect of roof spectral reflectance SR on building energy consumption



Energy and environmental benefits of « vegetalisation » strategies

- Solar protection of buildings
- Evaporative cooling
- Wind shield
- Increase of particles deposition
- Natural sequestration of carbon
- Noise reduction
- Stormwater runoff management



Green wall and roof technologies

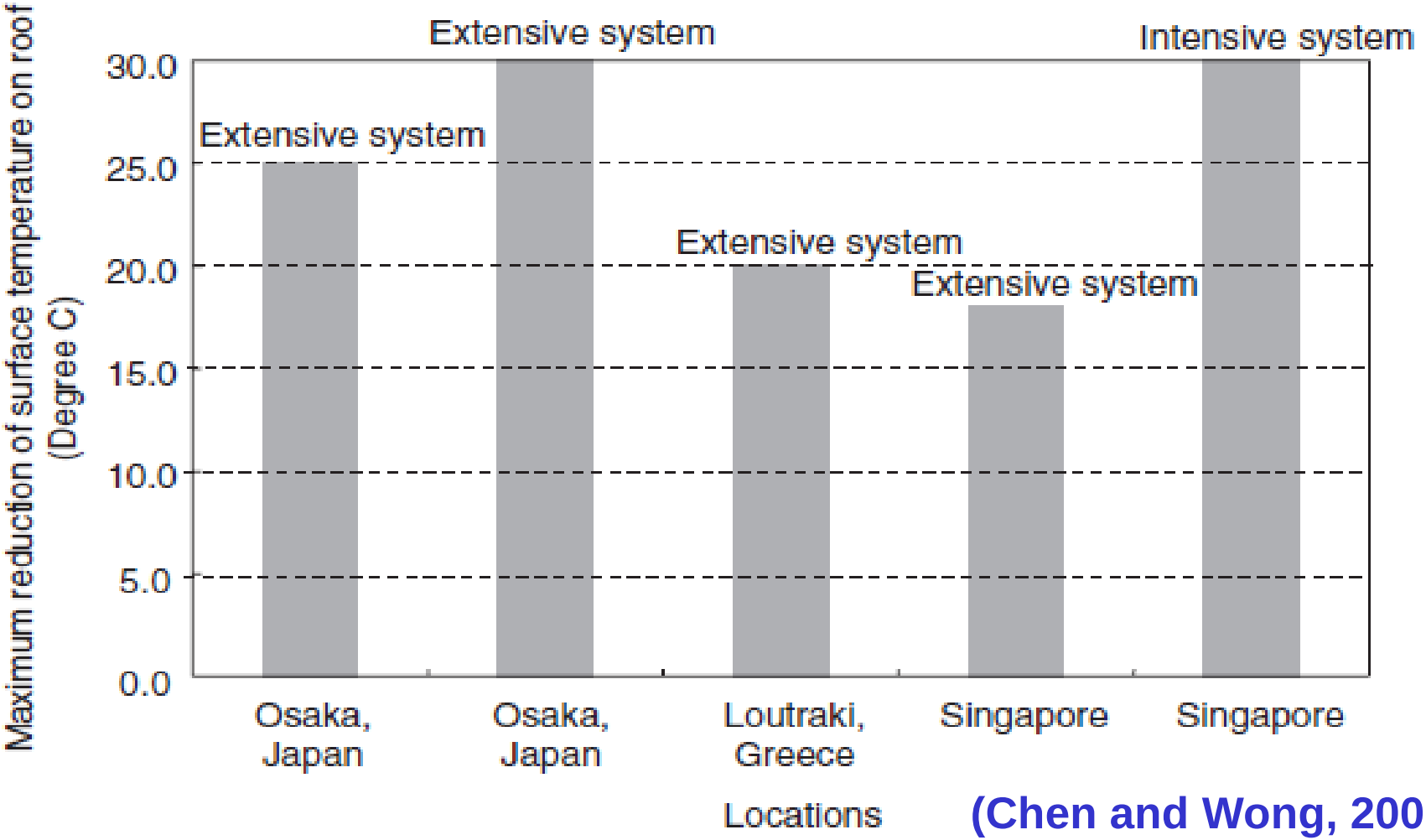
Green wall

Intensive green roof

Planted facade

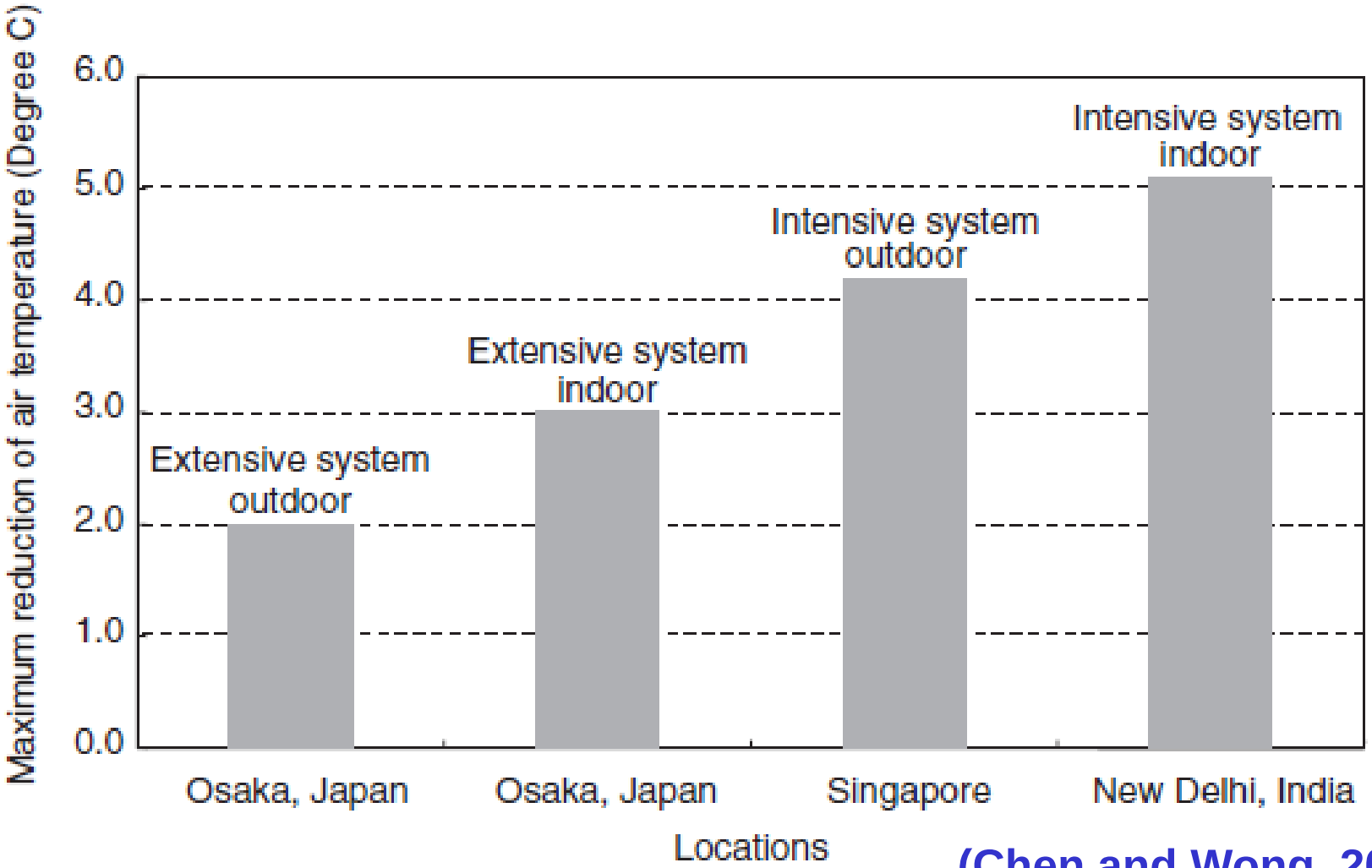
Extensive green roof

Reduction of roof surface temperature caused by green roofs



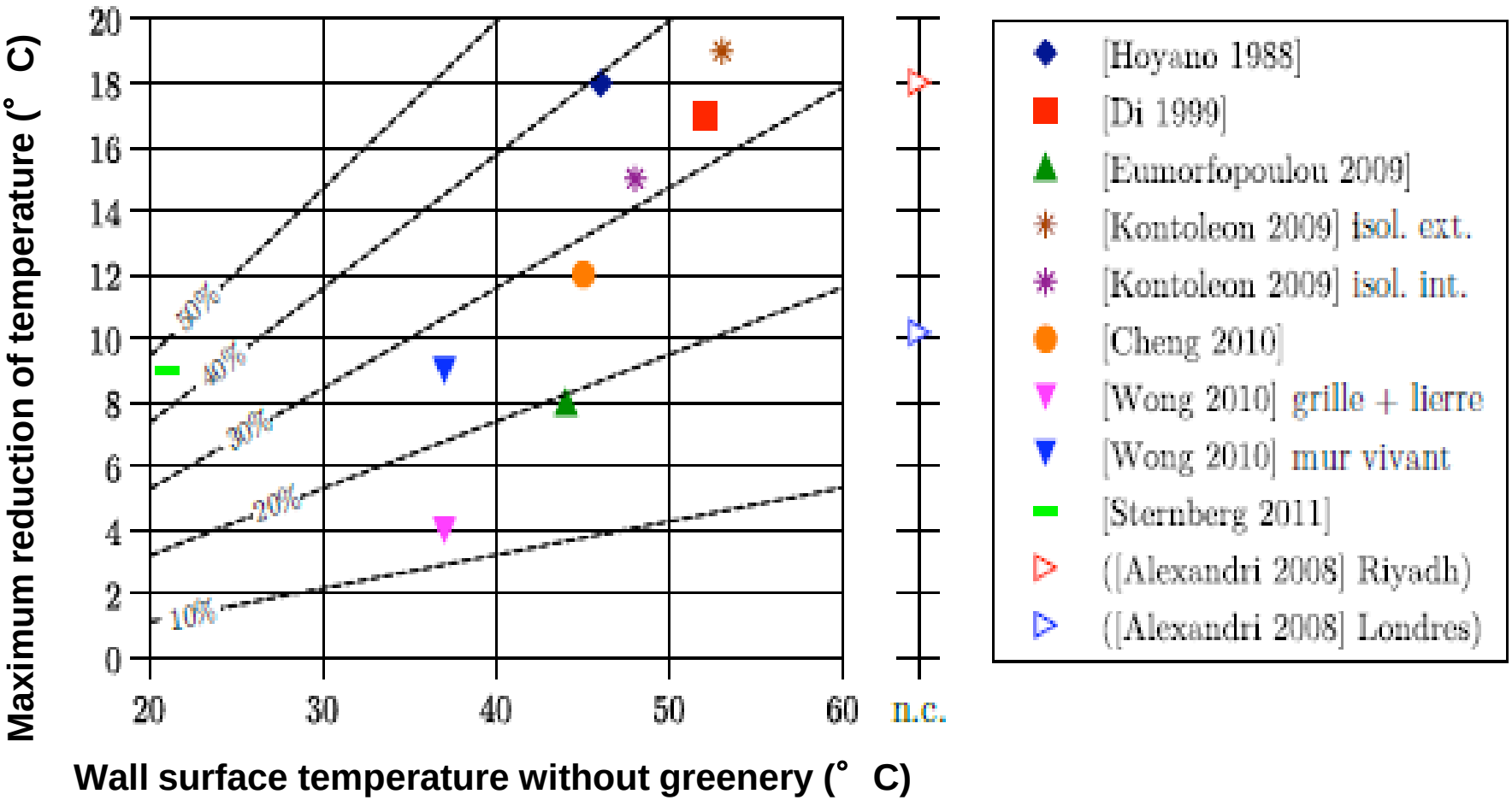
(Chen and Wong, 2009)

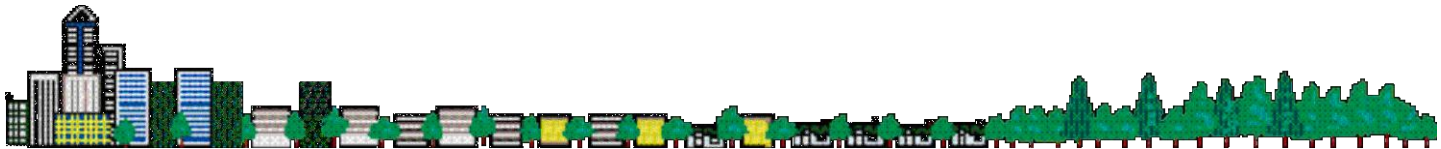
Reduction of air temperature caused by green roofs



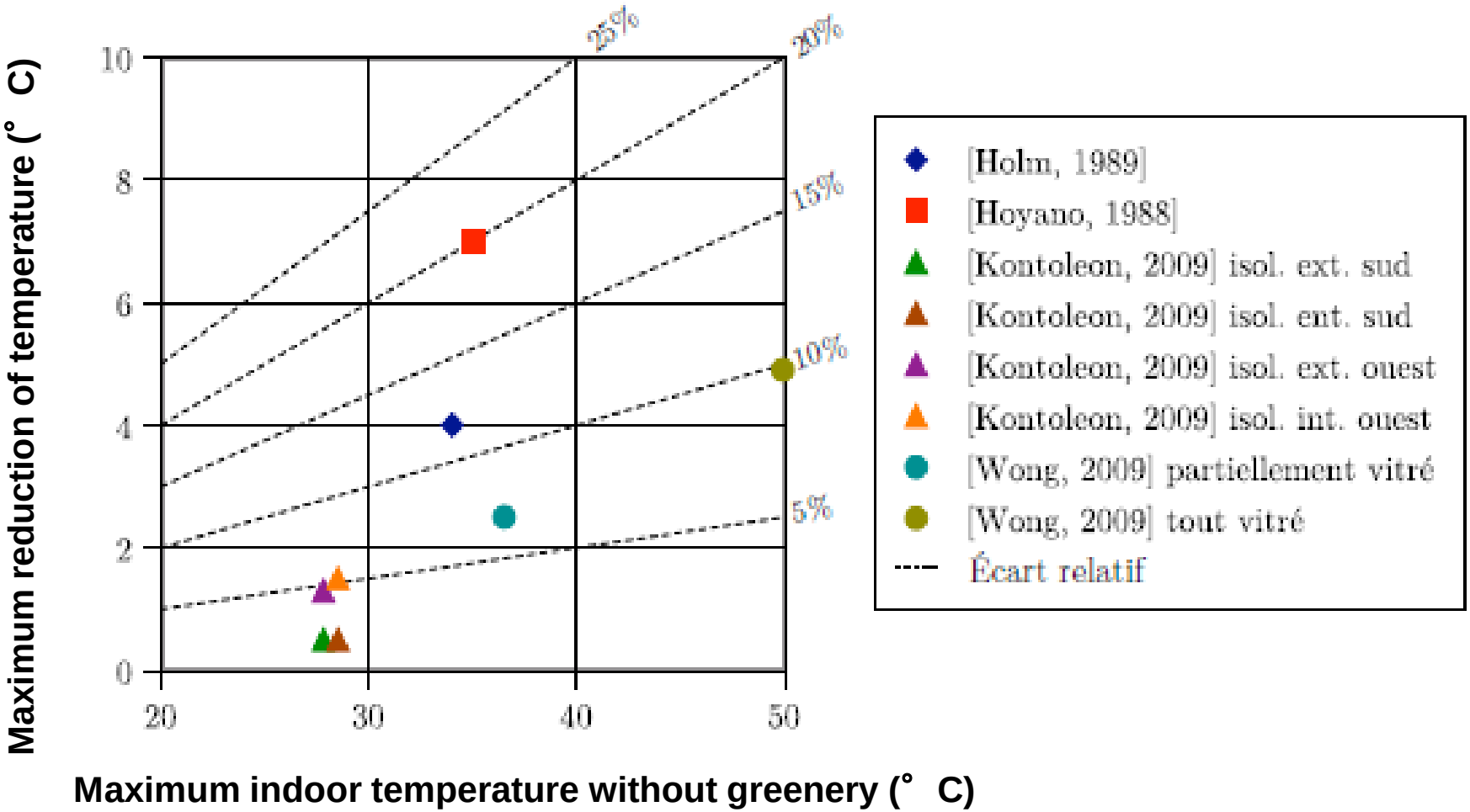
(Chen and Wong, 2009)

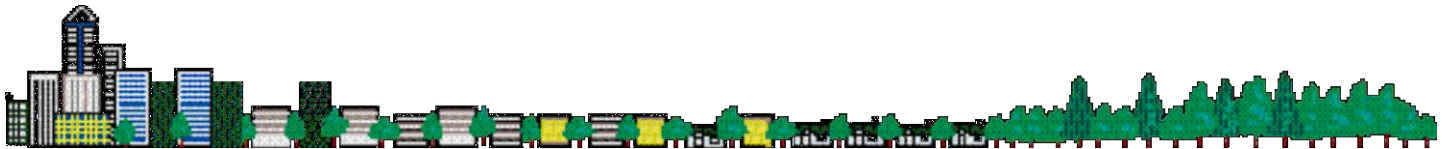
Reduction of wall surface temperature caused by green walls





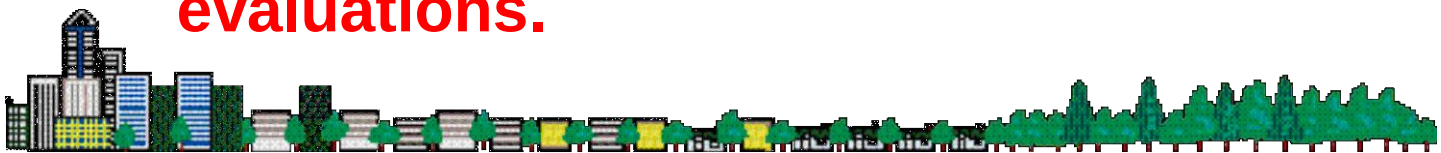
Reduction of indoor air temperature caused by green walls





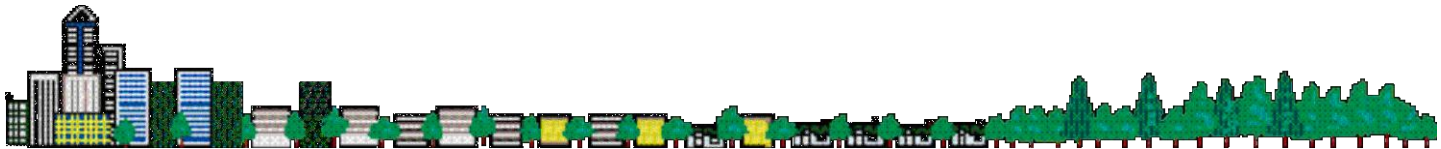
First findings

- More than 70% of our buildings are located in urban sites,
- Improving their energy efficiency and IEQ as well as the quality of urban environments needs an **integrated** approach taking into account the **strong interactions** between buildings and the urban environment,
- New sustainable technologies are necessary for comfortable and healthy buildings in Urban Environment,
- **New tools and models are needed for these evaluations.**



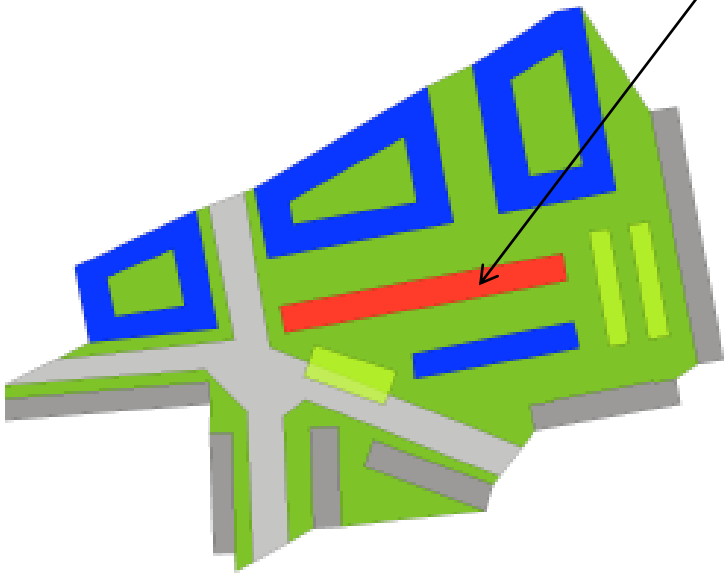
Development of a new numerical tool

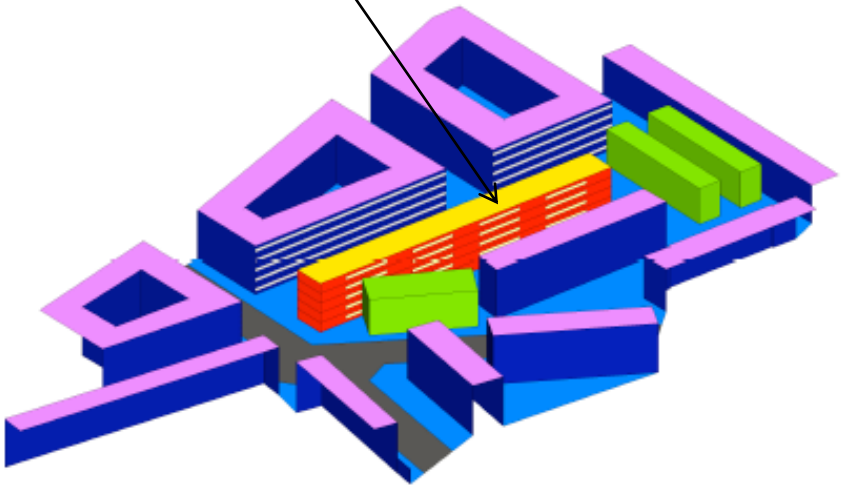
- Numerical study: modelling
  - Outdoor airflow
  - Radiative exchanges
  - Green surfaces
  - Buildings
  - Coupling
- Lanscaping strategies
  - Green surfaces benefits
  - Indoor thermal comfort
  - Energy consumption…



Case study

Studied building (99.2x9.6x15 m)



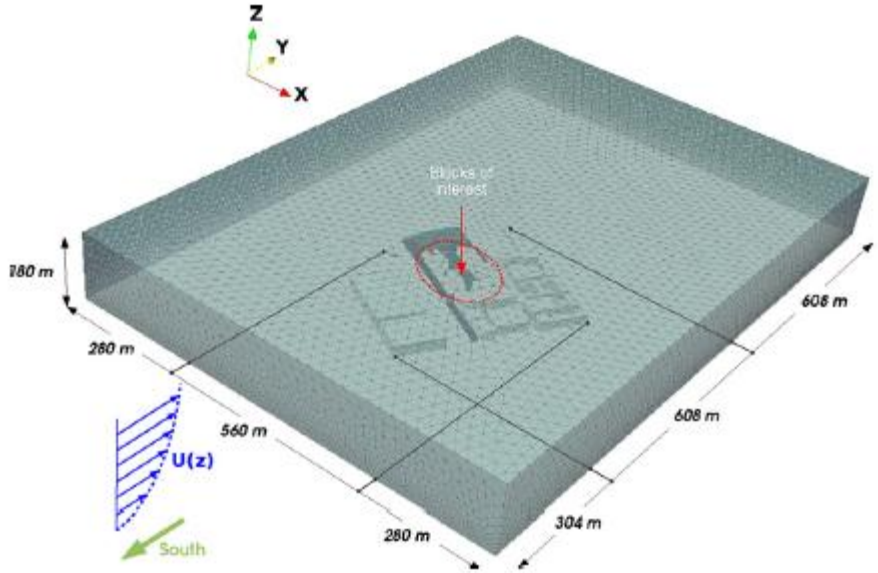


Top view

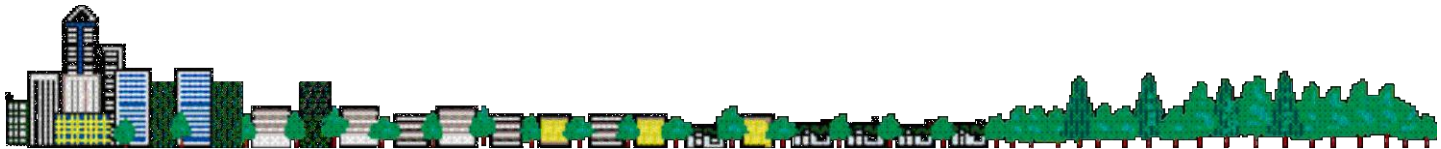
3D view

Pin Sec district in Nantes (France)

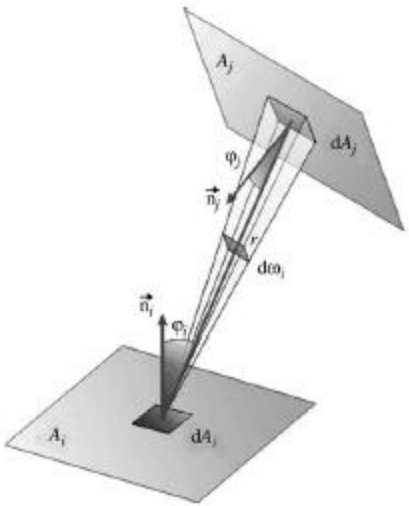
Outdoor airflow modelling

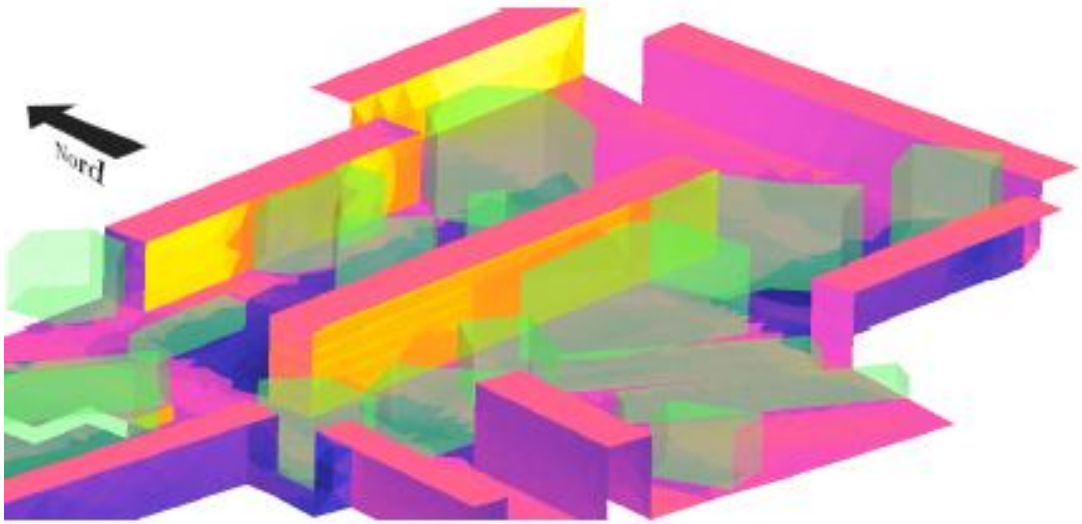


- CFD code FLUENT
- Numerical wind tunnel
- 3D unstructured grid of 1,725,000 tetraedral air cells
- k-ε turbulence model



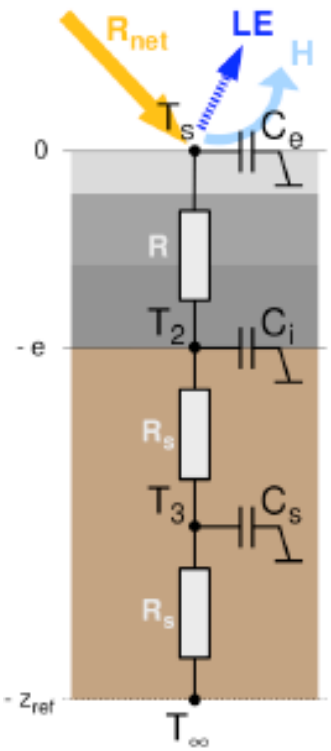
Radiative exchanges

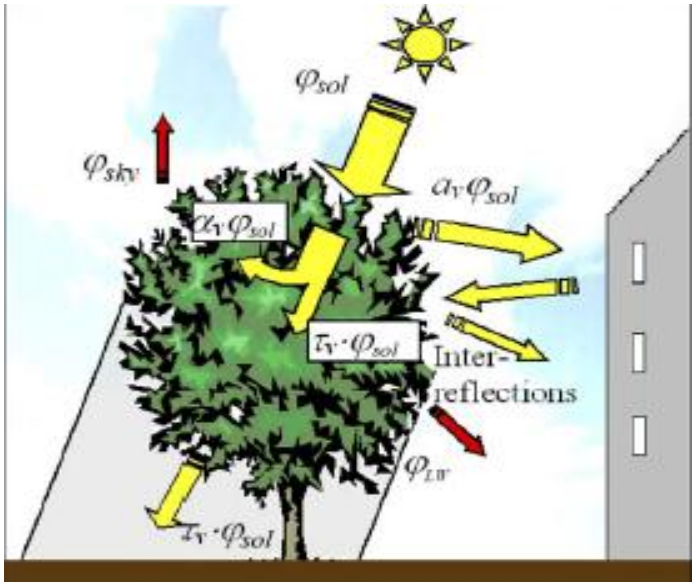


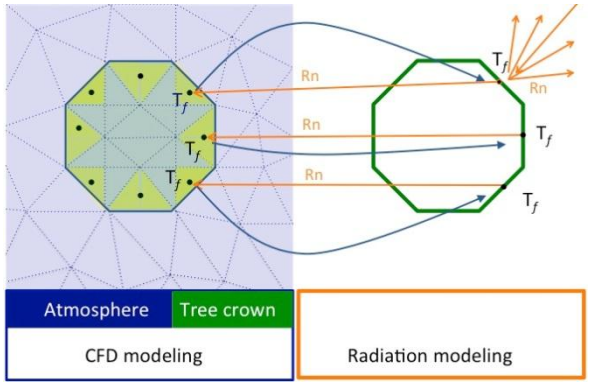


- SOLENE code
- Short-wave and long-wave radiation
- Sun and sky modelling: “all weather” Perez model
- Radiosity method
- View factor (contour-integration)

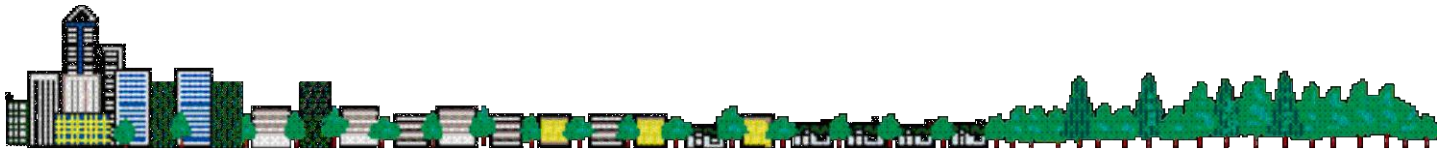
Green area modelling



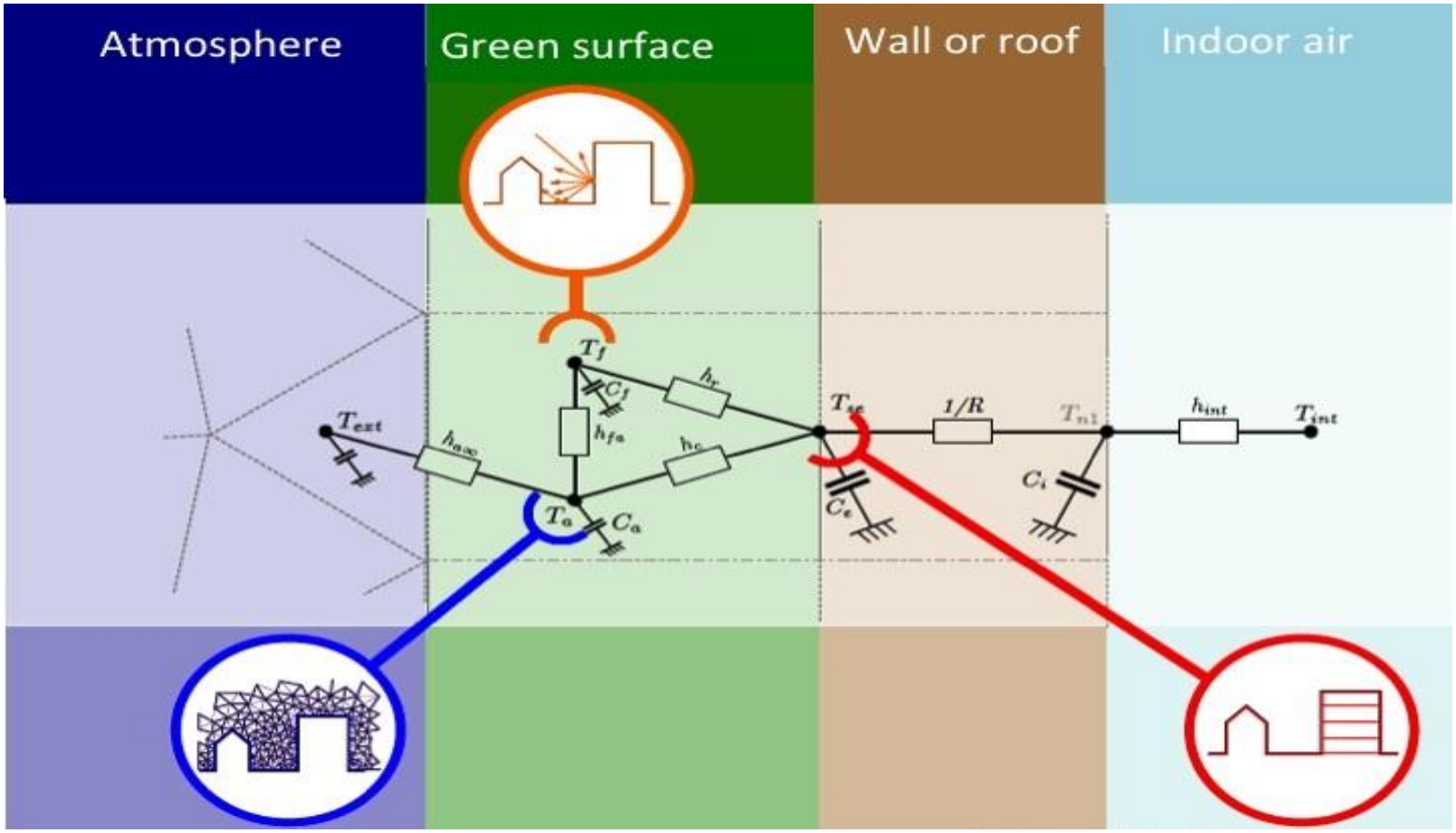




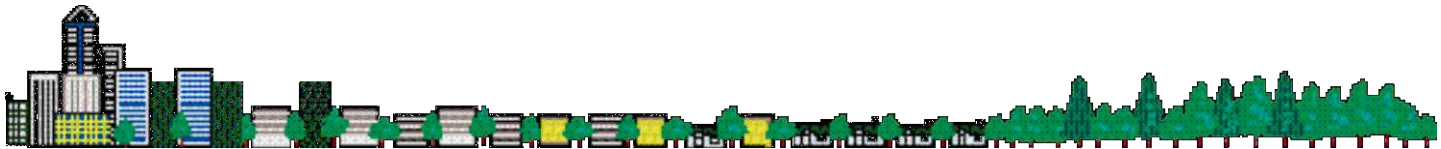
- ❑ **Tree**
- ❑ **Ground**



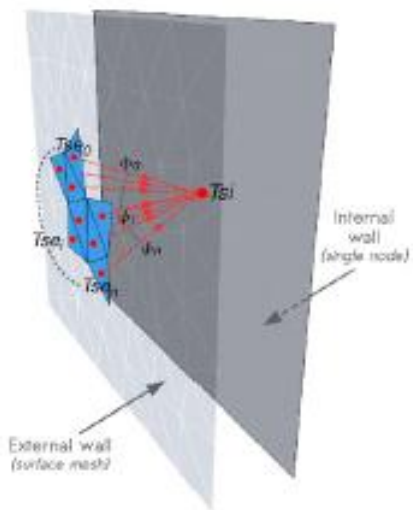
Green area modelling

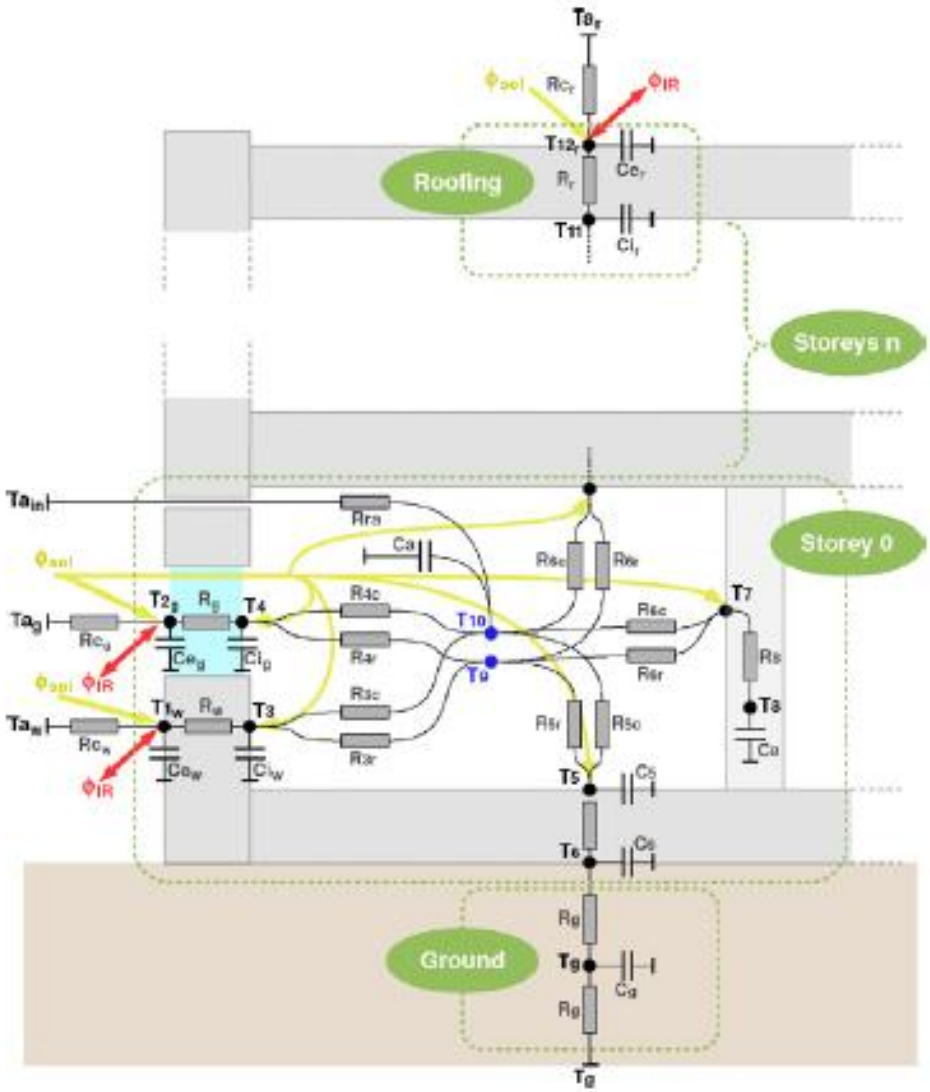


- ❑ Green roof
- ❑ Planted facade



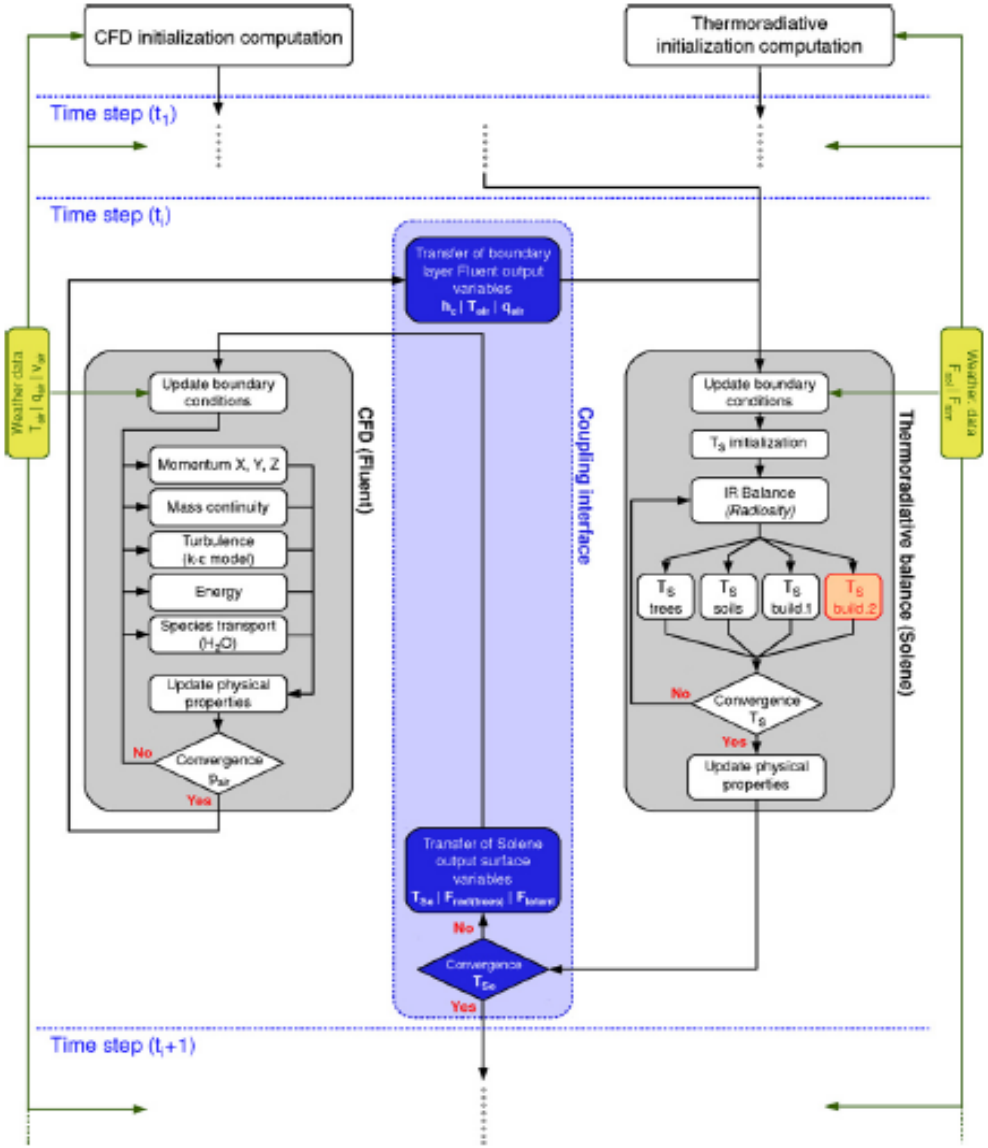
Building thermal model



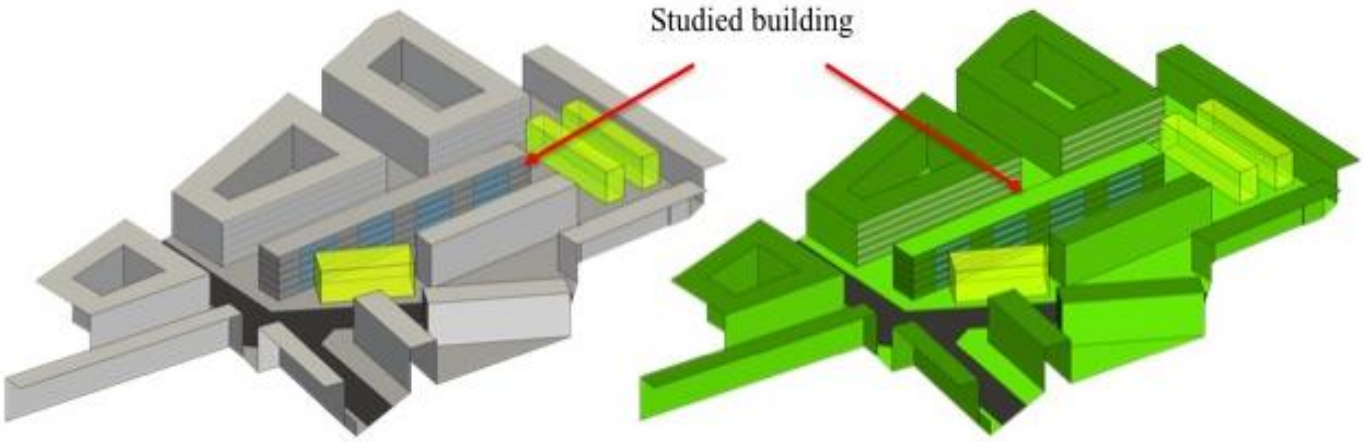


- SOLENE sub-model
- Multizone building model
- Nodal network

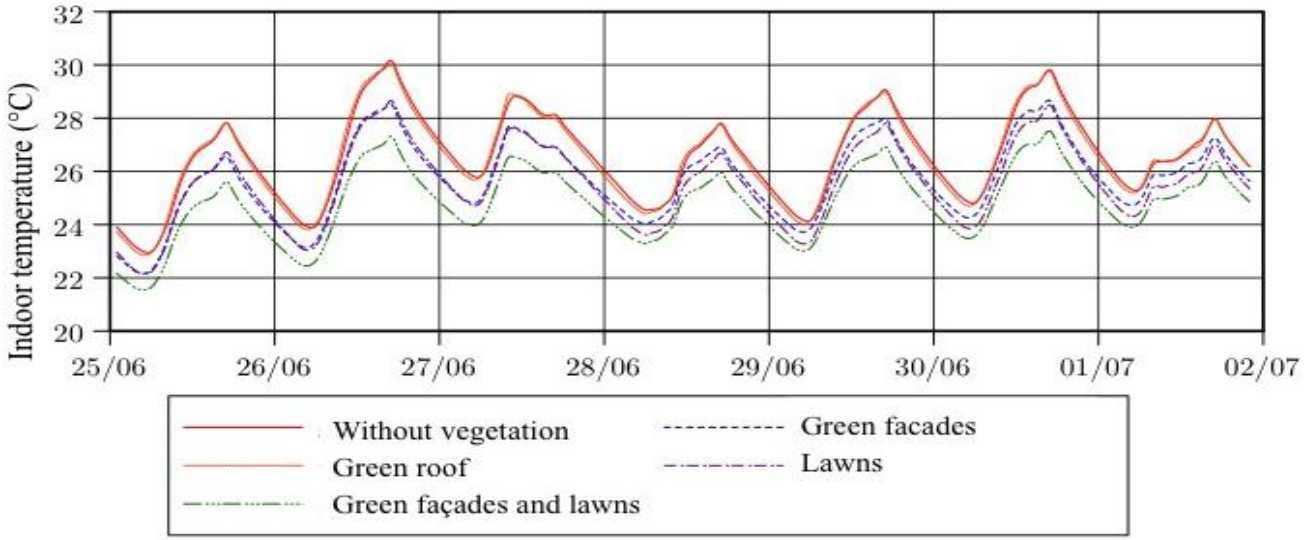
Coupling method



Hot period free running indoor temperature

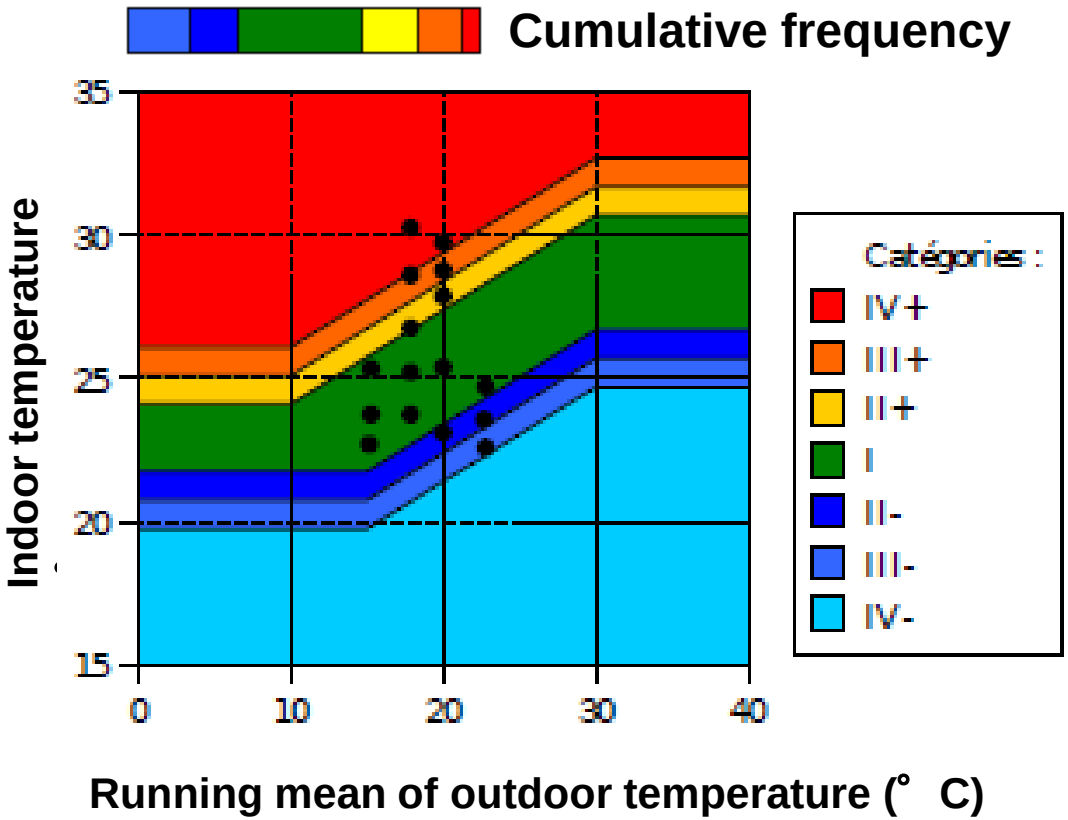


(a) Urban block without green surfaces (b) Urban block with green surfaces

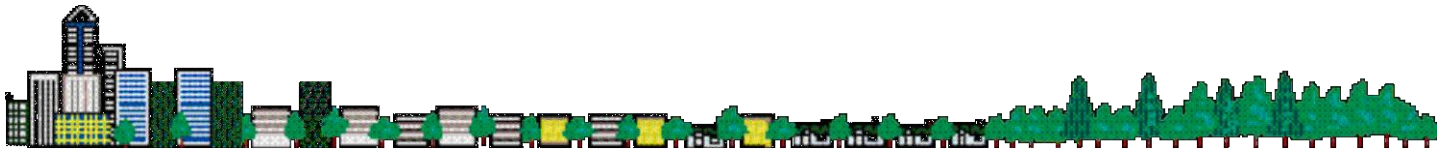


(c) Indoor temperature in the second floor of the central building – Non insulated building

Hot season indoor thermal comfort

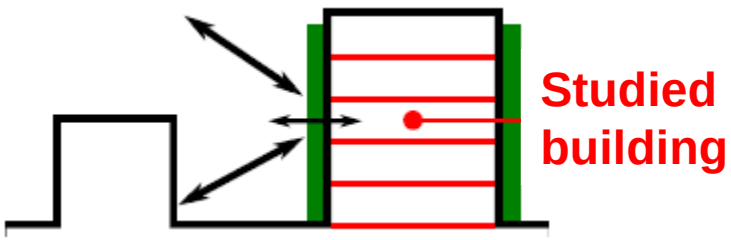


Standard EN15251: Indoor environmental input parameters for design and assessment of energy performance of building addressing indoor air quality, thermal environment, lighting and acoustics

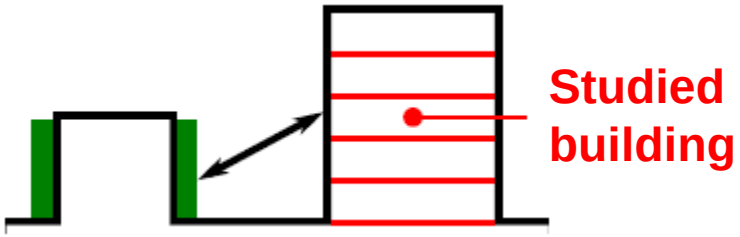


Parametric study

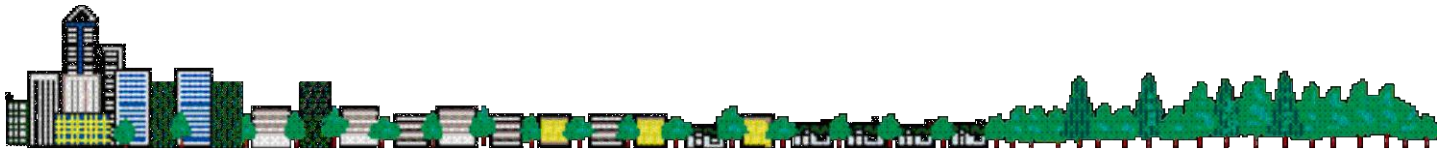
- Indirect effects of green surfaces on indoor thermal comfort in the studied building
- Coupled indirect and direct effects on indoor thermal comfort in the studied building



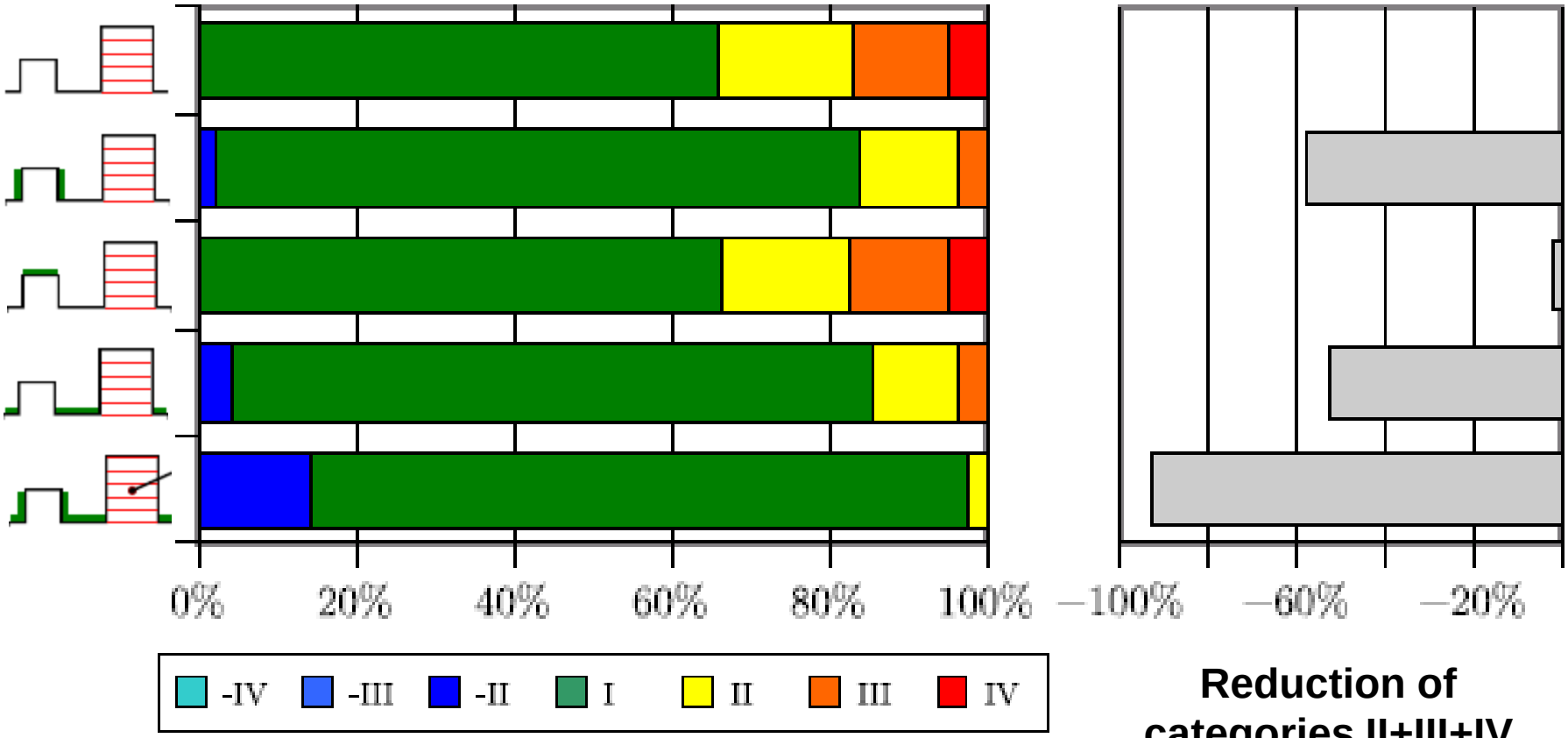
Direct effect of planted facades



Indirect effect of planted facades

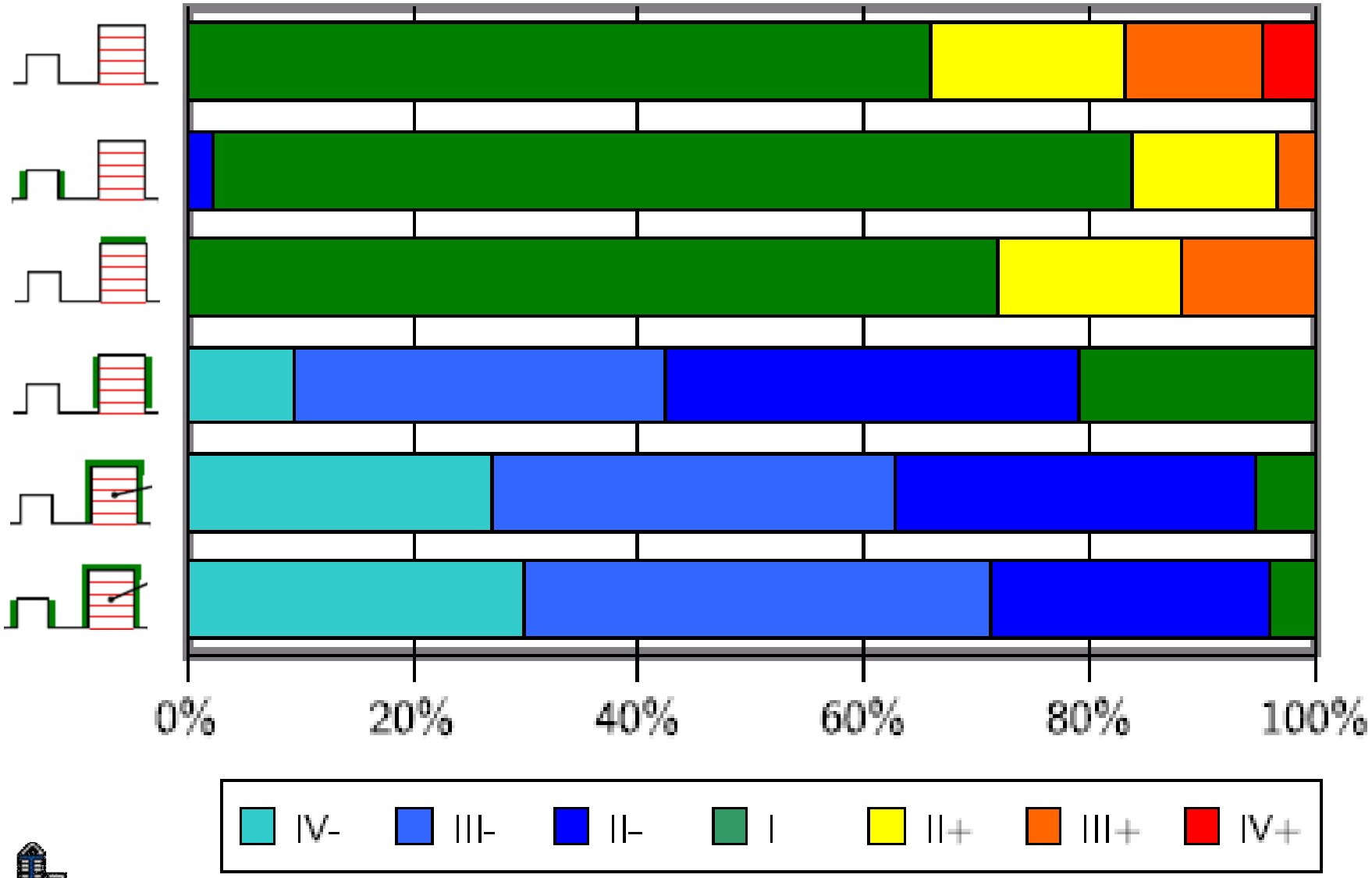


Parametric study: indirect effects



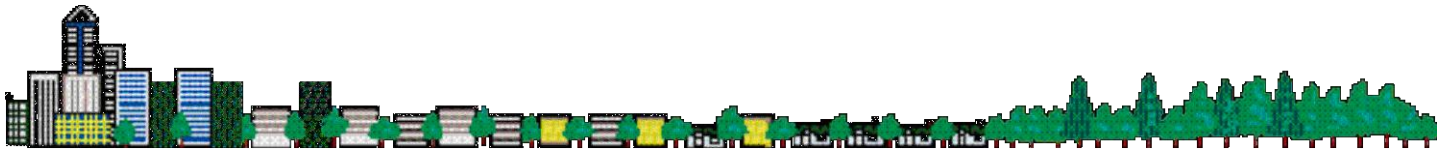
Reduction of categories II+III+IV compared to case 0

Parametric study: Indirect vs direct effects



Conclusion

- Development of models: outdoor airflow, radiative exchanges, thermal building, green surfaces
- Models coupling: urban climate assessment numerical tool
- Parametric study on a real district (Nantes, France)
- Direct and indirect effects of green surfaces on indoor thermal comfort



Thank you for your attention