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TEB overview

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Aim

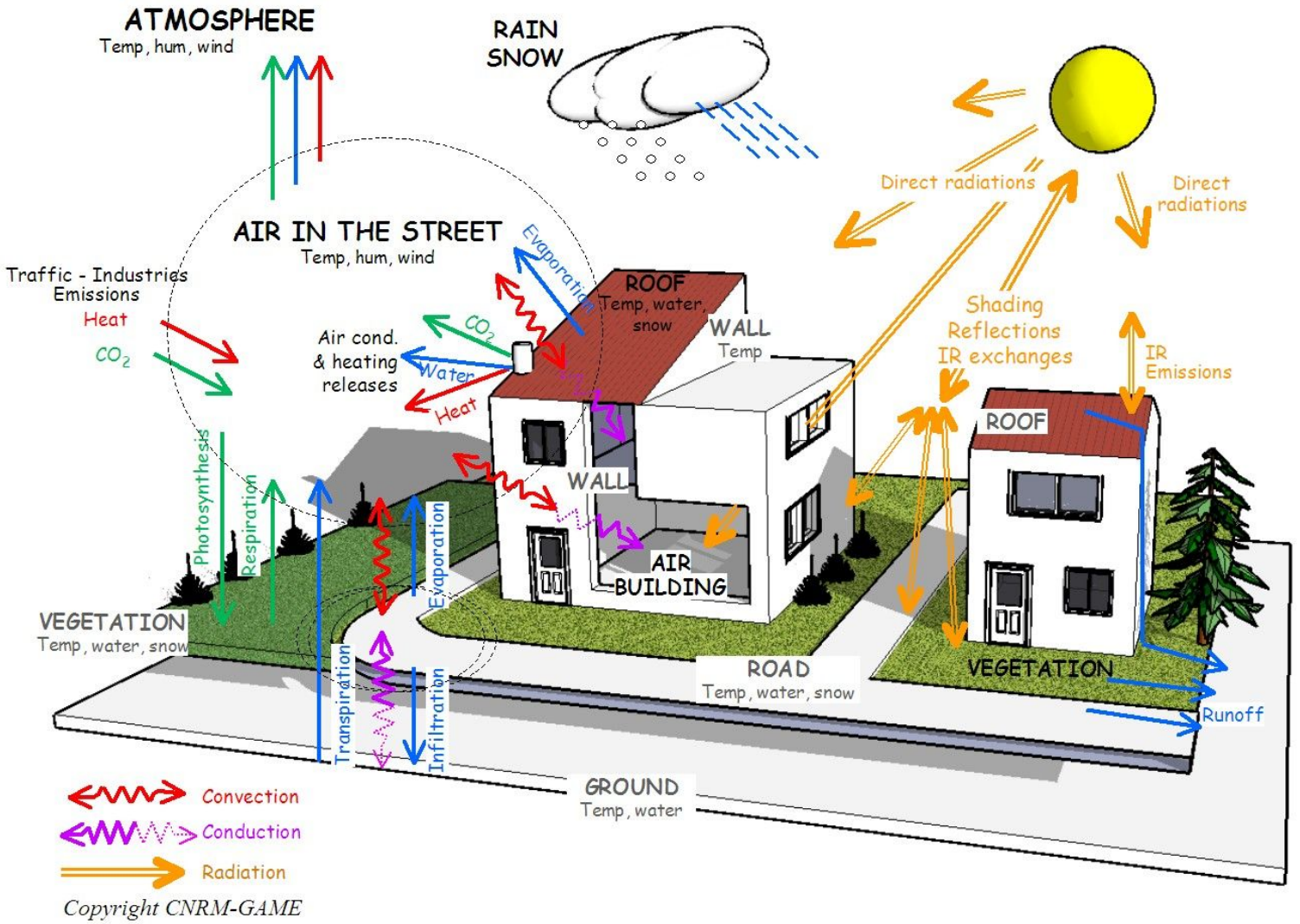
To present basic concepts of the Town Energy Balance model TEB:

- as it might typically be used for mesoscale **NWP**
- (my own knowledge comes from **applying** TEB for research)

Why model towns

- Interactions between the atmosphere and the surface. Compared to vegetated land surfaces, cities are characterised by:
  - high roughness
  - capacity to store heat and trap long wave radiation
  - limited evapotranspiration (paved surfaces, sewage systems)
  - anthropogenic sources of heat and moisture
- Cities are important in their own righty; conditions and processes affect people and activities
  - weather parameters; comfort and health of denizens (e.g. air quality, urban heat island)
  - energy consumption for domestic heating and cooling, local energy production
  - road and pavement maintenance (ice and snow)

Processes in the urban system



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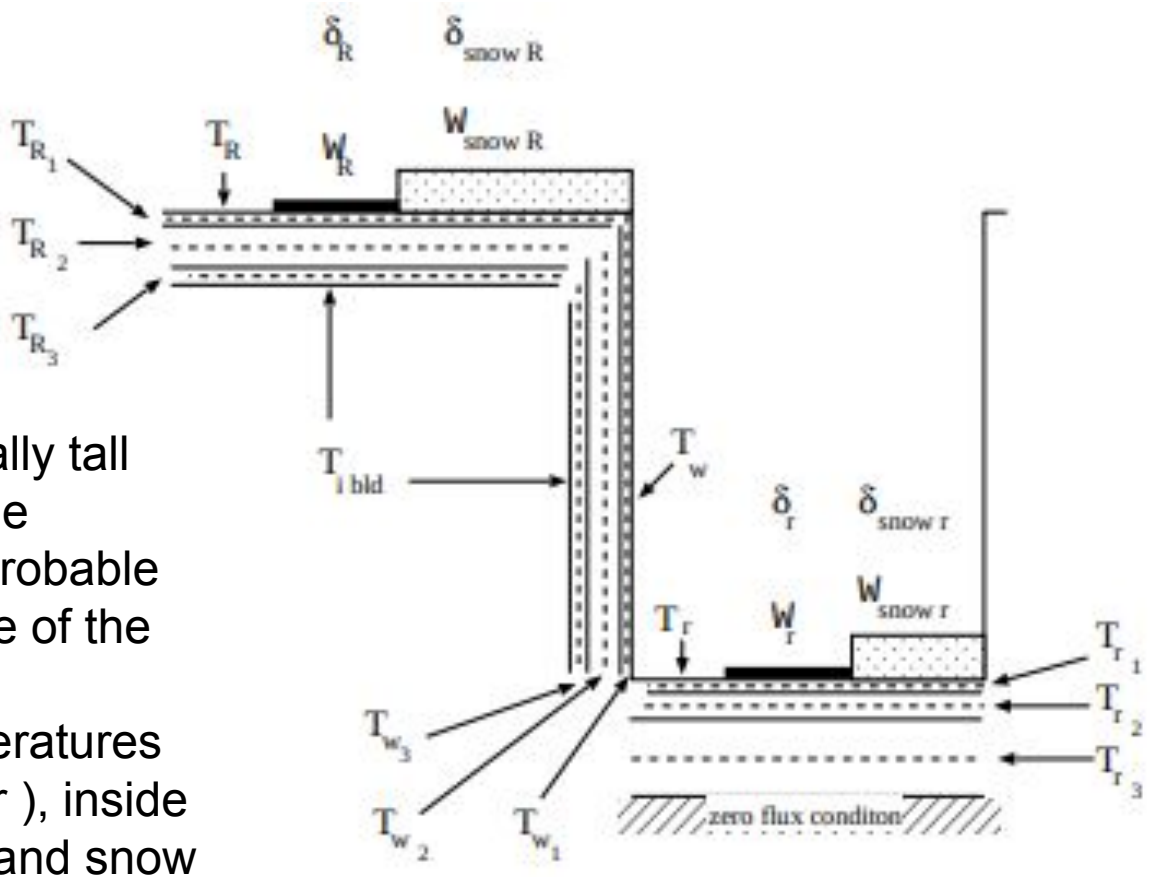
TEB conceptual model (original)

- The town consists of **buildings** and **roads** forming long **canyons** without intersections
- Roofs, walls, and roads have separate energy budgets, accounting for radiation, turbulent fluxes of sensible and latent heat, and conduction into the materials
- In a grid cell, all buildings are equally tall and wide and all roads equally wide
- All canyon directions are equally probable
- Roof-tops coincide with the surface of the atmosphere
- Prognostic variables are the temperatures in roofs (R), walls (w), and roads (r), inside the building, and water reservoirs and snow mantles on top of roofs and roads



Phenomena modelled in TEB

1. Directly influencing the surface-atmosphere interaction:

- 3D geometry of the city
- Radiative trapping, shadows
- Conduction in roofs, roads and walls separately (because they have very different materials)
- Water interception and evaporation, also snow mantle evolution on roads and roofs
- Turbulent exchanges:
  - road <-> canyon
  - wall <-> canyon
  - canyon <-> atmosphere
  - roof <-> atmosphere
- Anthropogenic heating and moistening (prescribed)

Radiation

- View-factors depending on urban geometry

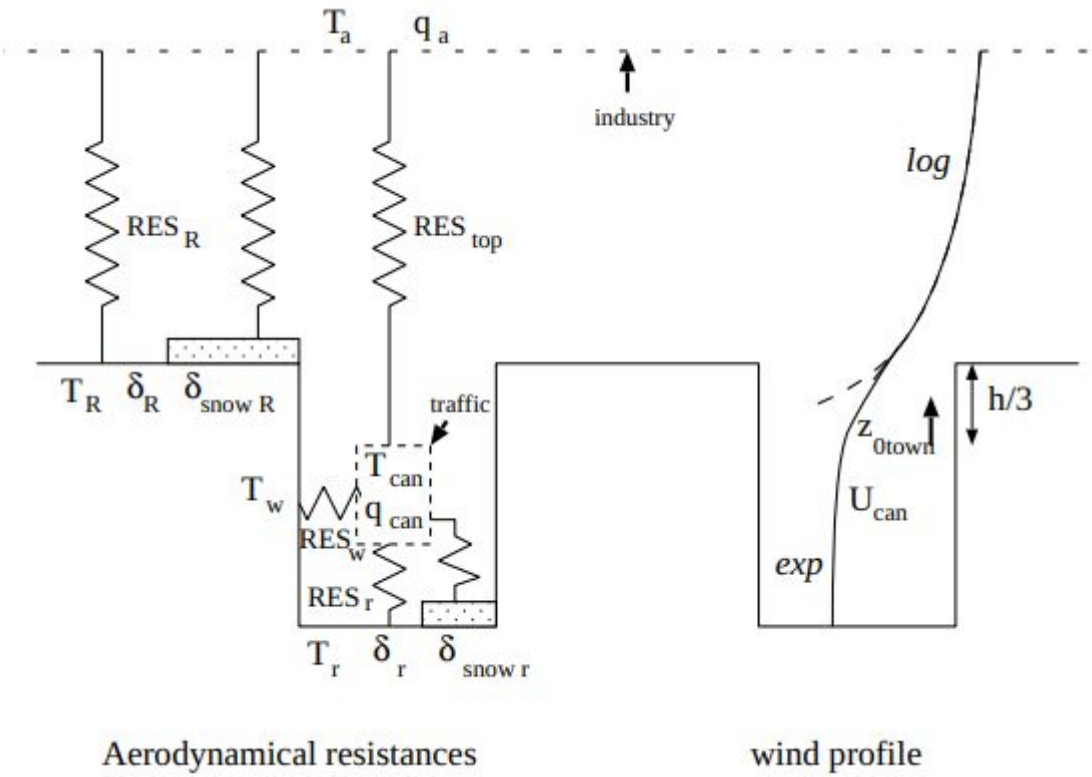
$$\Psi_r = [(h/w)^2 + 1]^{1/2} - h/w$$

$$\Psi_w = \frac{1}{2}\{h/w + 1 - [(h/w)^2 + 1]^{1/2}\}/(h/w)$$

- Shadow effects of direct short wave radiation accounting for orientation
- Infinite number or reflections of scattered short wave radiation
- Trapping of long wave radiation accounting for one re-emission

Turbulent exchange

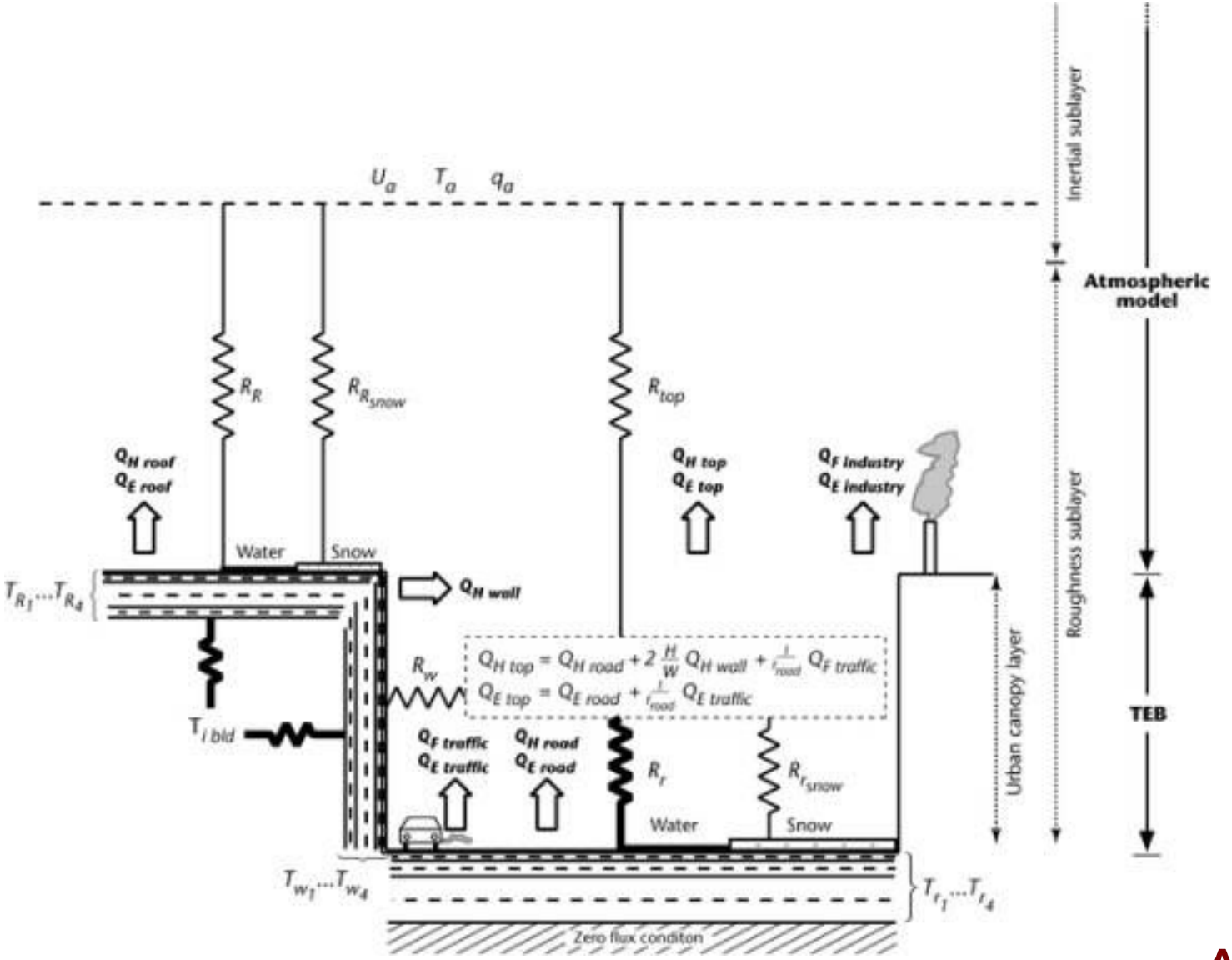
Turbulent exchanges are controlled by aerodynamic resistances accounting for local roughness, wind speed and stability



Anthropogenic sources of heat and moisture

- **Domestic** heating is explicitly resolved assuming a constant minimum temperature inside the buildings (290.15 K, by default), and released through roofs and walls
- Heating and moistening by **traffic** are prescribed according to urban type, and released into the **canyon**
- Heating and moistening by **industry** are prescribed according to urban type and released into the **atmosphere** above the canyon

Heat fluxes of the entire town



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The Surface Boundary Layer scheme (SBL)

- Originally, temperature, moisture content and wind speed in the canyon are diagnostics of TEB
- When activating the SBL:
  - profiles of wind, temperature, and humidity in and above the canyon become **prognostic** variables
  - obtained by parameterising vertical turbulent exchange
  - prognostic TKE and closure by mixing length
  - accounting for drag by buildings

Phenomena modelled in TEB (2)

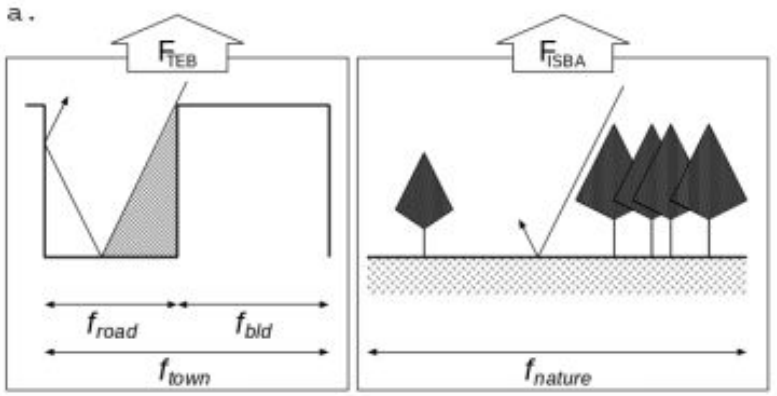
2. Determining conditions in the town:

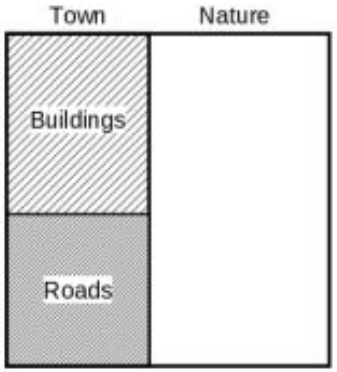
- Shadows on vegetation and influence of gardens on street geometry
- Internal building energy balance and windows
- Domestic heating and air conditioning parameterization
- Human comfort index

TEB-veg (vegetation inside the canyon)

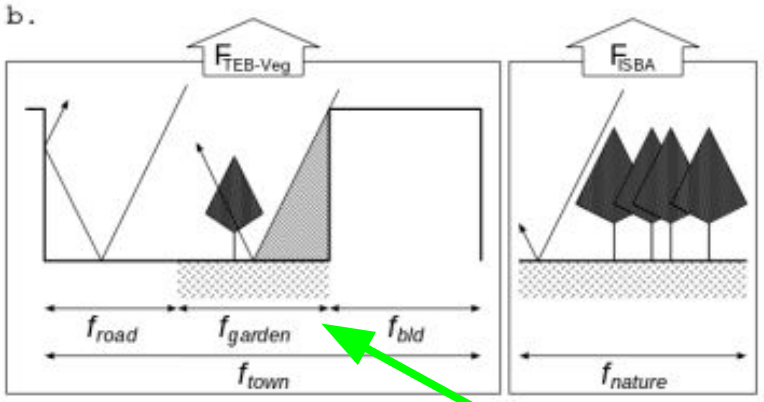
The vegetation in gardens

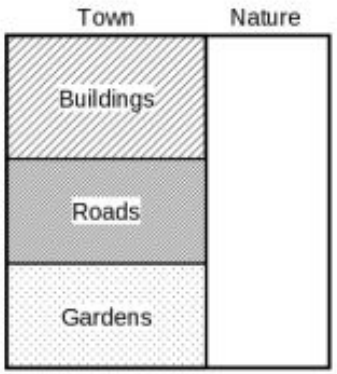
- flattens the canyons (more horizontal area)
- feels the shadowing effect of buildings
- interacts with the canyon-air





Original





TEB-veg

- realised by calling ISBA inside TEB
- low vegetation only
- possible to account for irrigation

Treatment of buildings

Simple:

- Heat conduction through walls and roofs
- Prognostic internal temperature
- Energy used for heating, simple

Building Energy Model (Optional):

- Detailed HVAC system (heating,cooling)
- Ventilation and infiltration
- Solar radiation through windows
- Vegetated roofs (ISBA)

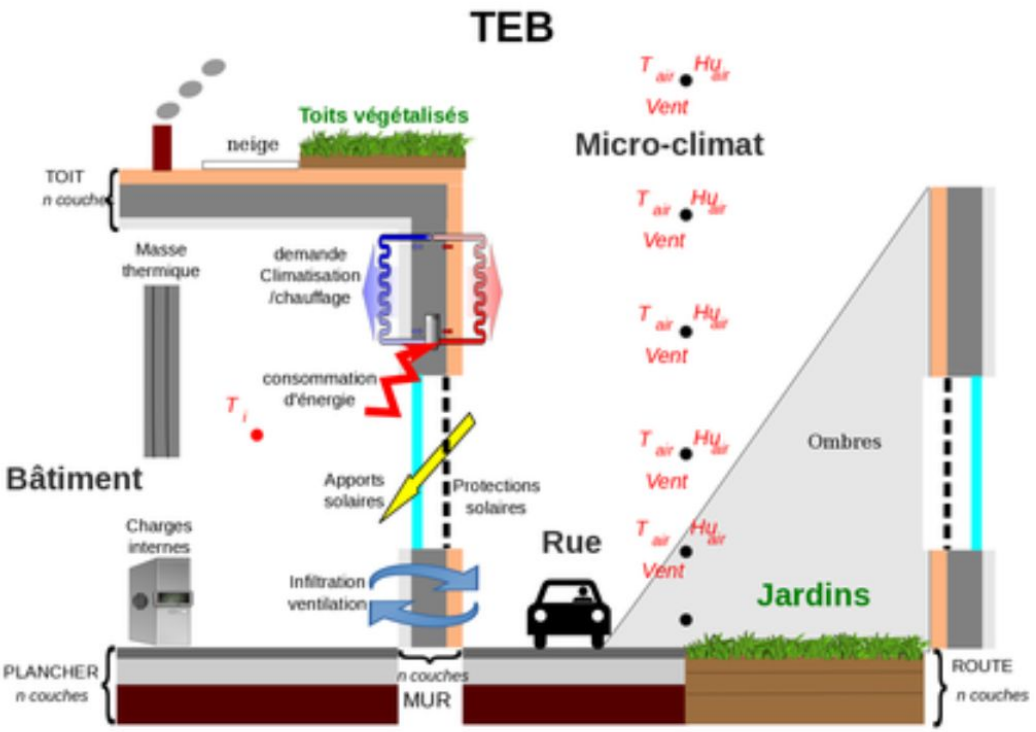


Schéma conceptuel de TEB

Thermal comfort

The Universal Thermal Climate Index, UTCI

- has a unit of temperature
- typically classified into categories of **no, moderate, or severe** heat or cold **stress**
- output of instantaneous and cumulative exposure
- approximates the heat balance of the human body
- accounts for:
  - temperature and humidity (vapour pressure) at 2 m height
  - wind speed at 10 m height
  - mean radiant temperature (exposure to radiative heating/cooling)
- calculated for:
  - outdoor exposed to direct sunshine
  - outdoor in shade
  - indoors (if no cooling device active)

Outlook: in SURFEX 9

- Building Energetics :
  - up to 6 compartments within the building
  - Energetic behaviour of inhabitants and users
  - CO2 fluxes
- New radiative exchanges with SPARTACUS (no canyon any more)
- Inclusion of water transfer into walls (for old & medieval neighborhoods)
- Street trees & garden updates
- Green roofs and walls & CO2 fluxes on vegetation
- Hydrology in the road & building subsoil, including sewer
- Snow cover and ice on roads
- Multi-layer coupling with the atmospheric model

Thank you for your attention

Your comments and questions, please

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