Integration of air quality in the LCA of neighbourhoods

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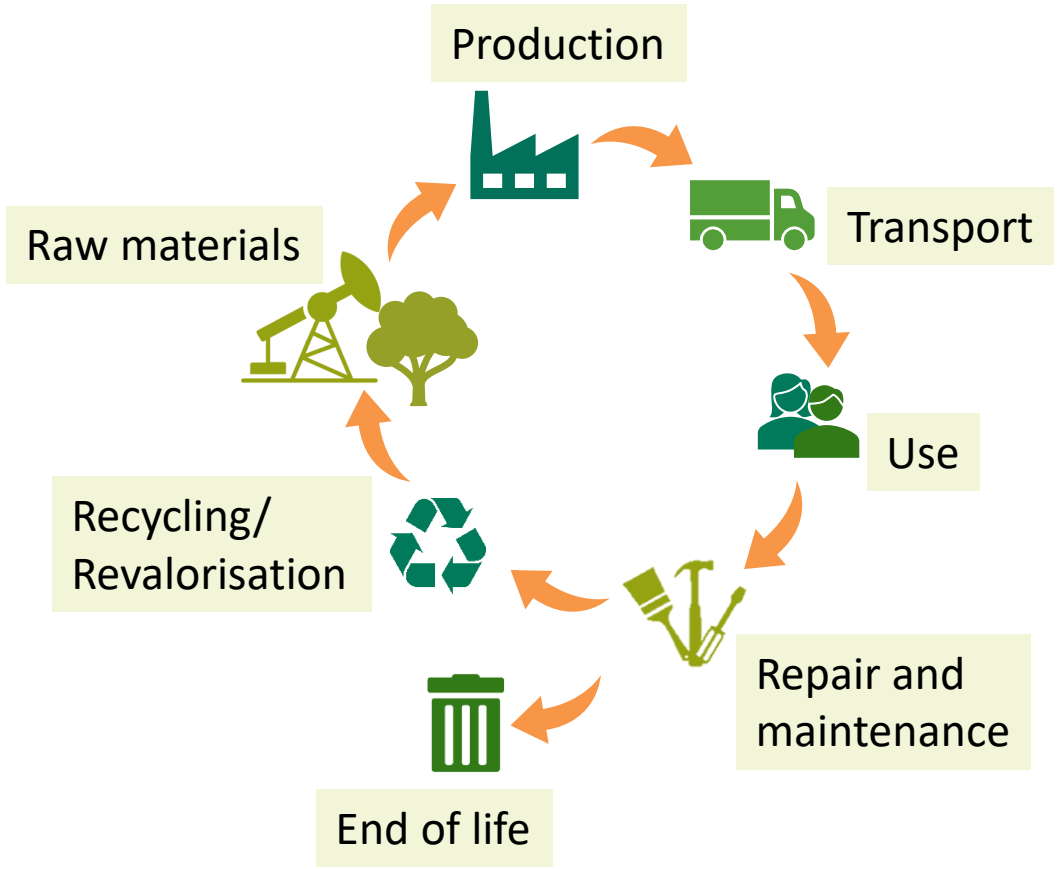
Life cycle assessment (LCA)

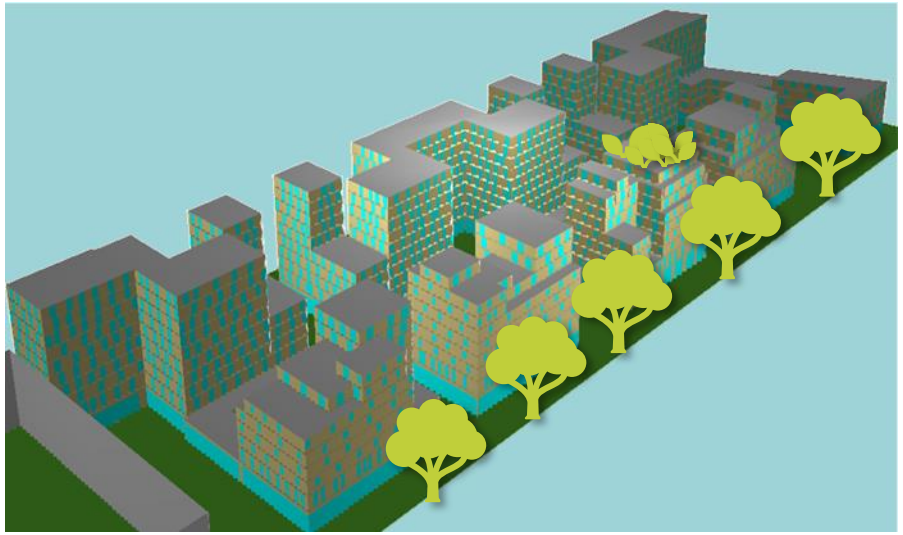
Systemic and multicriterial approach to quantify **environmental impacts** (health, biodiversity, ressources) over the lifetime of the studied system

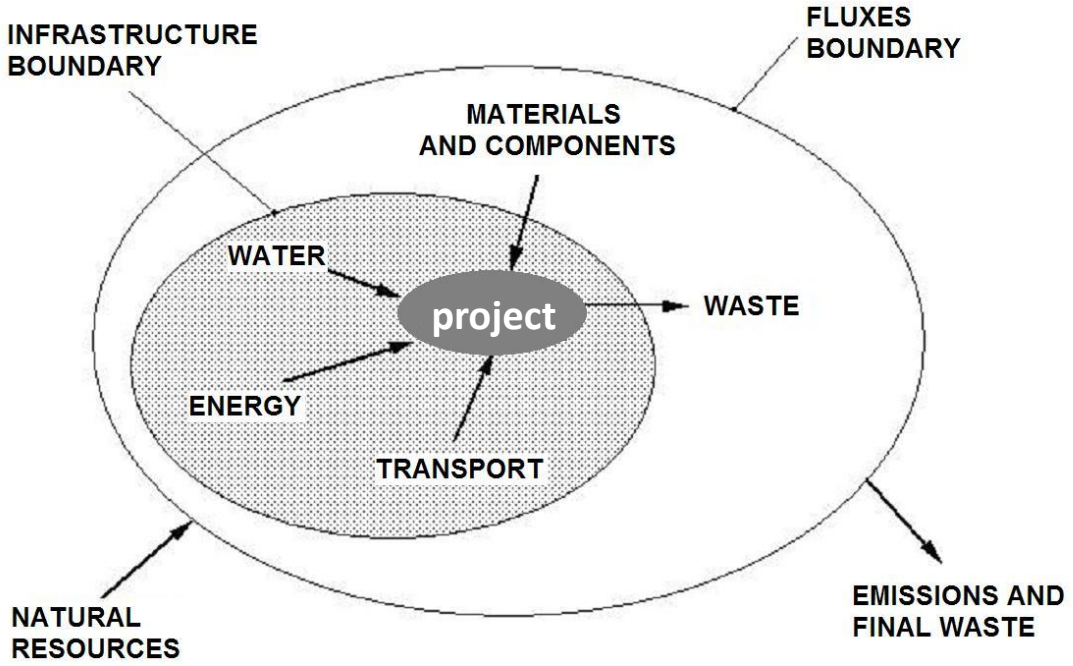
- Developed with a scientific approach, based on observations – reduce instictive choices
- **Better traceability**: assess all life cycle steps, study origins of materials, energy mix…
- **Decision-making tool**: study different aspects of an object/service to improve its environmental performance, **right from its design**



LCA of neighbourhoods

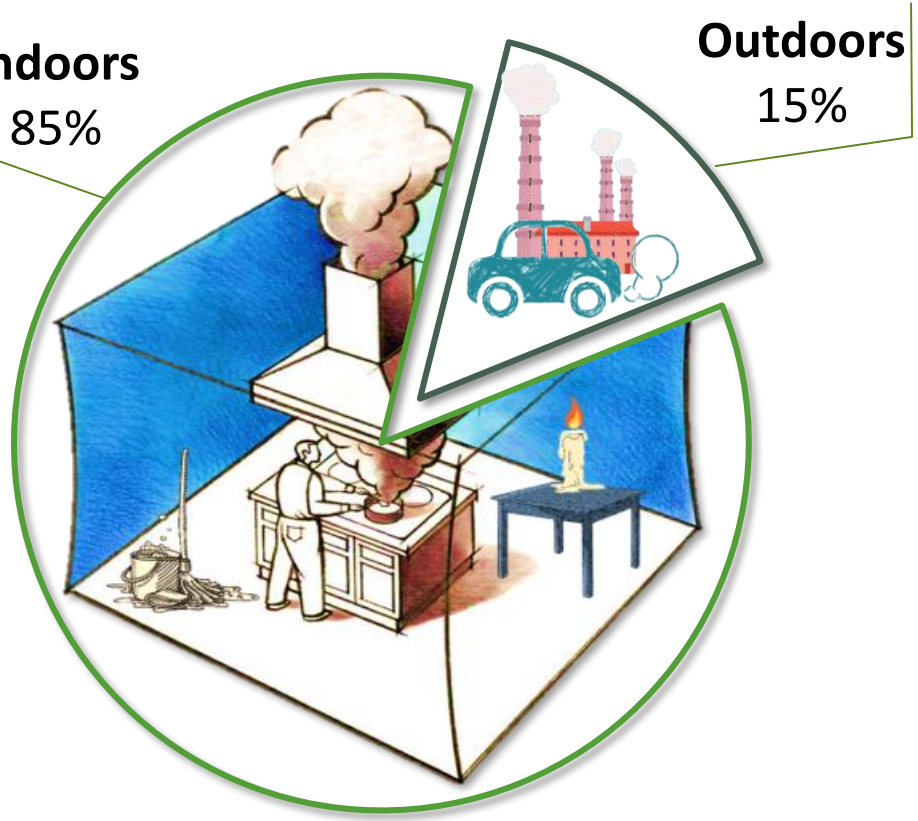
- Help integrate human health impacts due to atmospheric pollutants (indoors and outdoors) in the LCA of neighborhoods
- Help to integrate environmental benefits of urban greening
- Building energy simulation, LCA and urban planning tools -> help in decision-making





Air pollutants and their potential health effects

Home
Office
Shop
Gym



Street
Yard
Forest

Health effects

Short-term
Dizziness, coughing, head aches
Skin, throat, eyes and lung irritation

Long-term
Poor cognitive capacities
Stroke
Chronic obstructive pulmonary disease
Acute lower respiratory infections
Skin/ nose/ throat/ lung cancer

$PM_{2.5}$:
1st cause of DALYs (Disability-Adjusted Life Years) in 2021: 231 million DALYs
1st cause of deaths in 2021: 7.8 million Household air pollution responsible for 3.2 million deaths in 2020, incl. 237 000 children <5 years (WHO)

O_3:
8.8 million DALYs in 2021

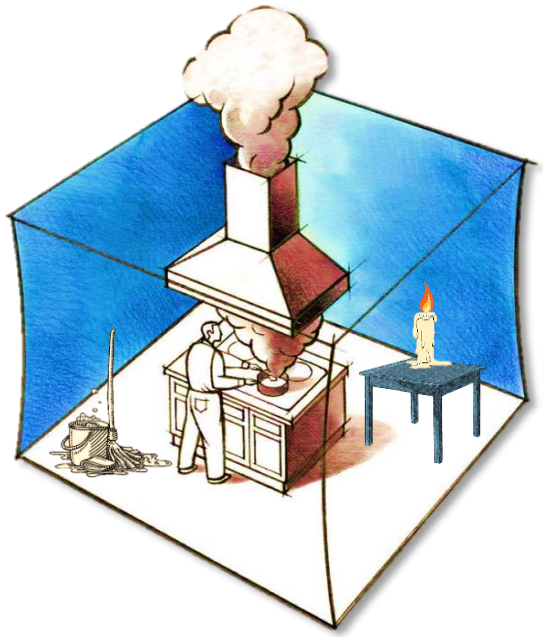
VOCs: Volatile organic compounds
$PM_{2.5}$: fine particulate matter <2.5µm (heavy metals, black carbon…)
CO_2: carbon dioxide, O_3: ozone, NO_x: nitrous oxides

Objective

Life Cycle Assessment

→ **Environmental and human health impacts**

Air Quality



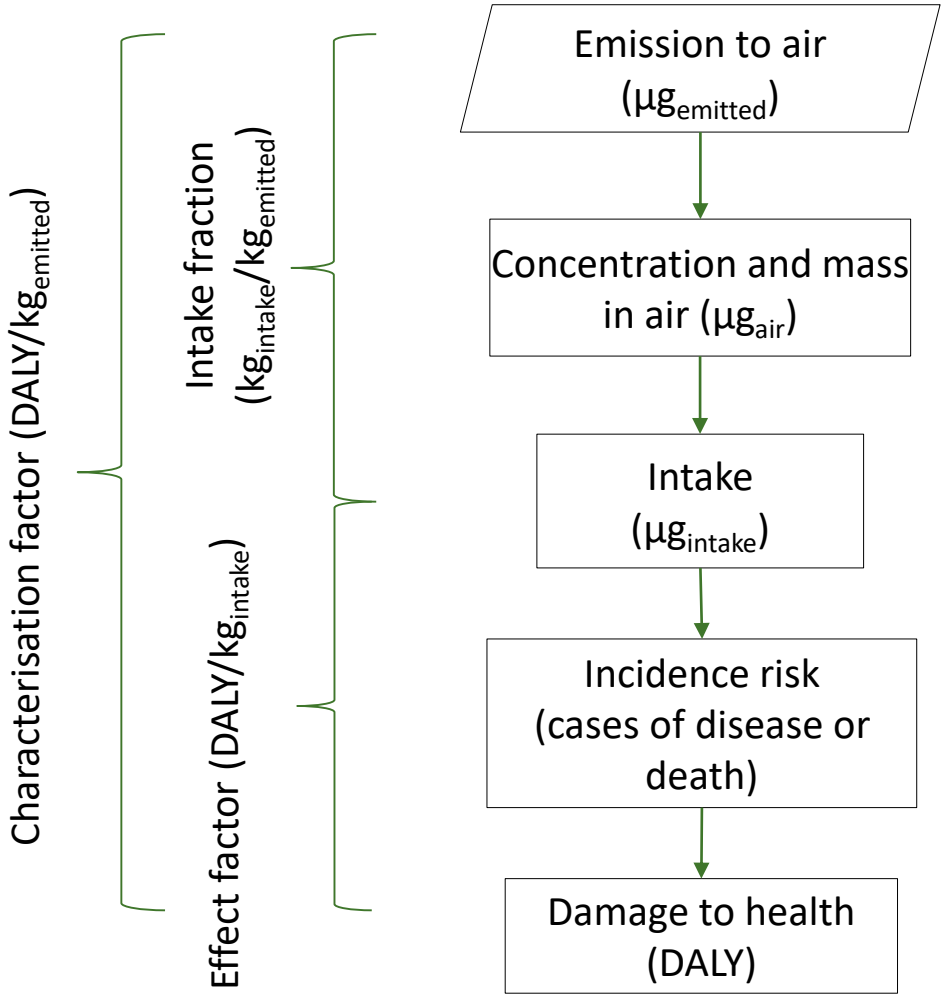
→ **Human health impacts**

LCA + AQ decision-making tool in the building / urban planning sector

Q: How to improve the evaluation of **AQ impacts** in **LCA**?

Impact assessment method

Metrics | **Pathway** | **Factors influencing different steps**



Emission
Activity duration
Emission rate (µg/h$_{activity}$)

Air renewal rate (h^{-1})
Room volume (m^3)
Particle size distribution

Exposure factor (h^{-1})
Breathing rates (m^3/h capita)
Room volume (m^3)
Number of occupants (capita)

Attributed disease/mortality
Epidemiological data → USEtox model
Mortality and diseases data → Global Burden of Diseases approach
Ambient pollutant levels (µg/m^3)

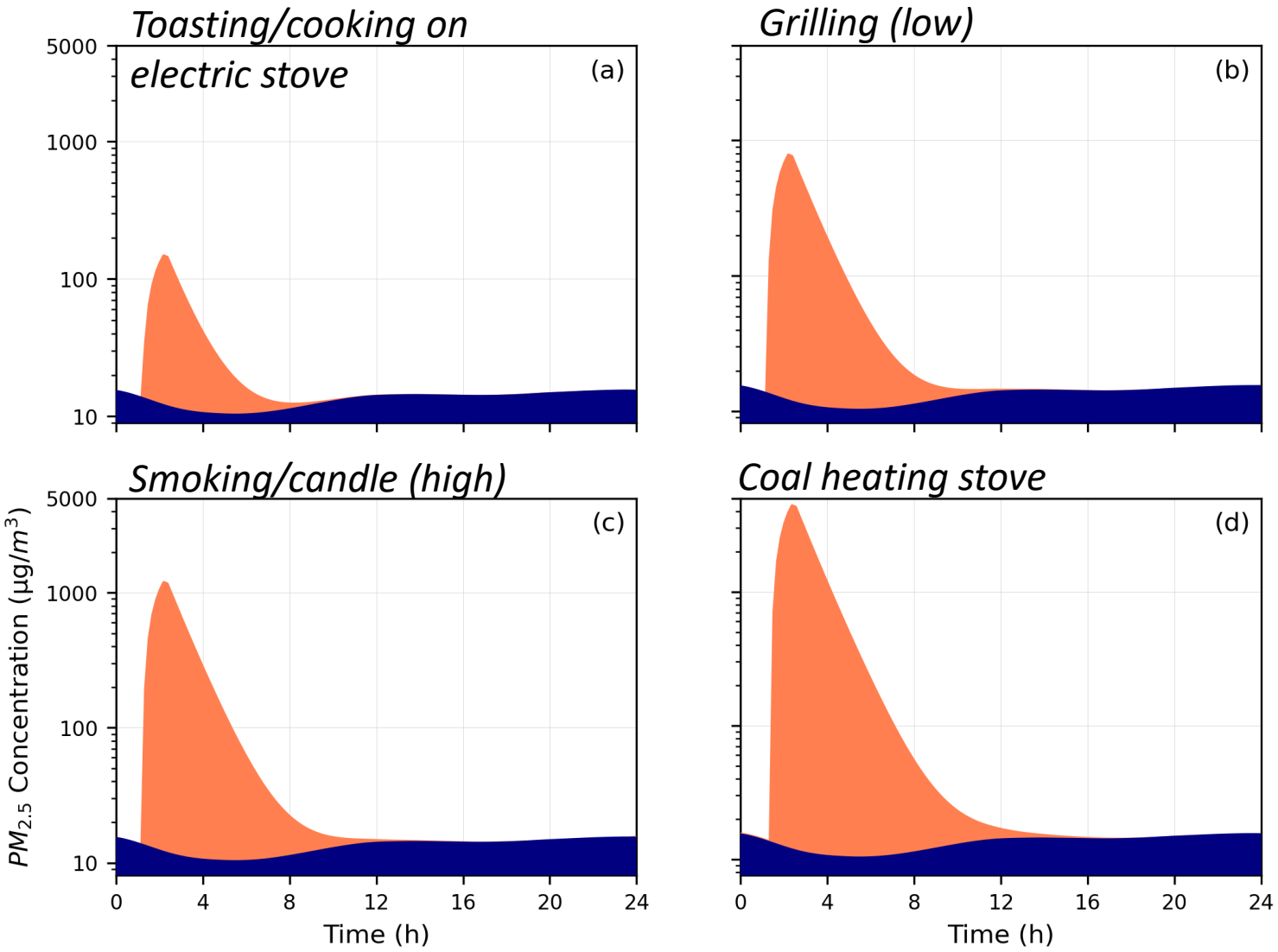
Severity factors
(DALY/case)

Intake

$$M_{in} = IR \int_{t=0}^{T} C(t)\, dt$$

Building ecodesign

Indoor concentrations



Indoor PM2.5 concentrations from outdoors (navy) and increment from one hour activities (orange) over 24 hours at 0.6 ACH

- Concentrations modelled with INCA-Indoor
- Input: emission rates (µg/h)
- Based on
  outdoor concentrations (dynamic)
  deposition rate (dynamic)
  room volume (30 m^3)
  ventilation rate (0.6 ACH)

activity outdoors

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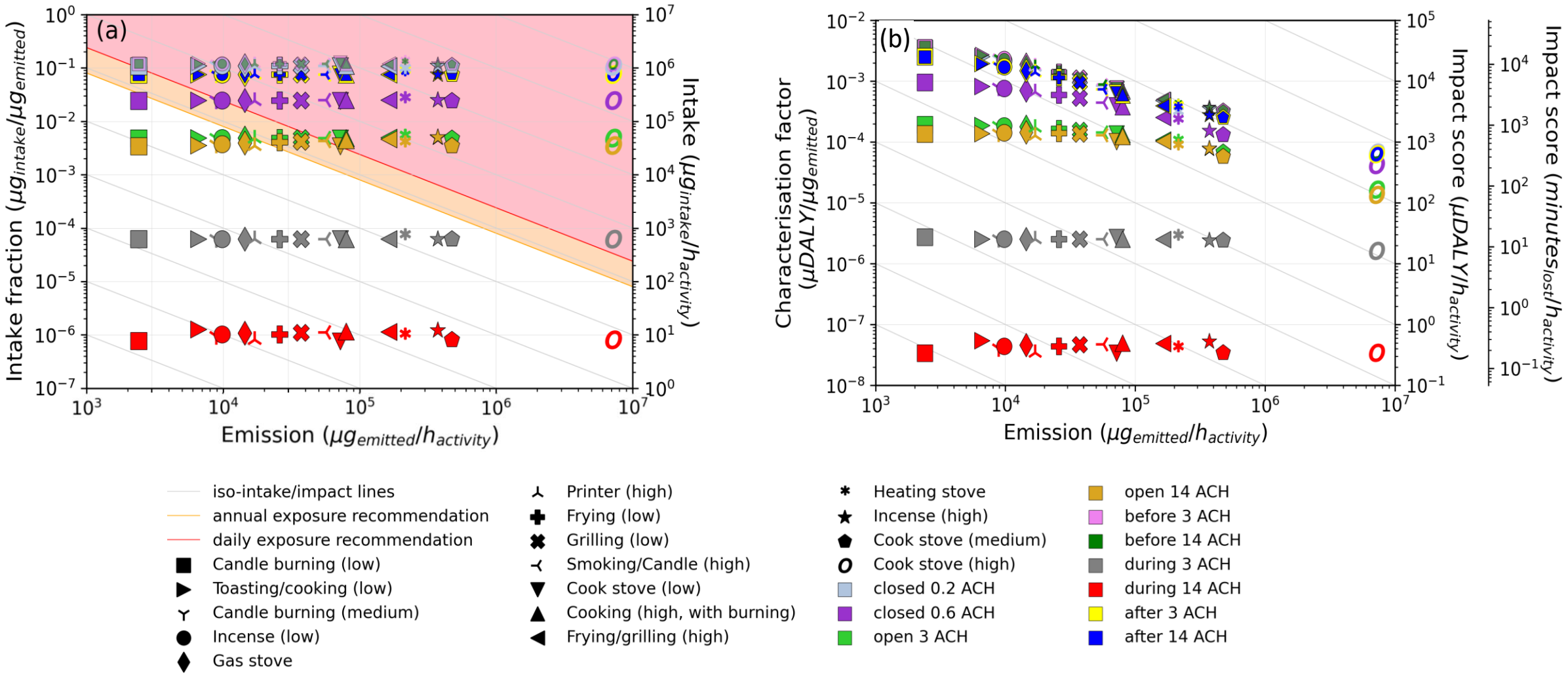
Fine particulate matter from indoor activities



(a) Intake of $PM_{2.5}$ and (b) health impacts for different activities and ventilation scenarios, compared to WHO recommended limits: daily exposure (red) and annual exposure (orange)

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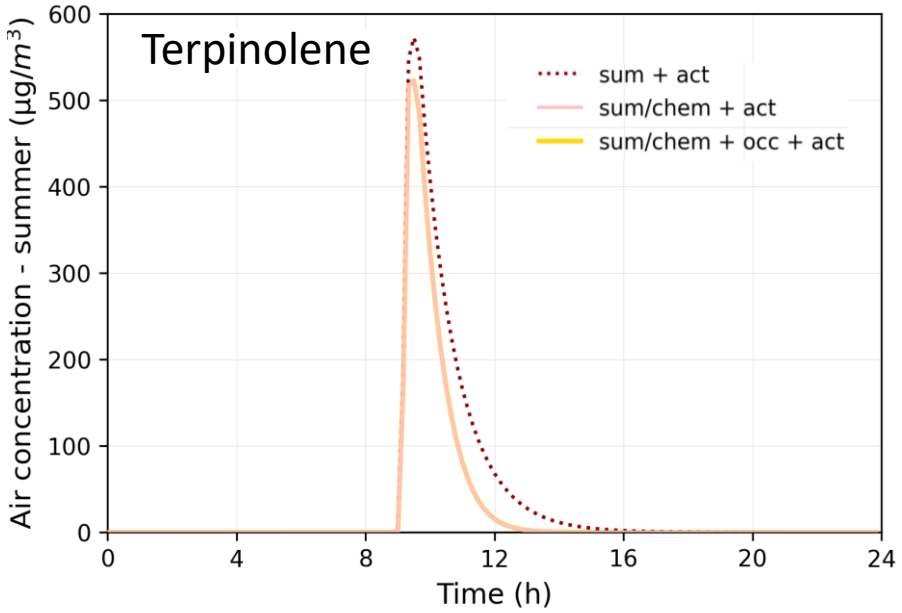
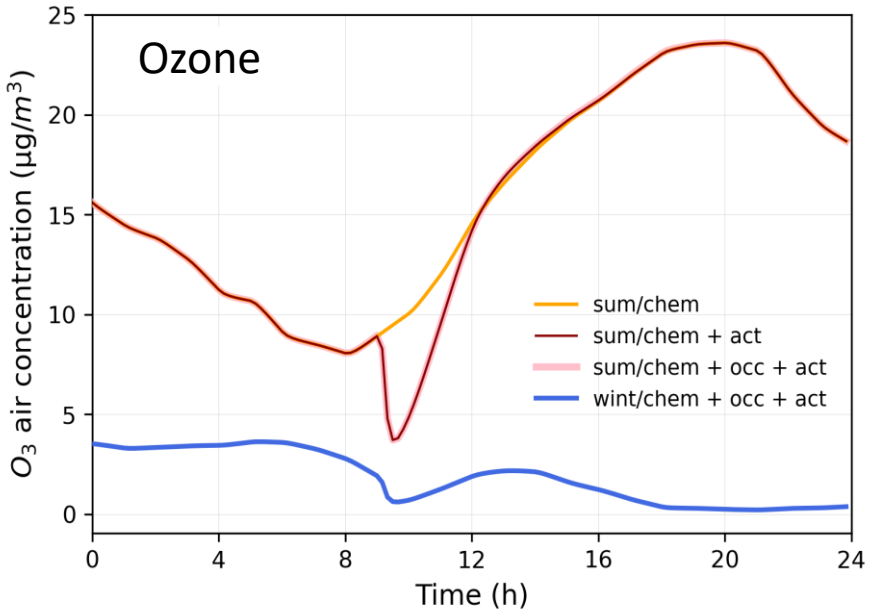
Activity VOC emissions and chemical reactions

- VOC emission data for cleaning with detergent and occupant skin/breath
- Indoor air chemistry model reference: SAPRC-07 model[1] (O3 and NOx + VOCs)





Terpinolene and ozone concentrations indoors in the presence of VOC emissions from floor cleaning and occupants

- Terpinolene produced by chemical reactions
- Ozone consumed
- Higher ozone concentrations in summer than winter: more reactivity

1. *Carter (2010)*

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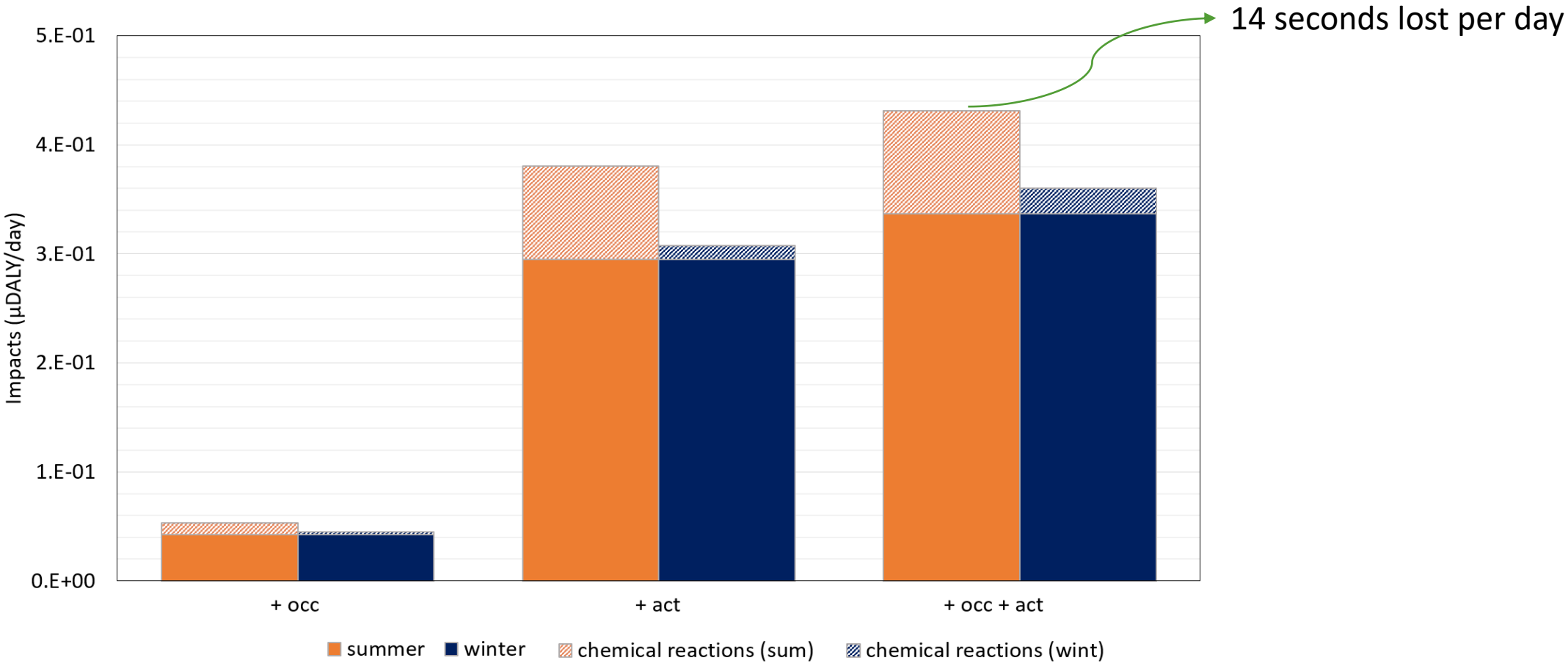
Health impacts



Health impacts due to occupant and activities VOC emissions, with the addition of chemical reactions

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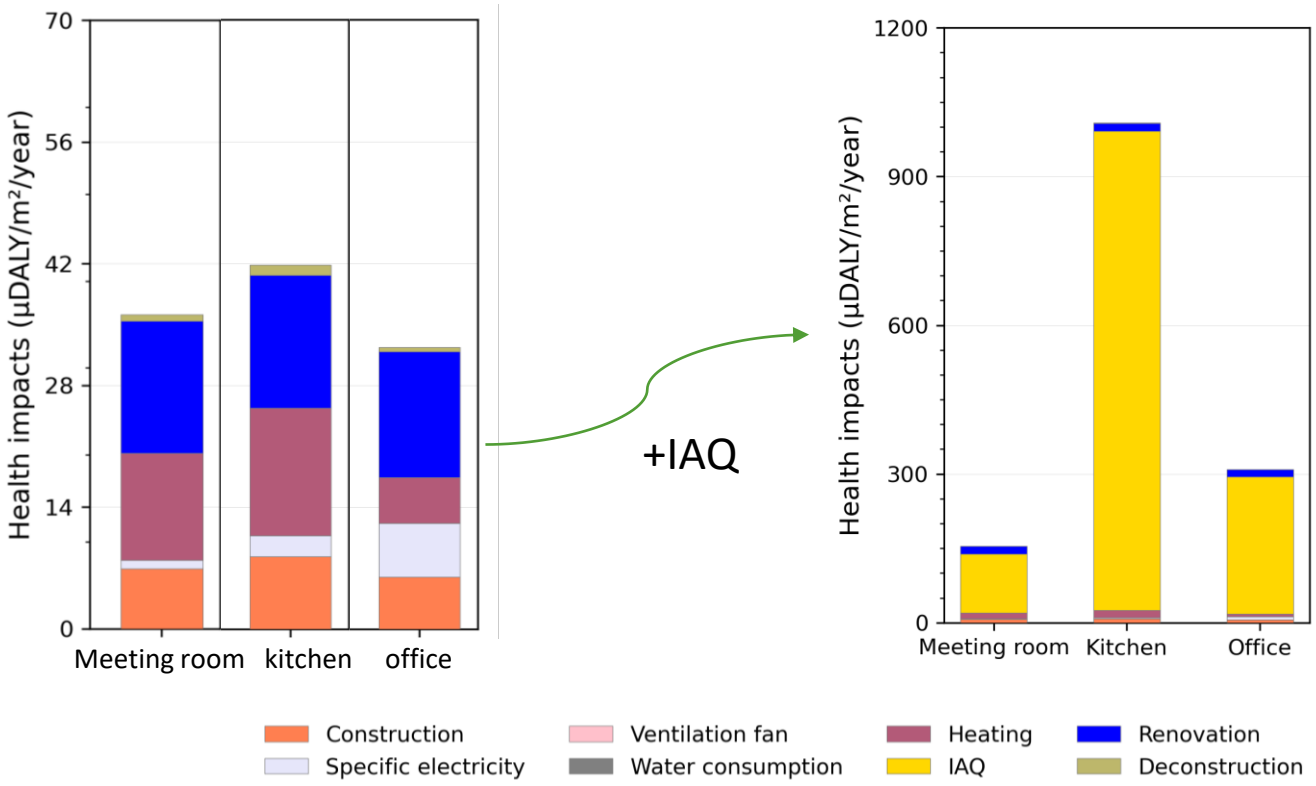
Building LCA



High impacts due to **heating**

and **IAQ** (VOCs and $PM_{2.5}$) at an average ventilation rate of 0.6 ACH

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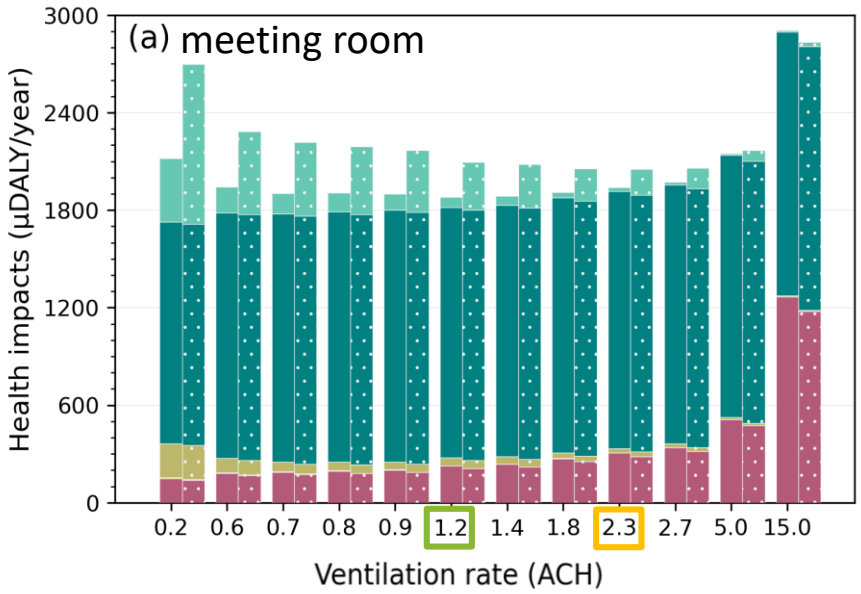
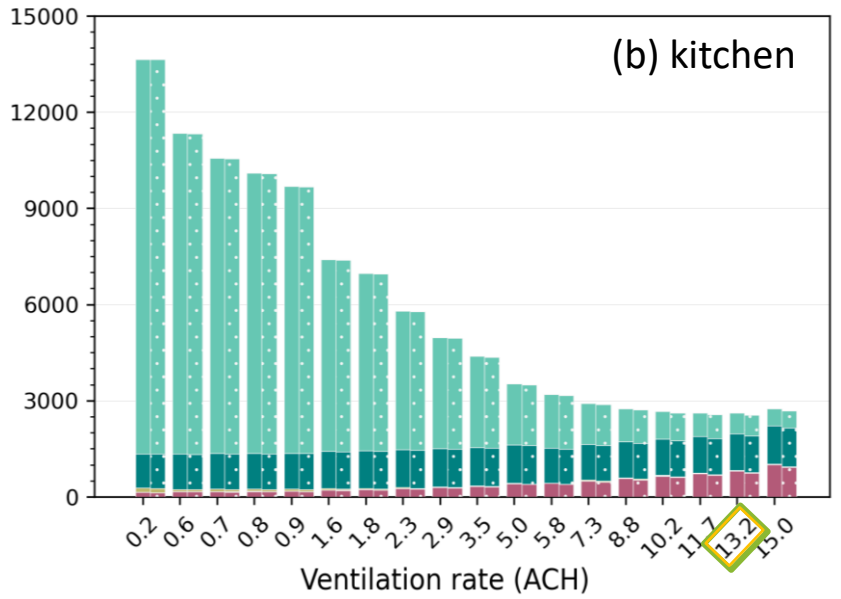
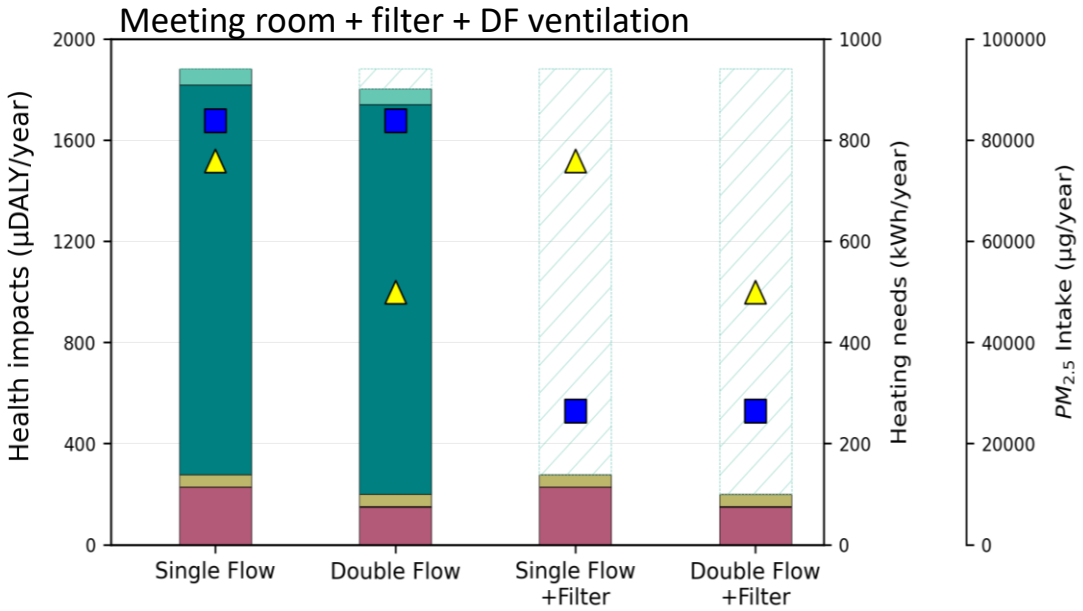
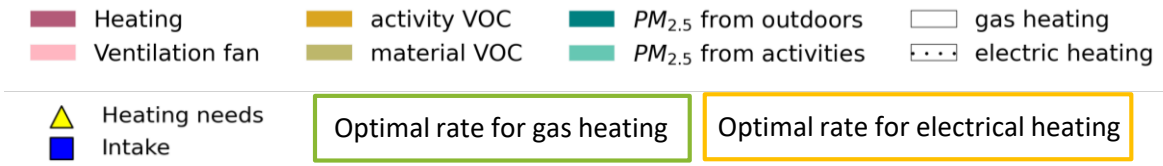
Optimal ventilation rates (office building)









Optimal ventilation rates **reducing all impacts**

Filter and DF ventilation allow to reduce IAQ and LCA (heat) impacts

Average ACH in OECD countries: **0.6 ACH**

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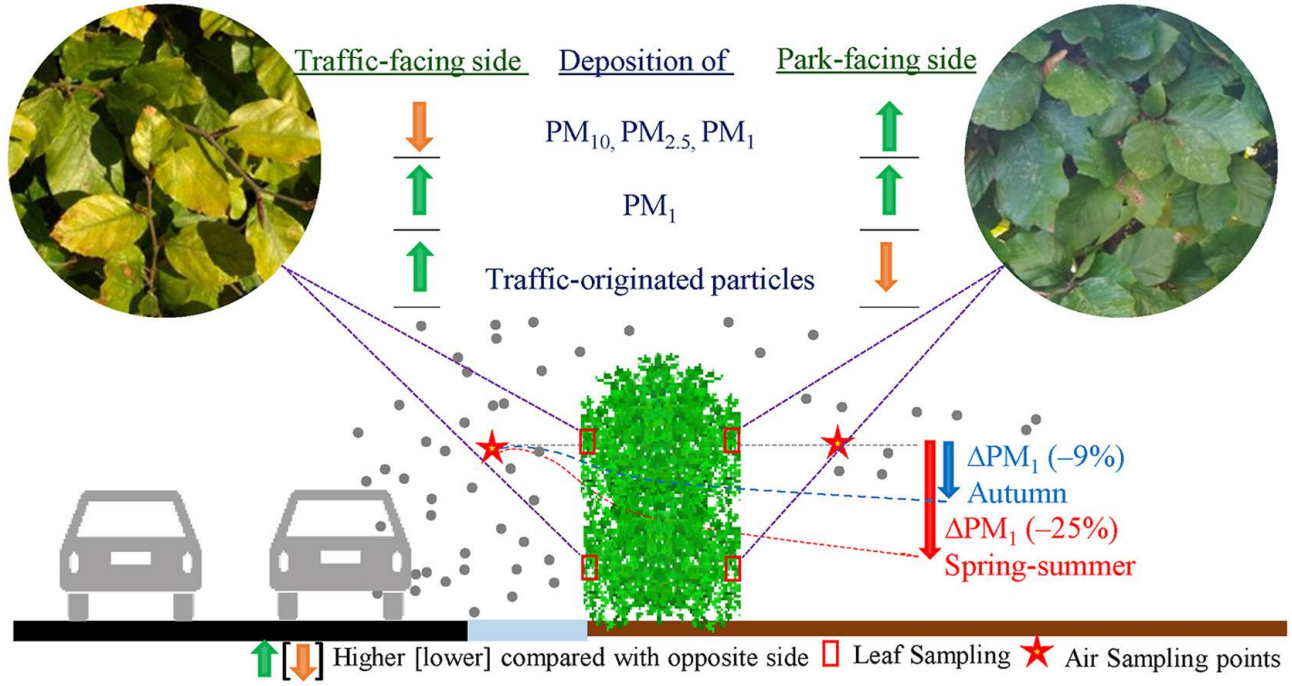
Urban vegetation

Vegetation and air quality

- **Absorption** (Leaf Area Index up to 5-6 times higher than ground suface)
- **Deposition**
- **Barrier effect**
- **Surfaces with no local emissions**

  (parks/forests…)



Abhijith et Kumar 2020

Site description

Jardin du Palais Universitaire in Strasbourg (STBG)

Vegetation

No vegetation	Reference scenario	High vegetation
	27% road 47% trees 26% grass	10% road 81% trees 9% grass

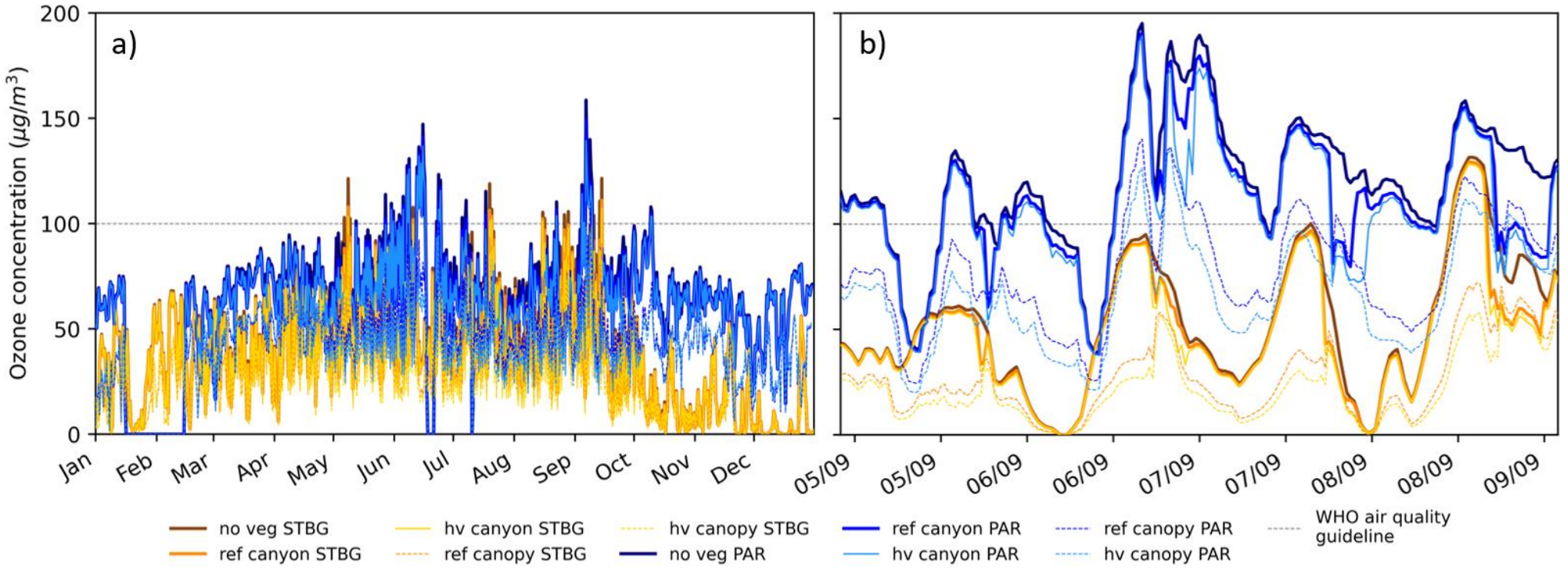
Ozone levels

Reference	High levels
From ATMO Grand-Est (Strasbourg)	From AirParif (Paris)

Average occupancy of 1 person over 12 hours (8-20h)
Results can be multiplied by different occupancy rates

Ozone reactivity NOT considered

Ozone concentrations (TEB-Surfatm)



O_3 canyon and canopy concentrations for no vegetation (nv), reference (ref) or high vegetation (hv) scenarios

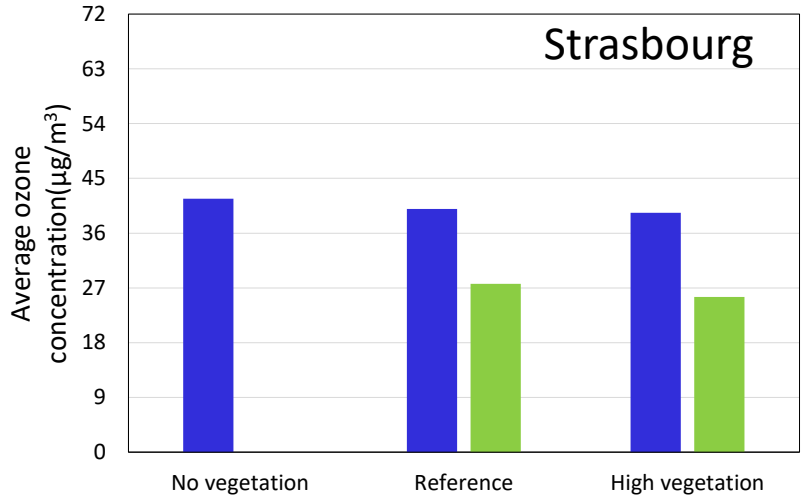
Canyon O3 concentrations are higher than the WHO guideline for:

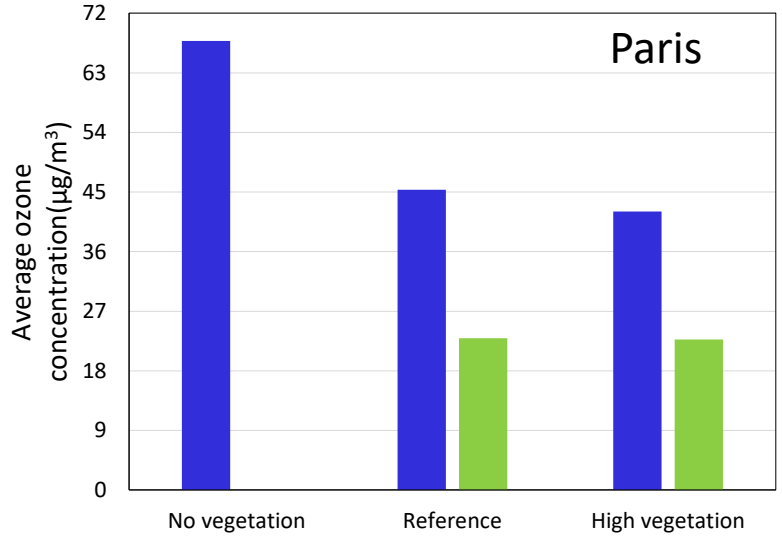
- 4% of the time in non-vegetated scenarios
- <1% of the time in vegetated scenarios.

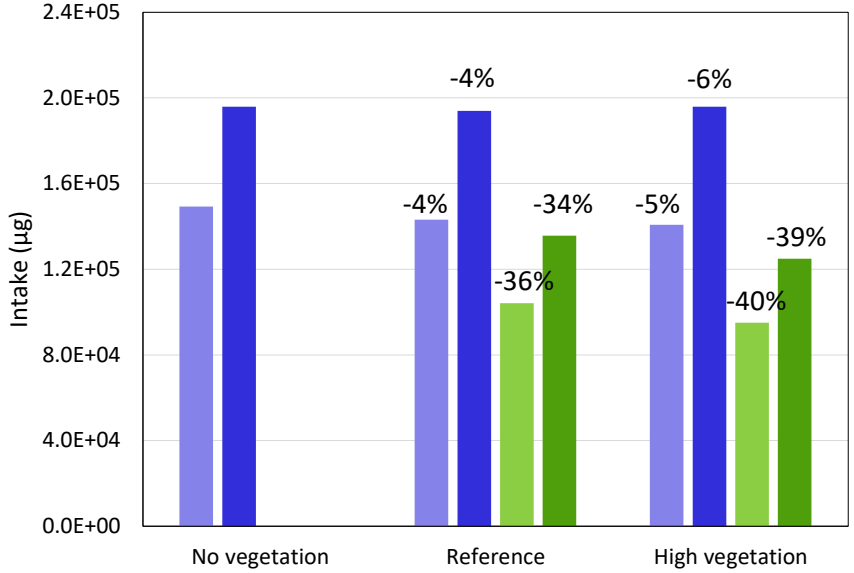
O3 concentrations decrease by:

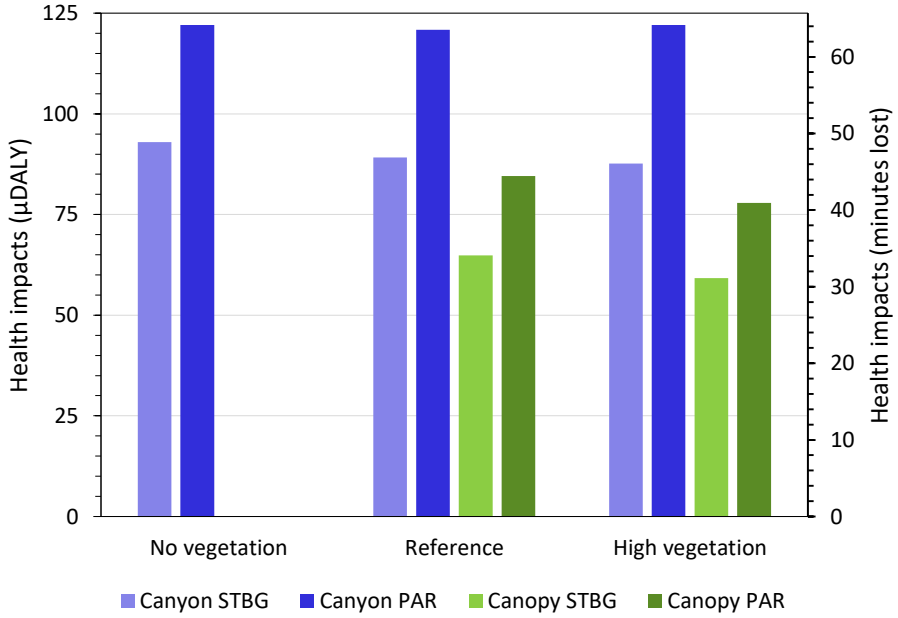
- up to 6% in the **canyon**
- 30 to 36% in the **canopy** with vegetation v/s without vegetation

Human exposure and impacts









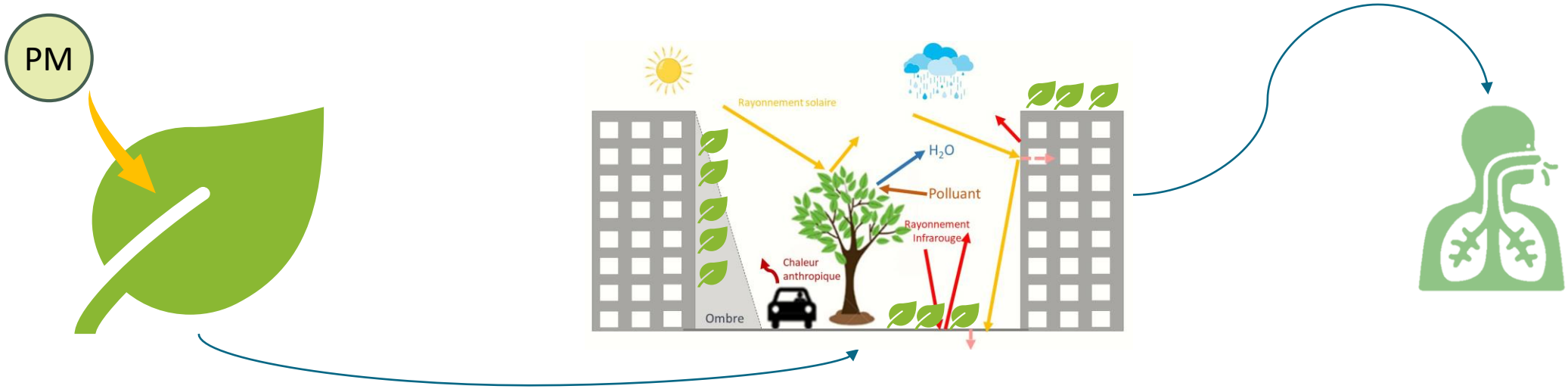
PM deposition: ongoing work

Reduction: lower emissions, dilution or **deposition**

Increase **deposition**: vegetation increases deposition surfaces (+absorption temperature regulation, biodiversity…)

Method

PM deposition model | **Air concentration** | **Exposure and damage model**



Next

Human health risks associated with indoor air pollutants (e.g. work places)

- Coordination of expert groups
- Research for methodological development (European PARC Project)

Questions?...