Mitigating urban air pollution by innovative design

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Three ways to mitigate urban air pollution

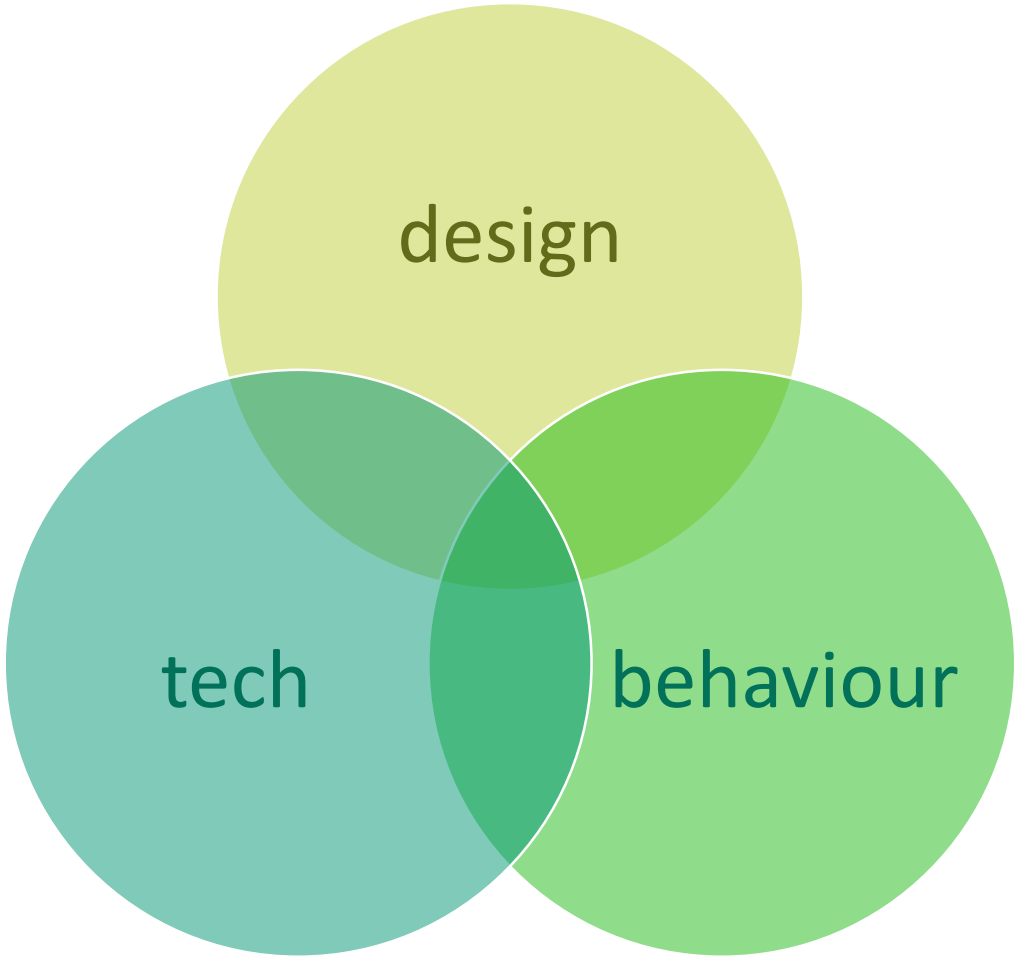
1) Improve **technology** (e.g.: transportation, construction, mass consumed products).

2) Change human **behavior** (reduce car dependency, change consumption habits, engage in citizen science and community-related projects).

3) Improve indoor/outdoor air quality by **design** (nature-based solutions, urban ventilation, bioclimatic and nZEBuildings, biomimicry).

important realization #1:

We can't design ourselves out of this situation unless design **interacts** with both human tech and behavior.



important realization #2:

Multiscale solutions are required to tackle complex issues such as urban air pollution.

Design across scales:

City

Neighborhood

Block

Plot

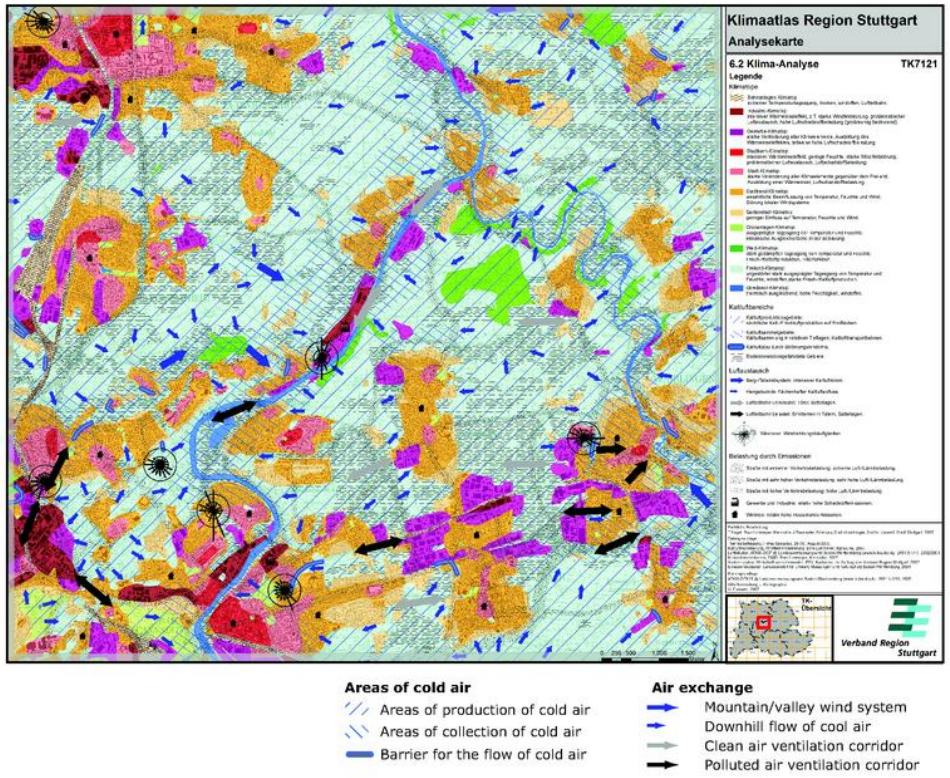
Building

Details

Seven key design goals for urban air quality

1. Urban Ventilation Corridors [city]
2. Smart and sustainable transport [city]
3. Urban Green Networks [city/neighborhood]
4. Climate-responsive urban blocks [neighbourhood/plot]
5. Bioclimatic buildings [building]
6. Clean construction technologies [building]
7. Biomimicry [details]

1. Urban Ventilation Corridors [city]



Climate analysis map for the Stuttgart region (climate-adapt.eea.europa.eu)

Aim: Improve wind flow regime in cities, thus increasing the removal of air pollutants.

Ventilation corridors: Any wide and open linear land feature

- Green networks (with non-obstructing vegetation!)
- Blue networks
- Highways
- Railways

Case Study: The urban climate atlas of Stuttgart:

- Define fresh and polluted air paths
- Maximize fresh air flow
- Minimize polluted air flow
- Restrict development in climate-sensitive locations
- Guide landscape preservation and tree-planting strategy

Provide nature-based solutions by design

Cheonggyecheon greenway in Seoul, Korea (Wikimedia Commons, 2016)

2. Smart and sustainable transport [city]

The BRT system (Wikimedia Commons, 2016)

Aim: Reduce car dependency and car-related pollution via alternative means of transport.

Case Study: Curitiba Masterplan 1964

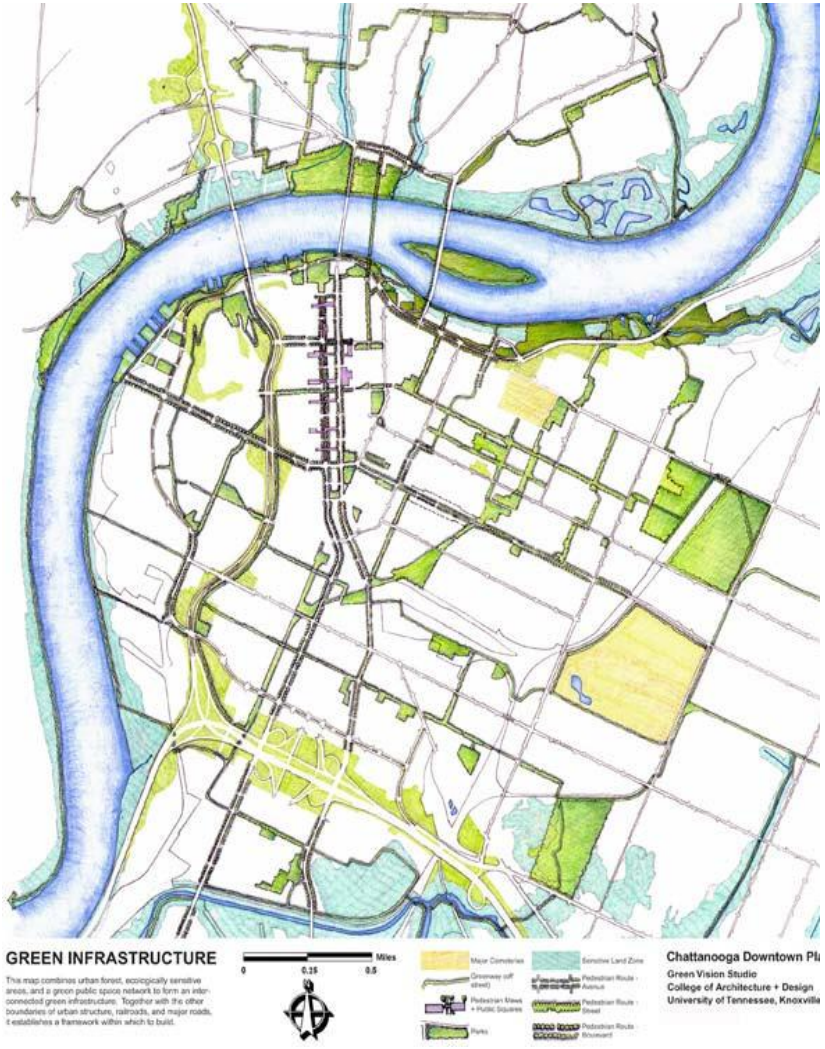
- Developed the Integrated Transit Network, including corridors dedicated to **Bus Rapid Transit (BRT)** systems.
- Provided BRT smart incentives (e.g. recycling bonuses)
- Combined mass transit with compact urban development

The results:

- **85%** of residents use public transport
- Air pollution still an issue but **reduced to EU standards**, in contrast to other Brazilian cities.
- Increase of public green space from **0.5m²** per capita in the 1970s to **50m²** per capita of green area in 1992.


Curitiba downtown (blueroom.org.au, 2017)
High-tech is optional
Political commitment to the vision is essential

3. Urban Green Networks [city/neighborhood]



Green infrastructure plan (DeKay and Moir-McClean, 2003)

Aim: Use vegetation to trap pollutants and sequest carbon emissions

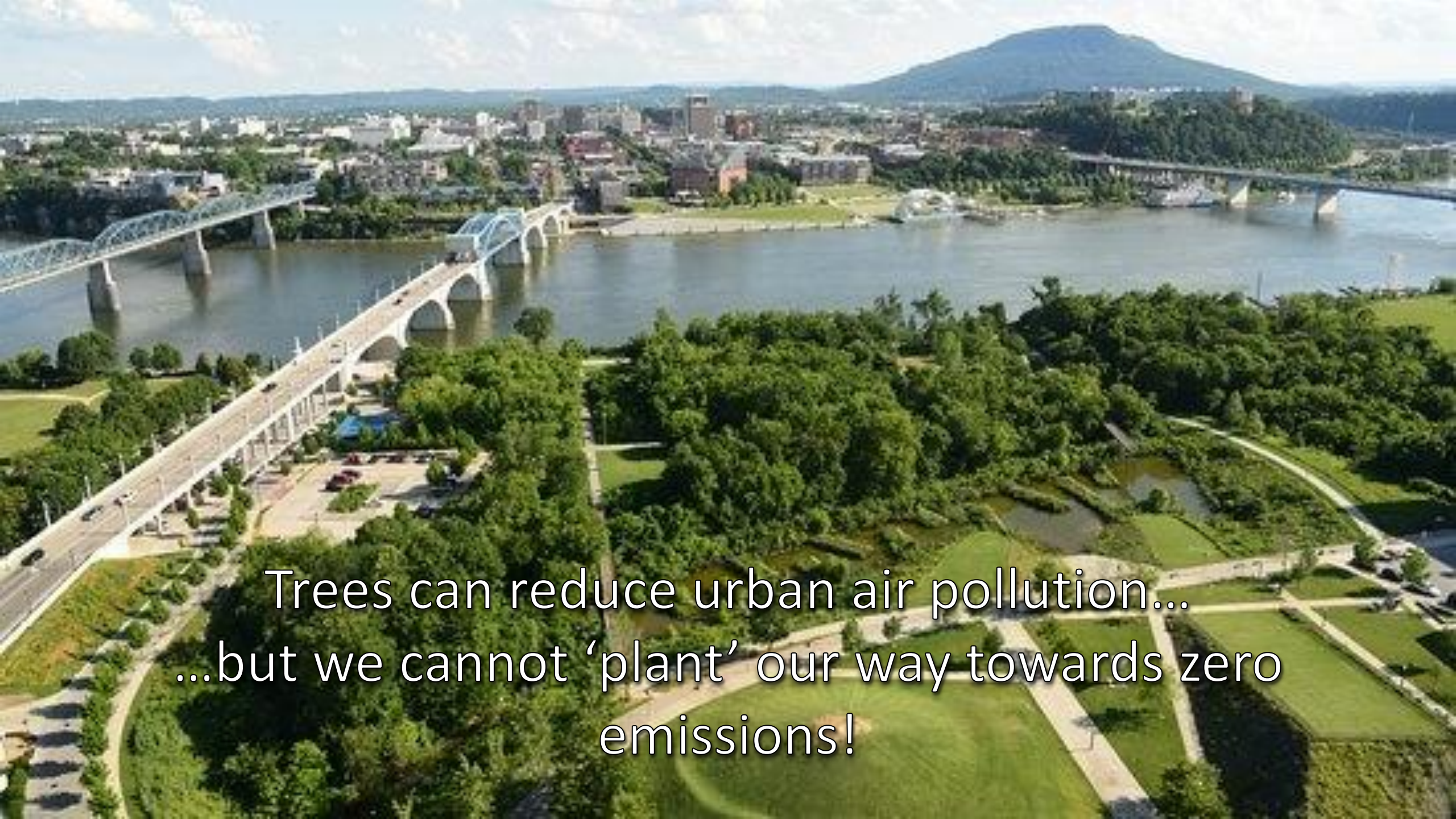
1Ha of densely wooded land (a lot of trees):

- produces approx. **40** peoples worth of oxygen per year (Cooper, 2010)
- fixes approx. **6** average dwellings worth of carbon per year.
- Traps **7% - 24%** of Particular Matter (PM) (TNC, 2016).

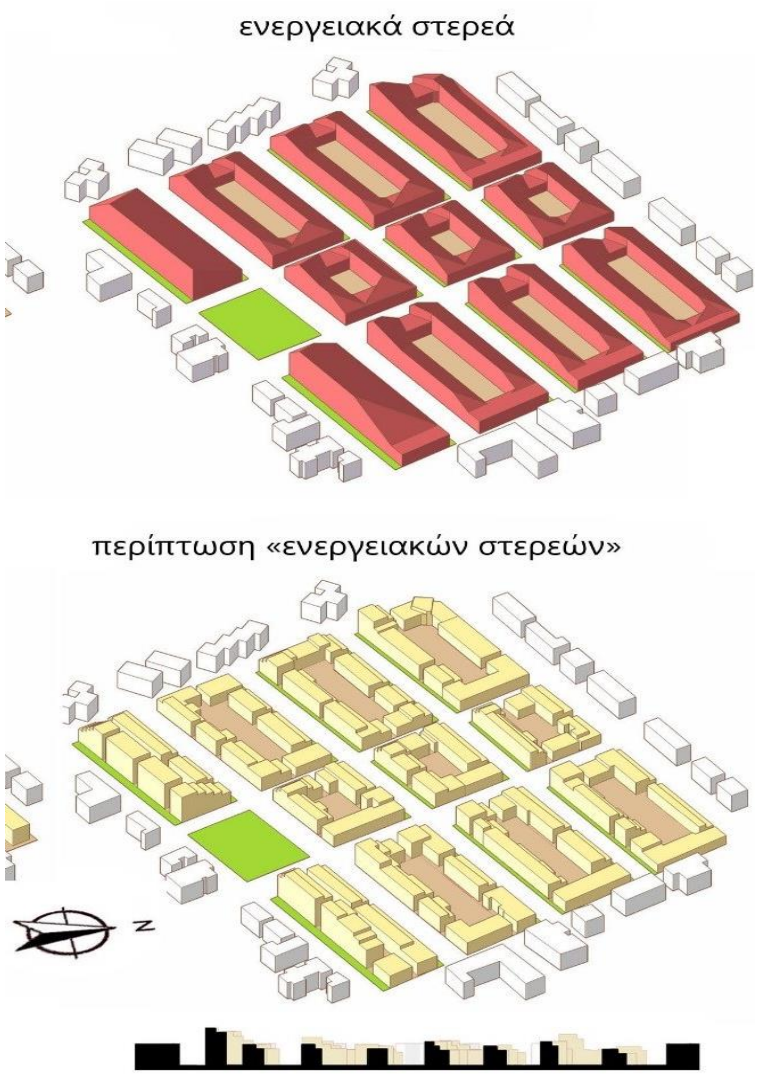
However!
Trees **emit** volatile organic compounds (VOCs) and may inhibit urban ventilation (Vos et al., 2012)

Case Study: The Green Center Masterplan for Chatanooga (TN)

- Development of an extensive network of ‘Civic Green Places’, ‘Connecting Green Links’, and ‘Dispersed Landscaping’.
- Zoning of areas with high environmental value
- Extensive urban reforestation
- Mix of uses and sustainable transport


Trees can reduce urban air pollution…
…but we cannot ‘plant’ our way towards zero emissions!

4. Climate-responsive urban blocks [neighbourhood]



RSB envelopes and resulting urban forms (Vartholomaios, 2016)

Aim: Adapt the urban form to climate to improve the bioclimatic potential of buildings, resulting in less emissions.

Block shape, orientation and volume influence:

- Winter **solar gains** and summer **shade** effectiveness
- **Natural lighting** availability
- The intensity of the Urban Heat Island (**UHI**)
- The immediate **microclimate** including the **wind flow** regime

Case study: The Residential Solar Block (RSB) Envelope

- It describes the maximum block volume that satisfies two criteria: compactness and winter solar gains.
- It is an update of the Solar Envelope concept proposed in the 1970s
- A pilot study in Thessaloniki, Greece revealed a significantly improved bioclimatic potential of urban blocks


Cultivate climate responsiveness from the earliest stages of design.

5. Bioclimatic buildings [building]

Bioclimatic residence in Panorama (Georgiadou, 2012)

Aim: Design bioclimatic buildings so that reliance to HVAC equipment and associated carbon emissions are reduced.

Bioclimatic design of houses in Mediterranean climates leads to:

- **50% - 75%** reduction of heating loads
- **>80%** reduction of cooling loads

Assuming no UHI and present climate

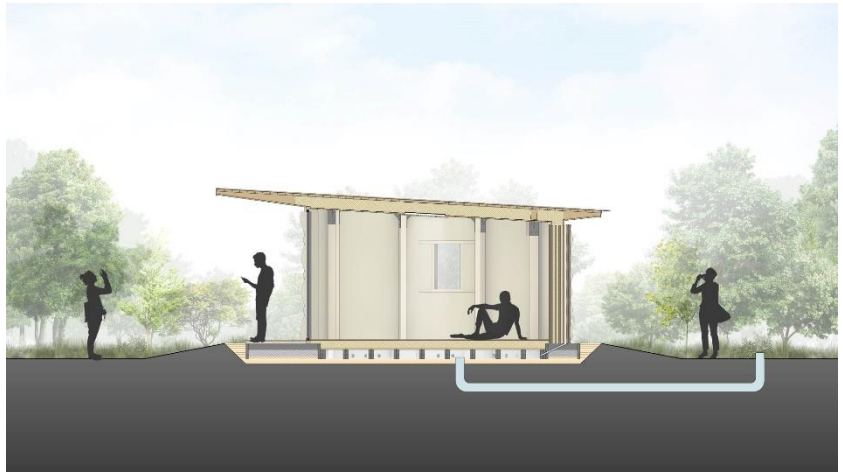
Case study: Bioclimatic residence in Panorama, Thessaloniki:

Basic design strategies:

- Conformity to the landscape
- Large southern openings, small northern openings
- Layout optimized for cross and stack ventilation
- Extensive shading, particularly in eastern/western facades
- High thermal mass + insulation and double glazing
- Green roof and Trombe walls


Bioclimatic school in Crete, (cretalive.gr, 2016)
Utilizing the climate = less HVAC reliance
Less HVAC reliance = less emissions

6. Clean construction technologies [building]



Gaia (3dwasp.com, 2018)

Aim: Reduce air pollution from construction activities and occupation.

Indoor air pollution may be **more severe** than outdoor air pollution (WHO, 2012; EPA, 2018; Logue et al., 2013)!

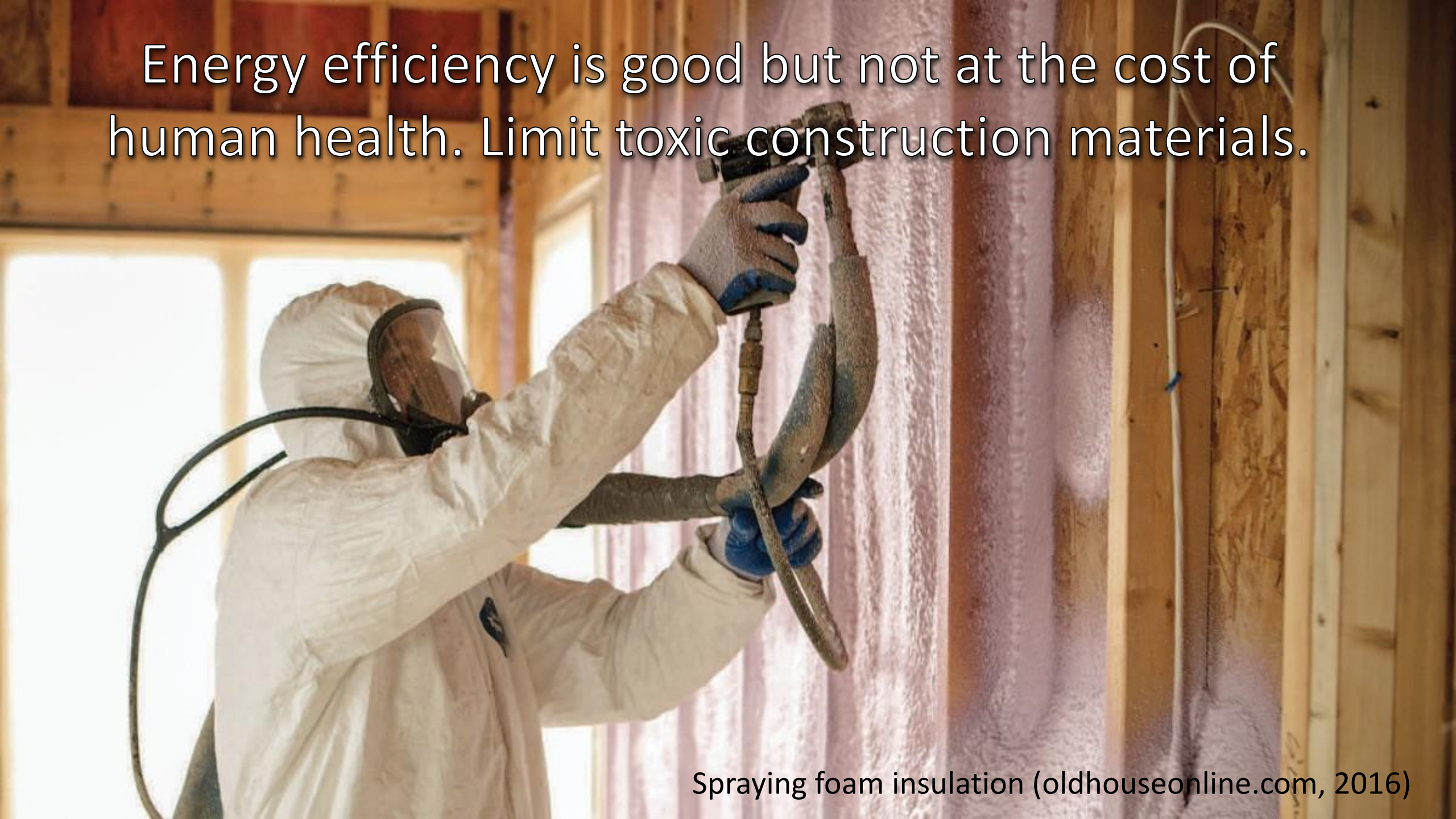
'Sick building syndrome' causes:

- Outgassing of toxic building materials (e.g. formaldehyde and phthalates)
- Concentration of VOCs, mold, smoke and ozone due to bad ventilation
- Common household industrial chemicals
- Poor HVAC design and maintenance

Case study: Gaia, the 3D printed earth house

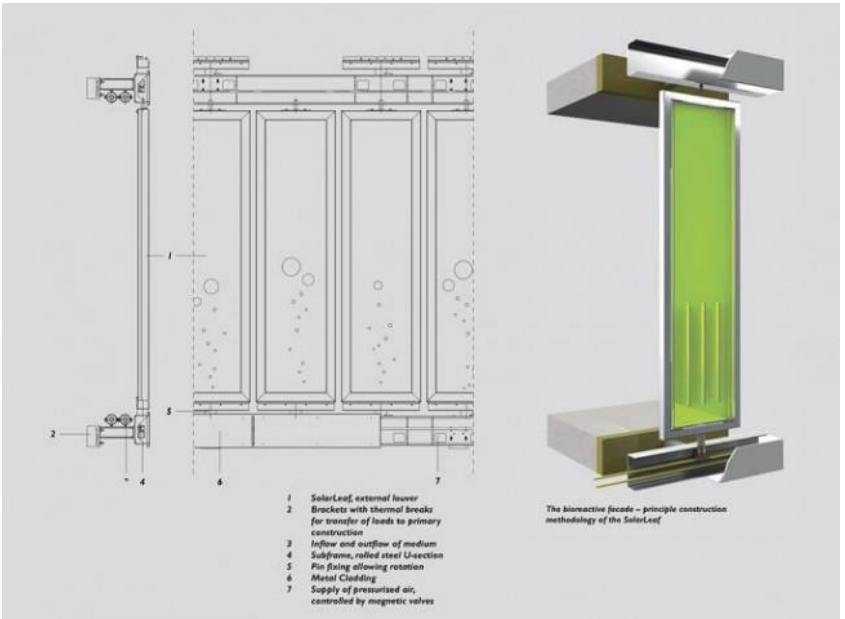
- use of clay earth, rice straw, and rice husk
- WASP special 3D printing crane
- Construction costs: 1000$ (not incl. labor)

Energy efficiency is good but not at the cost of human health. Limit toxic construction materials.



Spraying foam insulation (oldhouseonline.com, 2016)

7. Biomimicry [details]



(morethangreen.es, 2018)

Aim: Maximize urban surface area that actively captures carbon emissions and air pollutants.

Available technologies

- Green walls and green roofs
- Photocatalytic surfaces (self-cleaning and depollution using solar radiation)
- Algae bio-reactor façade (convert carbon to biomass)

Case study: SolarLeaf. Algae bio-reactive façade in Hamburg

- World's first façade bioreactor generating biomass and heat
- Requires minimal maintainance
- Bioreactor panels also provide shade when and where needed
- Covers 1/3 of the building's heating energy demand


Biomimicry can be a powerful design tool for improving urban air quality.
javawisata.com, 2017

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