Impact of solar installations on the urban energy surface-atmosphere budget

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The urban climate
Observed averaged minimum temperature during 2003 heat wave around Paris
The urban heat island

- Thermal stress
- Air pollution
- Affect more than half of the world population
- Scale now accessible for our numerical models

Observed averaged minimum temperature during 2003 heat wave around Paris
The urban heat island

TEMPORAL EVOLUTION
- Mainly a nocturnal phenomenon
- UHI generally starts during the daily cooling period

SPATIAL VARIABILITY
- Correlation between air temperature and urban properties
What urban heat island is not about...

$\text{CO}_2$ emissions $\rightarrow$ Global warming
What urban heat island is not about...

- CO₂ emissions → Global warming
- CO₂ emissions and Urban air pollution → Urban warming and urban Heat island
What urban heat island is not about...

- CO$_2$ emissions
- Global warming
- CO$_2$ emissions and Urban air pollution
- Urban warming and urban Heat island
What urban heat island is not about...

- CO₂ emissions
- Urban vegetation
- CO₂ storage
- Decrease of urban heat island

- Global warming
- Urban warming and urban Heat island

CO₂ emissions and
Urban air pollution
What urban heat island is not about...

- CO$_2$ emissions
- CO$_2$ emissions and Urban air pollution
- Urban vegetation

Global warming
Urban warming and urban Heat island
Decrease of urban heat island

CO$_2$ concentration, source NASA
What is UHI about...

- **Upward Heat Flux from the Surface**
- **Evaporation Vegetation Transpiration**
What is UHI about...
Other features of the urban climate

Impact on air circulation and dispersion of pollutants
The urban climate and the use of solar energy
The passive house:
- Use of solar energy and inertia to create a friendly indoor climate
- at the scale of the city and during summer: lead to issues of heating load
Solar collectors

- Heating

- Supply of hot water

- As for the passive house, enhance the heat load during summer => solution for seasonal storage of hot water? (Roulet, 2001)
Photovoltaic panels

- PV produce electricity:
  - Reduction of the available energy at the surface that is responsible of the urban climate?
  - Reduction of the needs of other source of energy?

- PV also change the heat transfer through the building envelope:
  - Change of albedo?
  - Change of emissivity?
  - Change of thermal conductivity?
Radiative properties of PV will generally not affect the radiative balance of the city or small tendency to enhance surface temperature.
### Thermal properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal conductivity $W \text{ m}^{-1} \text{ K}^{-1}$</th>
<th>Specific heat $\text{MJ kg}^{-1} \text{ K}^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>7.9</td>
<td>2.03</td>
</tr>
<tr>
<td>tiles</td>
<td>1.15</td>
<td>1.58</td>
</tr>
<tr>
<td>asphalt</td>
<td>0.82</td>
<td>1.74</td>
</tr>
<tr>
<td>Metal (Paris, Zn)</td>
<td>110</td>
<td>2.7</td>
</tr>
<tr>
<td>brick</td>
<td>1.15</td>
<td>1.58</td>
</tr>
<tr>
<td>insulation</td>
<td>0.04</td>
<td>$0.02 \rightarrow 1.5$</td>
</tr>
</tbody>
</table>

- PV thermal properties are in the range of traditional materials used in urban areas
Conversion of solar energy to electricity?

- Currently efficiency between 10 to 20%
- Given that albedo of PV is lower than averaged albedo of the city (0.1 versus 0.15), this means that the impact on the reduction of the available solar energy is between 5 to 15%
- Use of the energy generated by PV panels:
  - Energy used in the city -> reduce the use of other source of energy (combustion, etc...)
  - Energy used outside (or suburb where low density) -> reduce heat load over the city
The mounting of the PV

- PV modules have poor insulating properties but mountings on air gap and even ventilated (natural) air gap can greatly reduce the heat load in buildings
- In Tianjing (China) : reduction of 50% of the daily heat gain and the peak cooling demand in summer (Wang et al., 2006, Tian et al, 2006)
- Affect of less than 10% the winter daily heat loss and the peak heating demand
- Enhance the efficiency of the PV of about 5%
Impact of the urban climate on PV

- Air pollution by particles:
  - Reduction of the available energy at the surface between 10 to 20% => reduction of the output
  - Variation of the spectrum: more diffuse radiation which tends to enhance the efficiency of the PV
  - Reduction of surface temperature of PV => increase efficiency

- Increase air temperature: tends to decrease PV efficiency but UHI generally not the most significant at day

- Decrease of wind speed so lower convective exchange than over a PV panels in countryside.
MUSCADE project
ANR project leaded by CNRM
2010-2012
**Urban context**

- Population increase
- Urban expansion and inertia
- Energy consumption
- GHG emissions

**Energy use context**

- Consumption because of heating/cooling demand
- Thermal regulation
- Energy production

**Climate change**

- Warming
- Century time scale
- Objective of reducing GHG emissions
What will be the urban climate of a city in a context of urban expansion and climate change?

What will be the energy demand to provide thermal comfort inside housings?

What will be local renewable energy production capacity?
PARTNERS

GAME
Groupe d’étude de l’atmosphère météorologique
Project manager
Urban climate modeling

CSTB
Centre Scientifique des Techniques du Bâtiment
Technical buildings design

CIRED
Centre International de Recherche en Environnement et Développement
Urban economy and expansion modeling

LRA-GRECAU
Groupe de Recherche Environnement Conception Architecturale et Urbaine
Urban planning, energy and sustainable urban development

ESO
Espace et Sociétés
City evolution observations
**Scientific objective:**

Studying from now to 2010, interactions between the structure of the city, building processes, local energy production, urban micro-climate, and climate change.

**Technical objective:**

Develop a **numerical model** of urban expansion, simulation of the urban climate, simulation of building energy demand-offer at the city scale, applied to Paris urban area.
CONCLUSIONS

- Urban climate in the future?
- Energy supply in the future (emissions, depletion)?
- The use of solar energy impacts the urban energetics of the urban climate
- Need for solutions that integrate both features at the scale of the city