Effect on CO_2 Emissions Reduction of Building-Urban Area by Introducing Solar Reflective Paint

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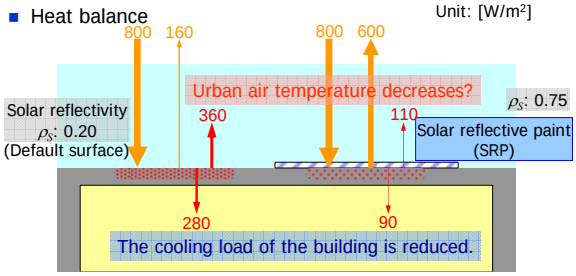
1. Introduction

Solar reflective paint (SRP) and urban environment

- Heat balance

Unit: [W/m²]



A large-scale introduction of SRP could also have an impact on the urban thermal environment.

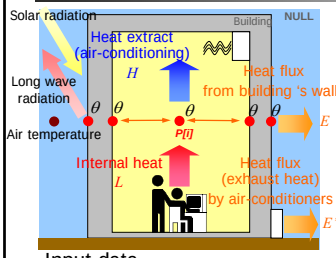
1. Introduction

Overview of research

- We focus upon the impact of solar reflective paint (SRP).
- Methodology
  1. We develop a model composed of building heat load simulation and urban thermal environment simulation, through calculating heat flux from building and estimating air temperature change throughout the year.
     It is important to recognized the interactions between building environment and urban environment.
  2. CO_2 reduction is evaluated in case of introducing SRP to the office building individually.
     (a direct effect by reduction of absorption of solar radiation)
  3. CO_2 reduction is evaluated in case of a large-scale introduction to all the office buildings in the Tokyo area.
     (considering also an indirect effect by ambient air temperature decreasing)

2. Building heat load simulation

Building heat load simulation model



Input data
- Meteorological elements
- Building specifications
- Daily schedules of internal heat and air-conditioning

Heat balance equation

$$[M]\{\theta^K|_P\} = \{V\}$$

- Equation at each point.
- Differential equation about θ converted according to backward difference method.
- M is a constant (matrix).
  V is a constant (vector).

Heat stored in building

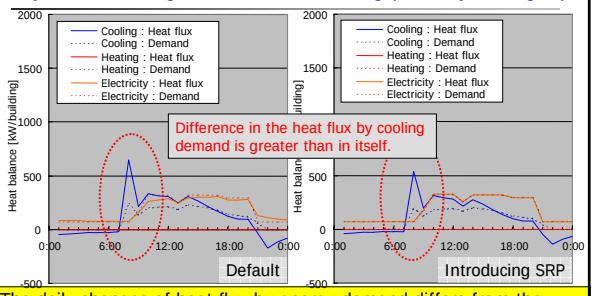
$$U = \sum_{i=0}^{N_P-1} C_P|_{P[i]} \left(\theta|_{P[i]} - \theta_{\mathrm{ref}}\right)$$

Heat flux from walls

$$\frac{U^K - U^{K-1}}{\Delta t} = (L - H) - E$$

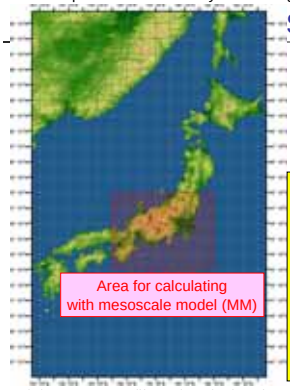
2. Building heat load simulation Simulation results

Daily heat flux change from the office building (weekdays in August)



- The daily changes of heat flux by energy demand differs from the daily change of energy demand itself.
- These results are input to urban thermal model as anthropogenic heat.

3. Air temperature decrease by introducing SRP



Simulation conditions

If SRP is introduced to all the office buildings as the commercial sector in the Tokyo area...

- Area for calculation
  Kanto & Chubu districts
  (33N-36N, 135E-142E)
  East-West: about 600[km]
  South-North: about 600[km]
- Grid size
  Horizontal: about 10[km]
- Area for evaluation
  Tokyo area

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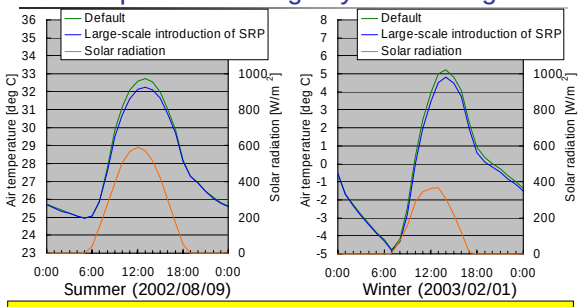
3. Air temperature decrease by introducing SRP Simulation results

Air temperature change by introducing SRP



- Air temperature decreases at most 0.5[deg C], in all seasons.
- This effect by introducing SRP is maintained even at night.

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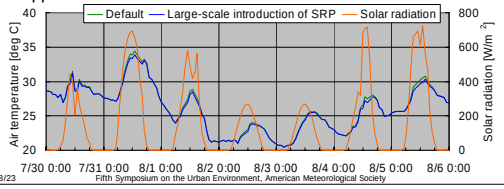
3. Air temperature decrease by introducing SRP Simulation results

Air temperature decreasing effect based on MM simulation

- Equation predicting air temperature decreasing
  - Simulation on MM requires much cost of computing
  - We simulated in representative days in each season, and extended these results to annual, using meteorological data.
  - Estimating equation: $(\Delta\theta)^{K} = \Delta_{I} I_{G}^{K} + \Delta_{(\Delta\theta)}(\Delta\theta)^{K-1}$

    Term related to reduction in the absorption of solar radiation

    Term related to decreasing effect at previous time (especially, at night)
  - Application:



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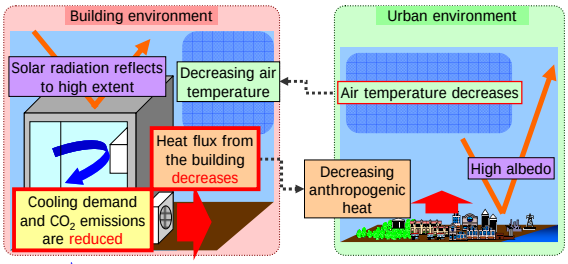
4. Building simulation considering urban environment

CO_2 reducing effect of buildings

- Direct effect and indirect effect



Interactions between building environment and urban environment should be taken into account.

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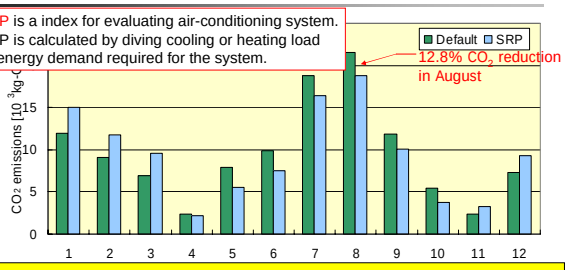
4. Building simulation considering urban environment Simulation results

CO_2 emissions from the office building considering only the direct effect

COP is a index for evaluating air-conditioning system.
COP is calculated by diving cooling or heating load by energy demand required for the system.



- Evaluation of the direct effects by a reduction in solar radiation.
- CO_2 are reduced in the summer, but 0.6% increase throughout the year.
  - Because heating COP (1.74) is greater than cooling COP (2.99).
- If SRP can be introduced only Apr. to Oct., one expects a 10.7% reduction.

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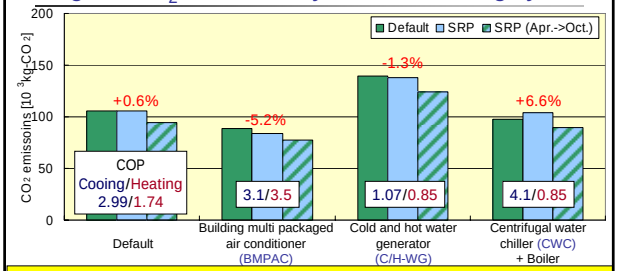
4. Building simulation considering urban environment Simulation results

Change of CO_2 reduction by air-conditioning systems



- According to the simulation, there is a large proportion of CO_2 emissions from heating system, because heating COP is small.
  Nowadays, BMPAC and C/H-WG become popular that have large heating COP.
- 5.2% CO_2 reduction in BMPAC vs. 6.6% increase in CWC + boiler.

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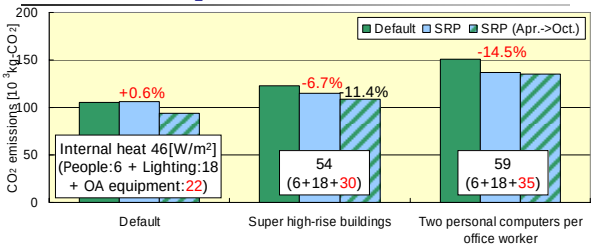
4. Building simulation considering urban environment Simulation results

Change of CO_2 reduction by office automation



- Nowadays, because of greater numbers of OA equipments, internal heat generation tends to increase.
- Office automating makes heating load decrease and cooling load increase.
  - These are advantageous for SRP.

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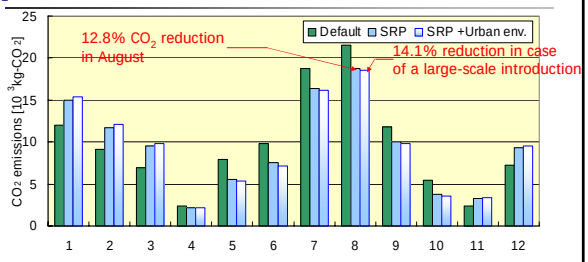
4. Building simulation considering urban environment Simulation results

CO_2 emissions from the office building considering also the indirect effect



- A large-scale introduction of SRP to all the office building in the Tokyo area may bring the indirect effect by temperature decreasing.
- A large-scale introduction of SRP leads to a 0.8% increase in the CO_2 emissions, larger than a 0.6% increase for an individual introduction.

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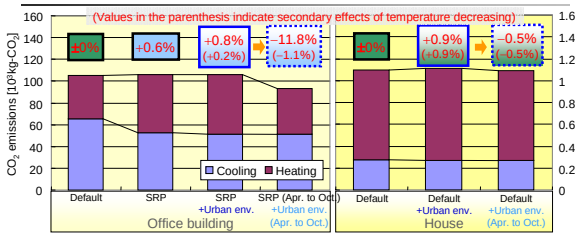
4. Building simulation considering urban environment Simulation results

CO_2 emissions with the indirect effect being taken into account



- A 0.8% increase vs. 0.6% increase with only direct effects.
- And it causes a 0.9% increase in the CO_2 emissions from houses with no painting because of air temperature decreasing effect.
- Switching (only introduction Apr. through Oct.) leads to an 11.8% CO_2 reduction and a 0.5% reduction in the house.

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Conclusion

- A new heat load simulation model was developed. Calculation of heat flux from buildings is significant.
- Using this model and urban thermal environment model, CO_2 reducing effects of solar reflective paint (SRP) were evaluated taking into account of the interactions between building environment and urban environment.
- A large-scale introduction of SRP in the Tokyo area, causes CO_2 emissions to increase by 0.9%, and in the residential sector by 0.5%. This is more than a 0.6% increase for introducing to the building individually.
- SRP is advantageous for CO_2 reduction throughout the year in the OA building and the building having a new air-conditioning system.