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2016 Purdue Conferences
Compressor Engineering
Refrigeration and Air Conditioning
High Performance Buildings

Conversion Factors for Comparing the Performance of Variable Refrigerant Flow Systems

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Background

Energy consumption of the building sector exceeds 30% of the total consumption

↓

CO_2 emissions reached 32 billion tons in 2013

↓

The ratio of air conditioning energy consumption in office buildings approached 40%

↓

Reduction potential is quite considerable

Background

In Japan

Performance evaluation of
VRF (Variable Refrigerant Flow) systems

Rated by JIS (Japan Industrial Standards) Committee

In 2006, the Committee revised
the air-conditioning performance evaluation

Background

Factors

COP = Coefficient of Performance

$$= \frac{\text{Rated capacity (kW)}}{\text{Rated power consumption (kW)}}$$

➡ No consideration of seasonal temperature changes

Far from the actual operation

APF = Annual Performance Factor

$$= \frac{\text{Annual total capacity of cooling / heating periods (kWh)}}{\text{Annual total consumption of cooling / heating periods (kWh)}}$$

➡ Proper evaluations

Close to the actual operation

Background

In the market

COP machines

COP = 2.6
COP = 3.3
:

APF machines

APF = 4.0
APF = 5.5
:

Difficult to compare

Conversion factors

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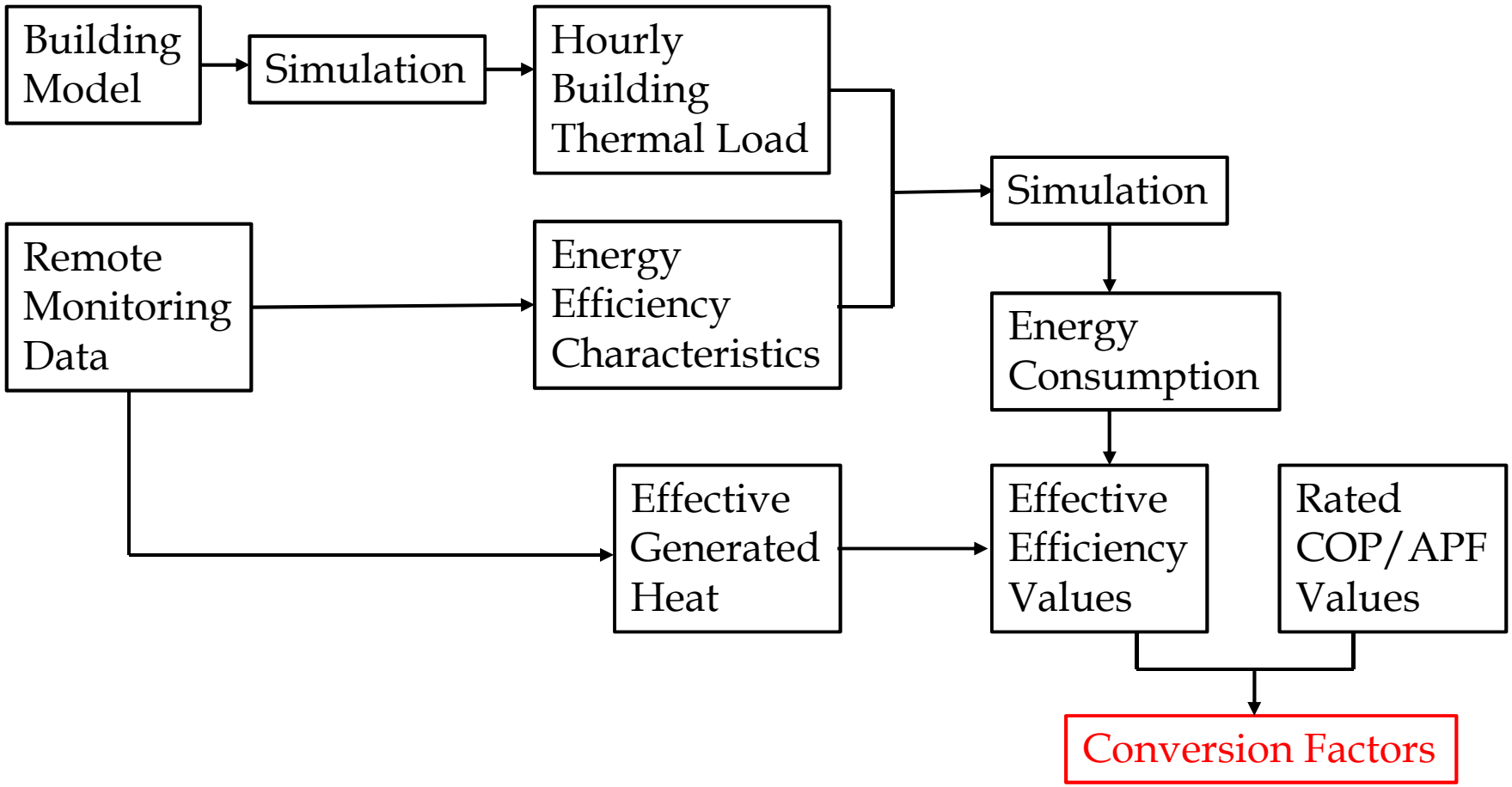
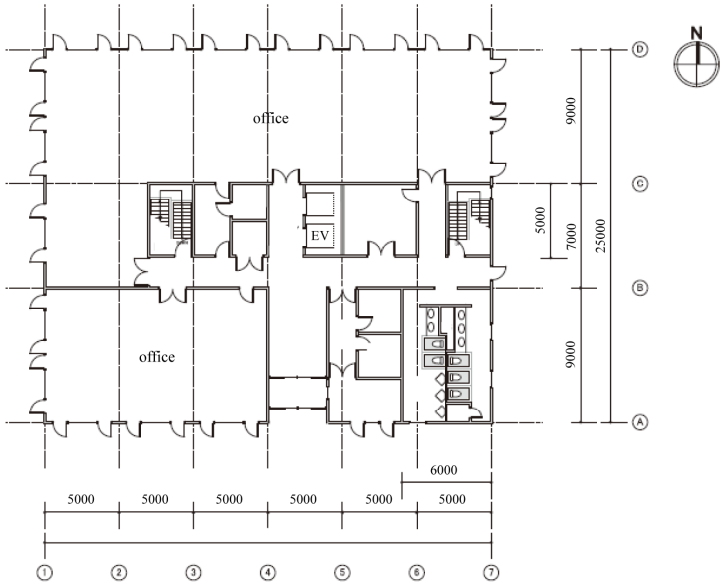
Study flow

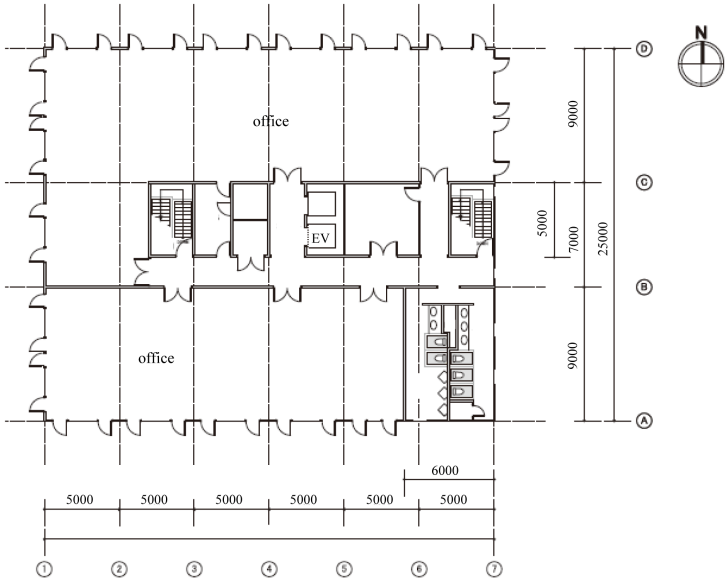

Building Model
Simulation
Hourly Building Thermal Load
Remote Monitoring Data
Energy Efficiency Characteristics
Simulation
Energy Consumption
Effective Generated Heat
Effective Efficiency Values
Rated COP/APF Values
Conversion Factors

Simulation model

Office building – 5000 m^2

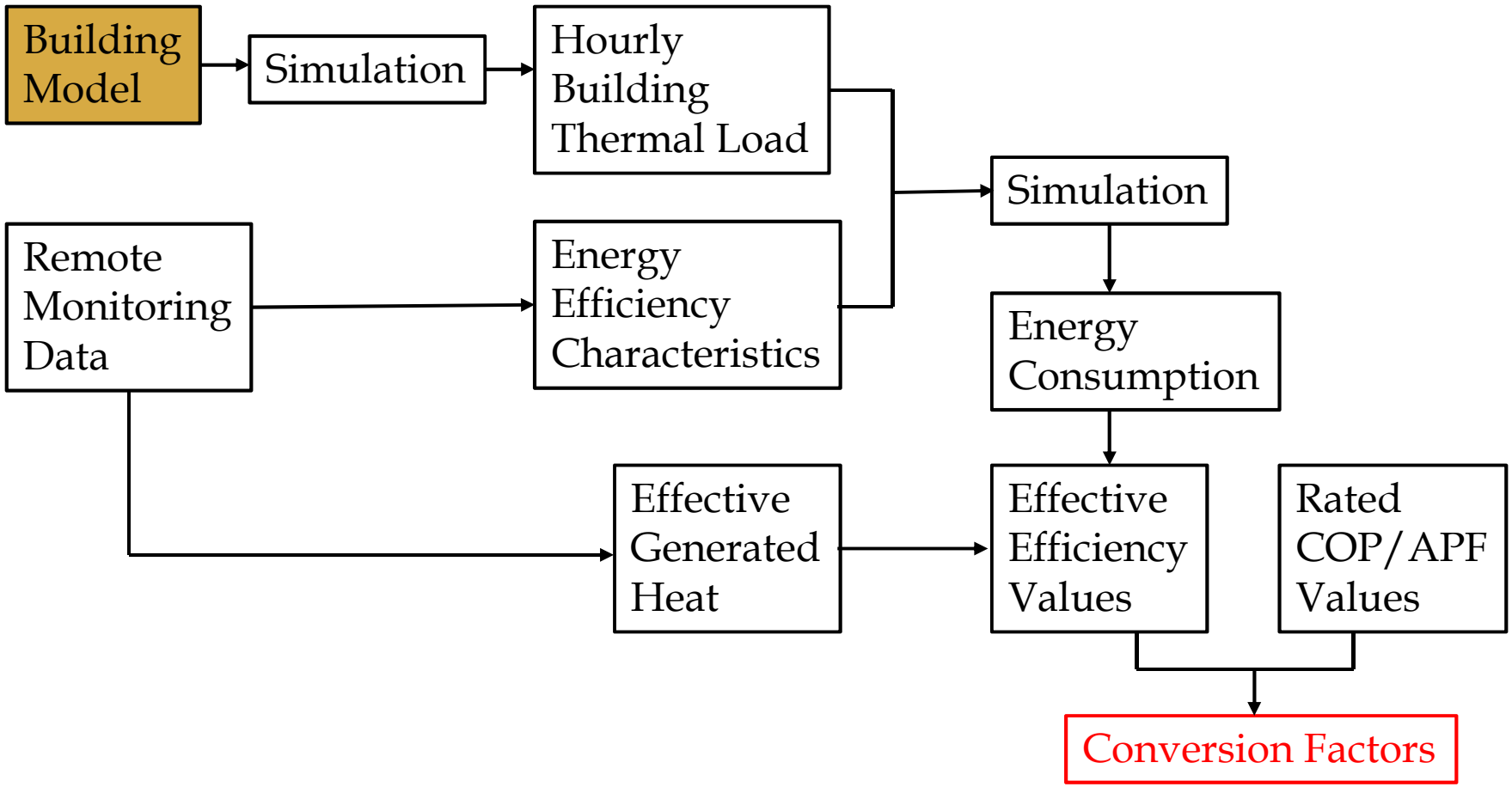


Floor plan (1st)



Floor plan (2nd-6th)

Study flow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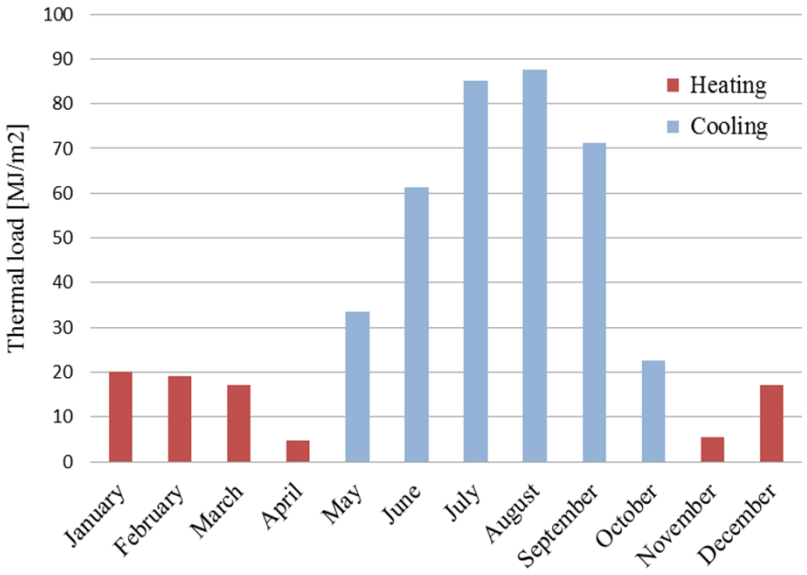
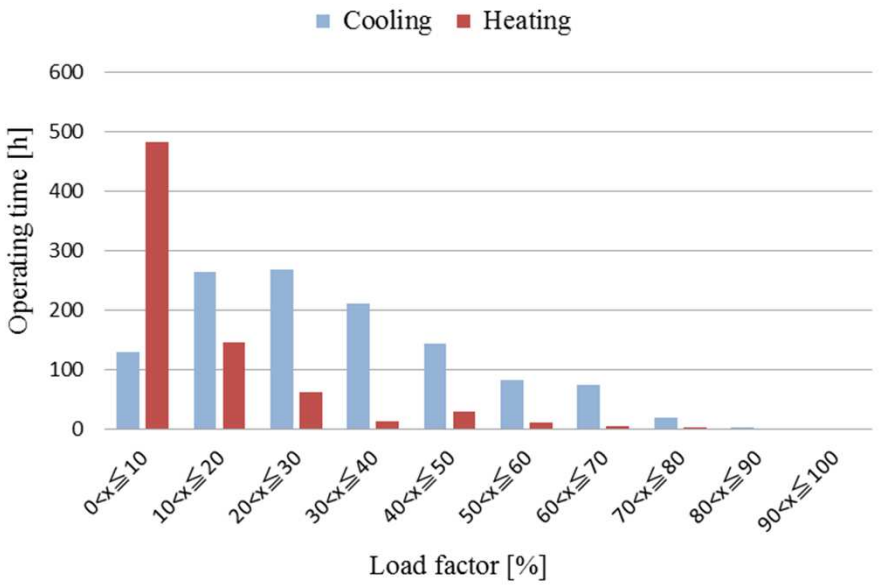
Simulation results

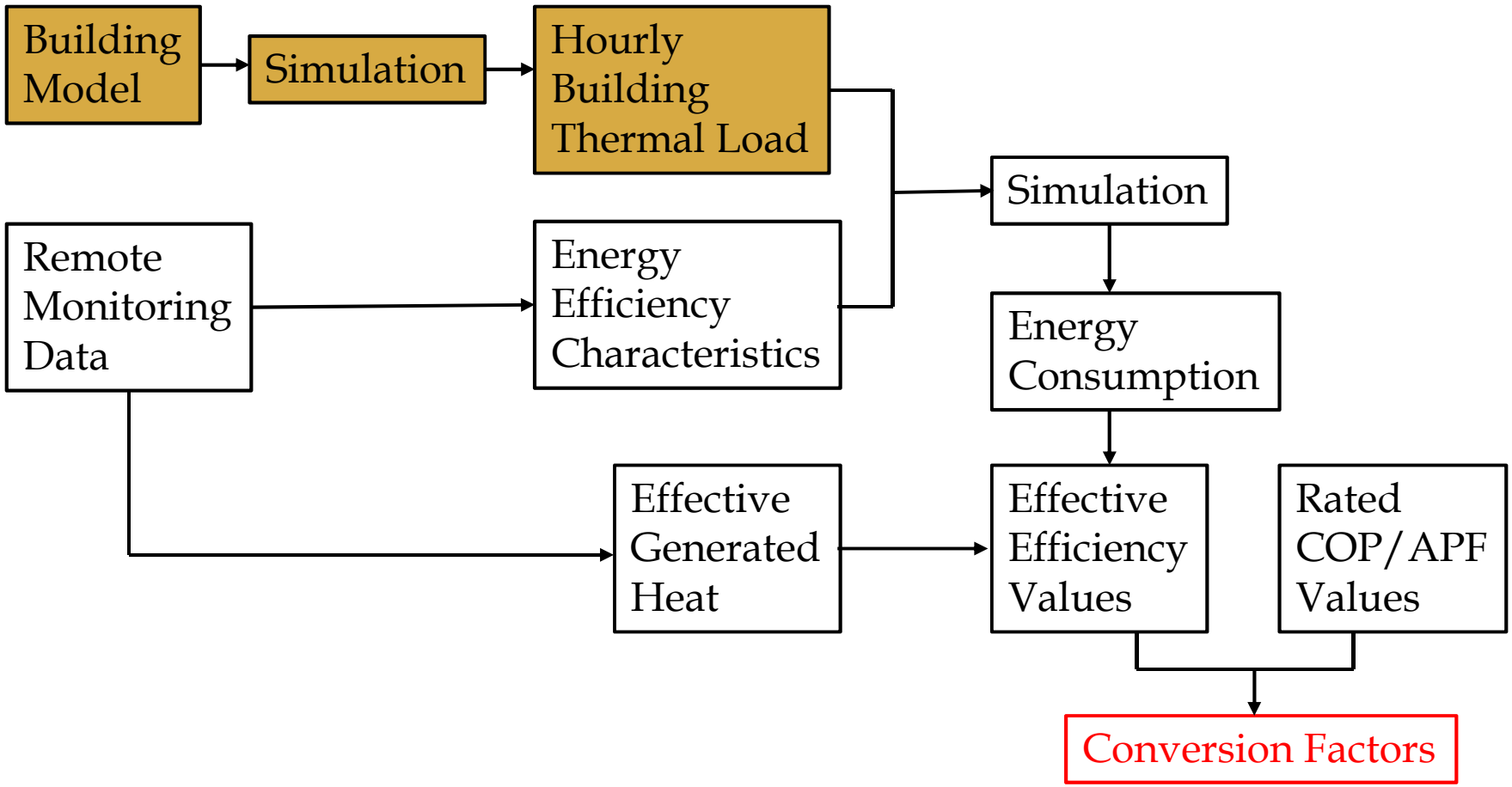


Monthly thermal load



Load factor

Study flow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Remote monitoring data

- Total energy consumption data
- Outdoor unit energy consumption data
- Indoor unit effective generated heat
- Refrigerant mass flow of a compressor per unit time
- Indoor suction temperature
- Preset temperature
- Refrigerant physical properties
- On-off time of defrost
- On-off time of thermostat
- Standby power

Obtained by
the Compressor Curve method

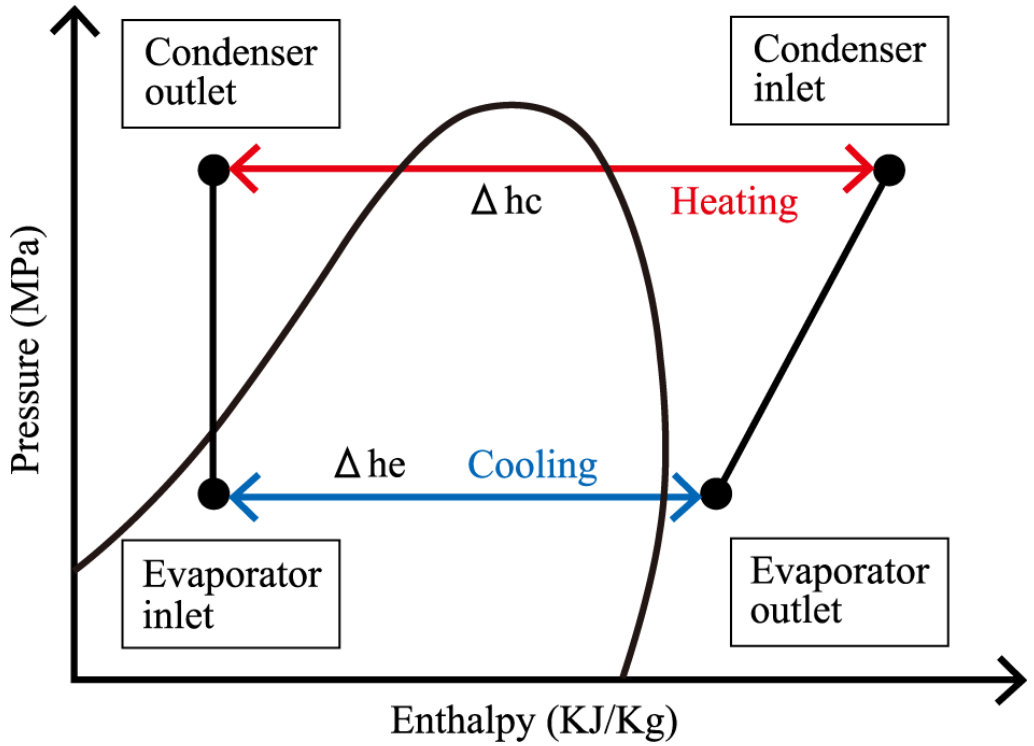
Compressor Curve method

$$Q = G_{comp} \times \Delta h$$

Q : Capacity (kW)

Gcomp :
Refrigerant mass flow
(kg/min)

Δh :
Specific enthalpy
difference
(kJ/kg)



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Compressor Curve method

$$G_{comp} = \rho \times V \times N \times \eta$$

ρ : Suction refrigerant density (kg/m^3)

V : Compressor displacement (m^3)

N : Compressor revolution (rpm)

η : Volumetric efficiency (-)

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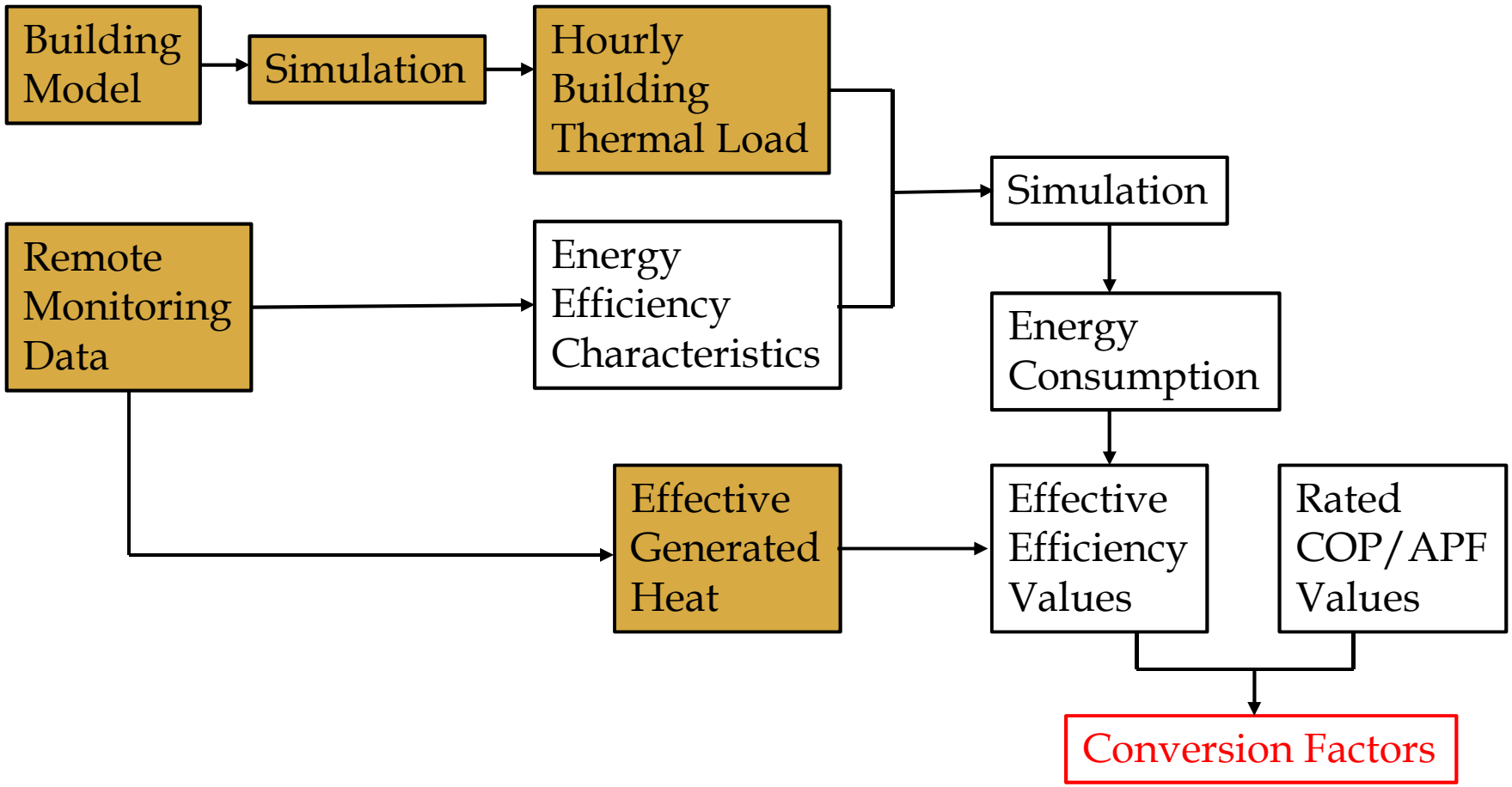
Study flow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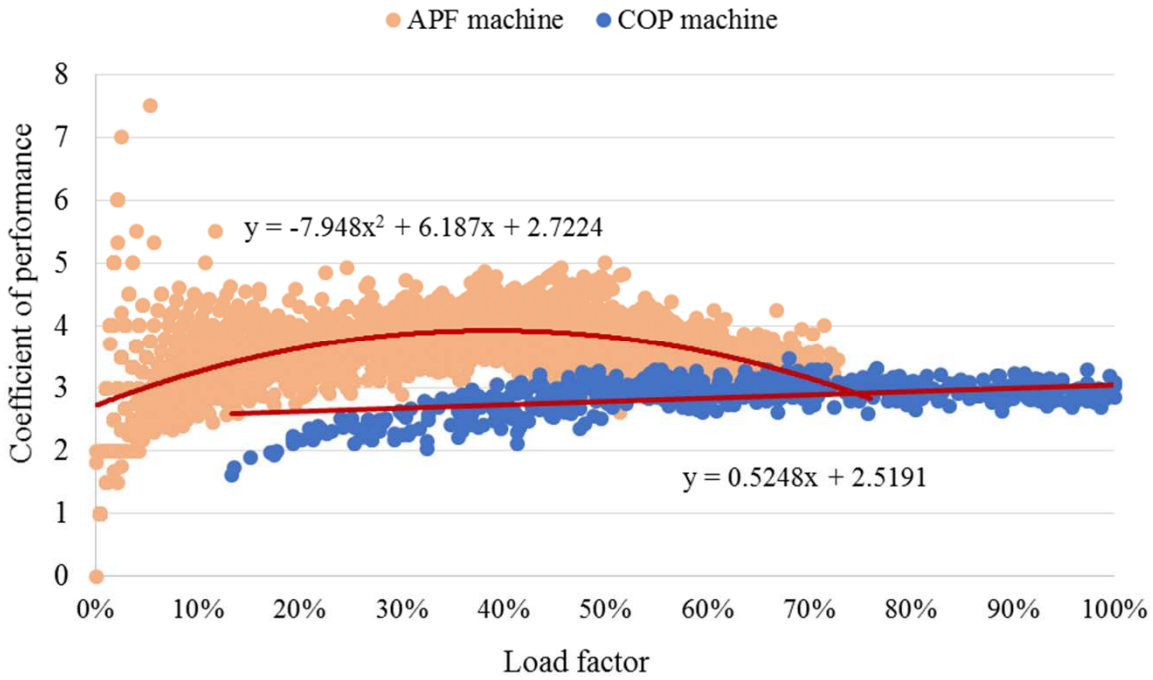
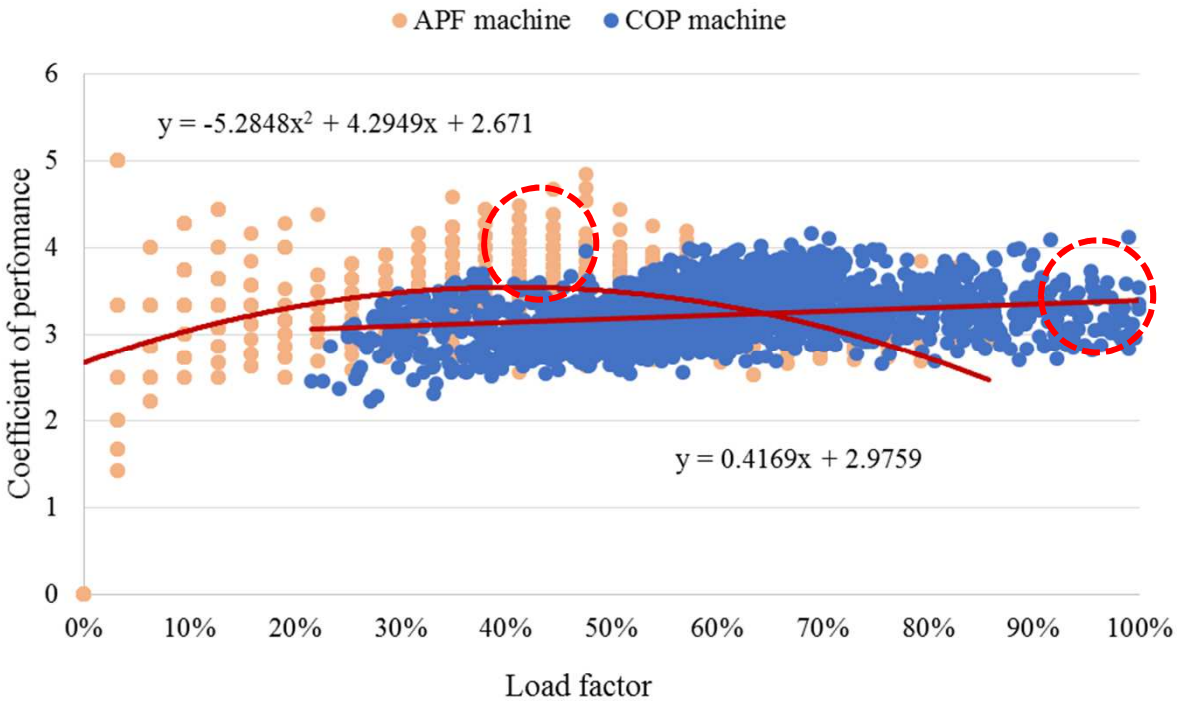
Comparison Results

Comparison of the COP and APF machines in the cooling operation



Comparison Results

Comparison of the COP and APF machines in the heating operation



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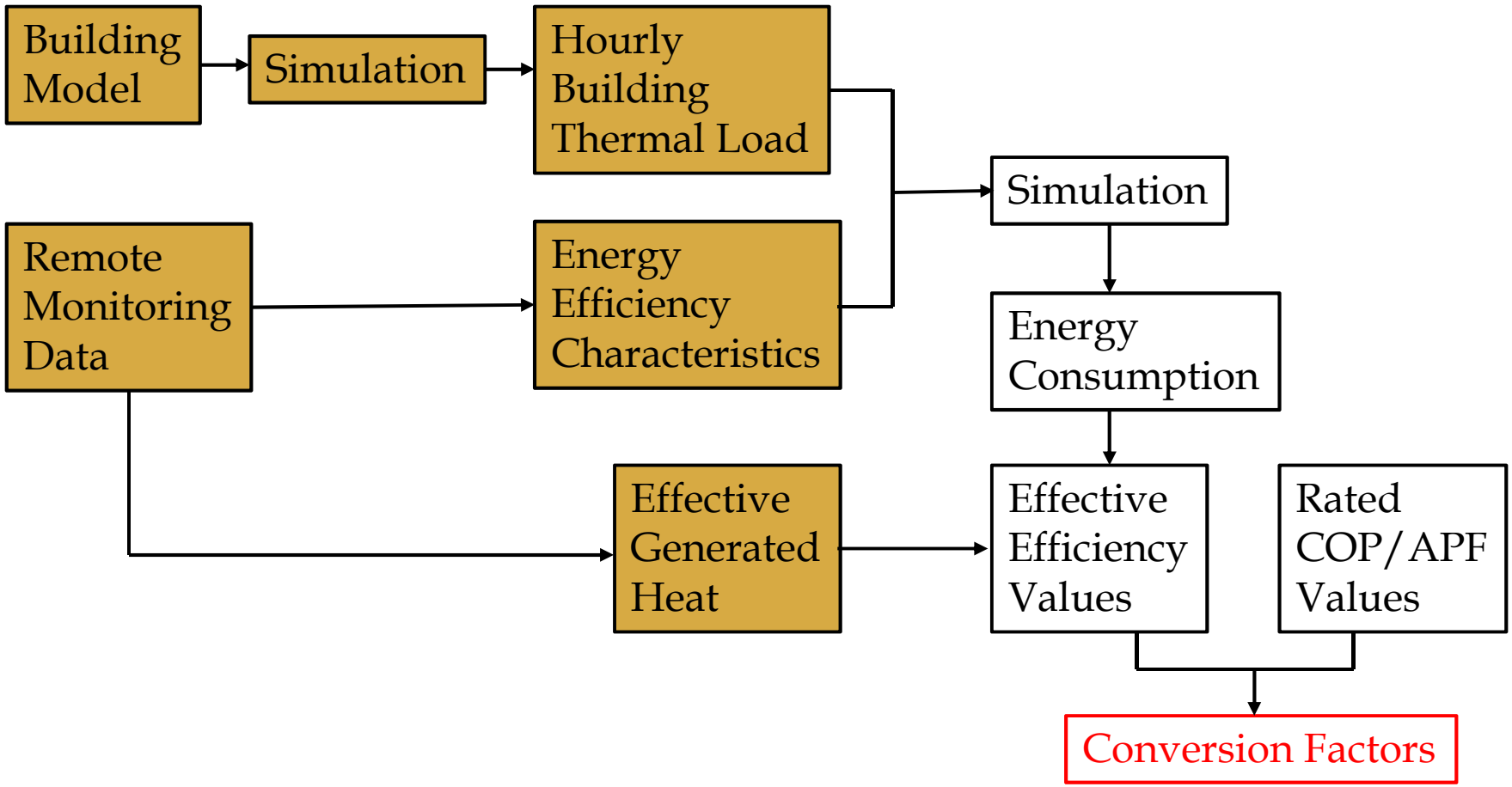
Study flow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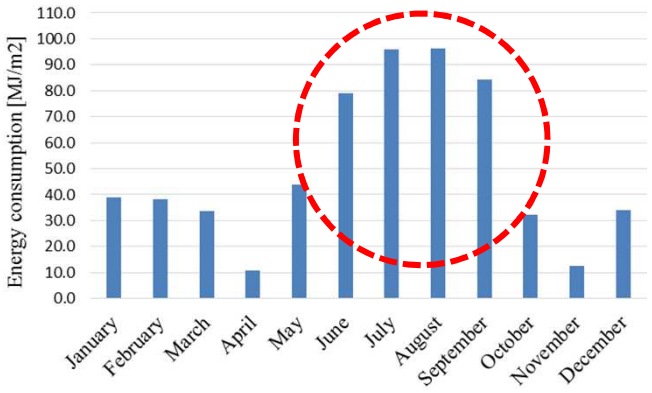
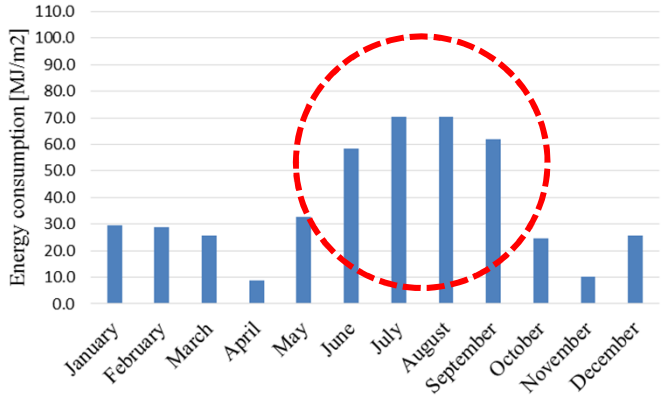


Energy consumption of the COP machine



Energy consumption of the APF machine

Monthly air conditioning energy consumption

Month	COP machine (MJ/m^2)	APF machine (MJ/m^2)
January	45.6	29.4
February	42.9	29.0
March	39.8	25.8
April	15.9	8.9
May	48.9	32.8
June	87.9	58.4
July	106.9	70.2
August	115.2	70.4
September	92.4	62.0
October	40.9	24.5
November	19.3	10.4
December	46.9	25.8
Total	702.6	447.6

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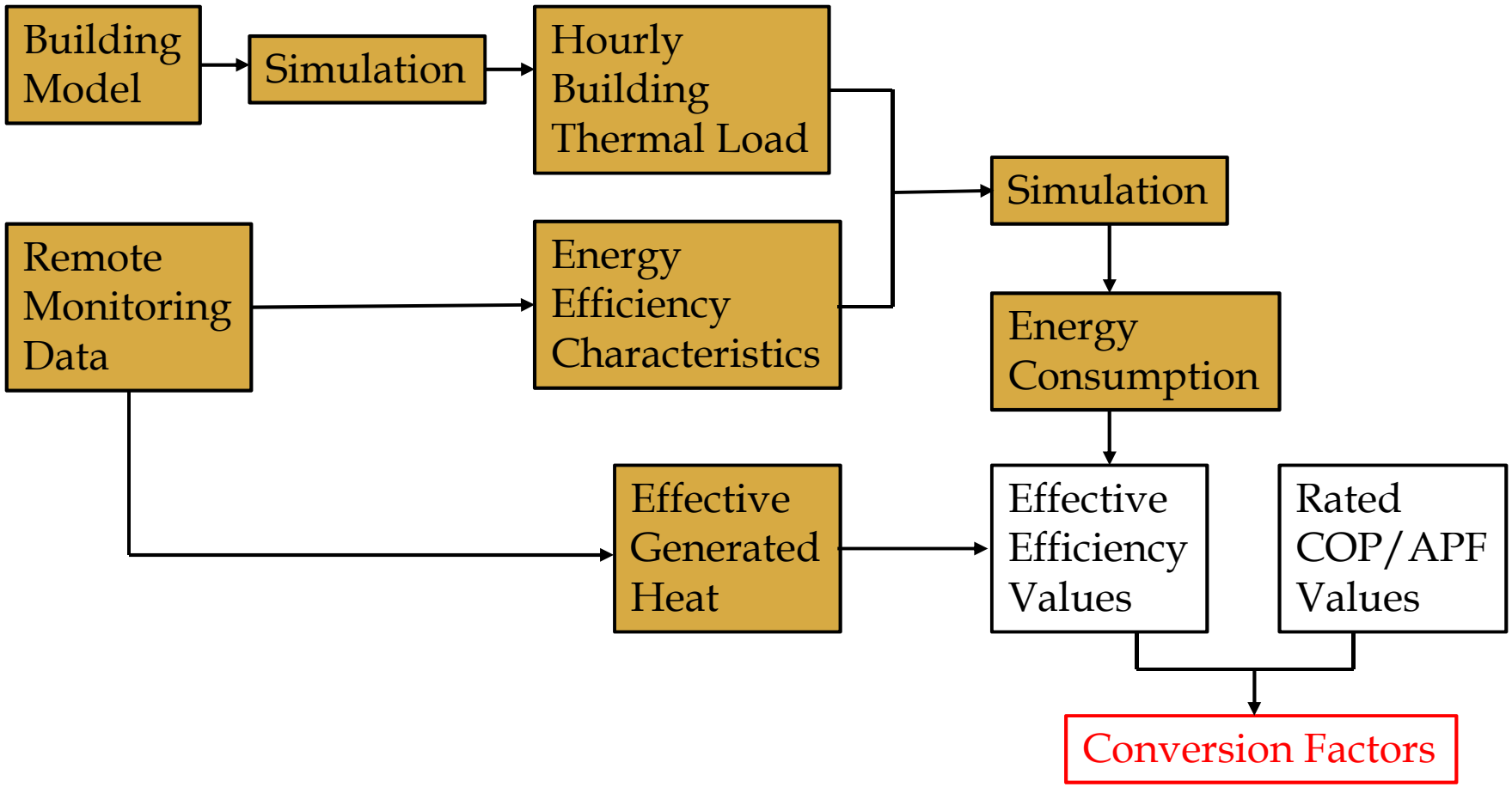
Study flow



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Simulation Results

Conversion factors

$$\text{Effective efficiency} = \frac{\text{Annual effective generated heat}}{\text{Annual energy consumption}}$$

$$\text{Conversion factor} = \frac{\text{Effective efficiency}}{\text{Rated average COP or APF values}}$$

Values	COP machine	APF machine
Catalog value	3.17	3.71
Effective efficiency value	0.69	1.08
Conversion factor	0.22	0.29

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Conclusions

- The performance of the COP and APF machines were different when comparing the energy efficiency characteristic diagrams.
- The conversion factors of the COP machine and the APF machine showed a difference.

- The performance of the machines can be easily compared for when evaluation standards change and new systems are installed.
- This approach can be applied to GHP (Gas driven heat pump) systems.

Thank you for taking the time

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