Standards & Labeling System for Air-conditioning Equipment in US, Europe and Japan

The Japan Refrigeration and
Air Conditioning Industry Association
(JRAIA)

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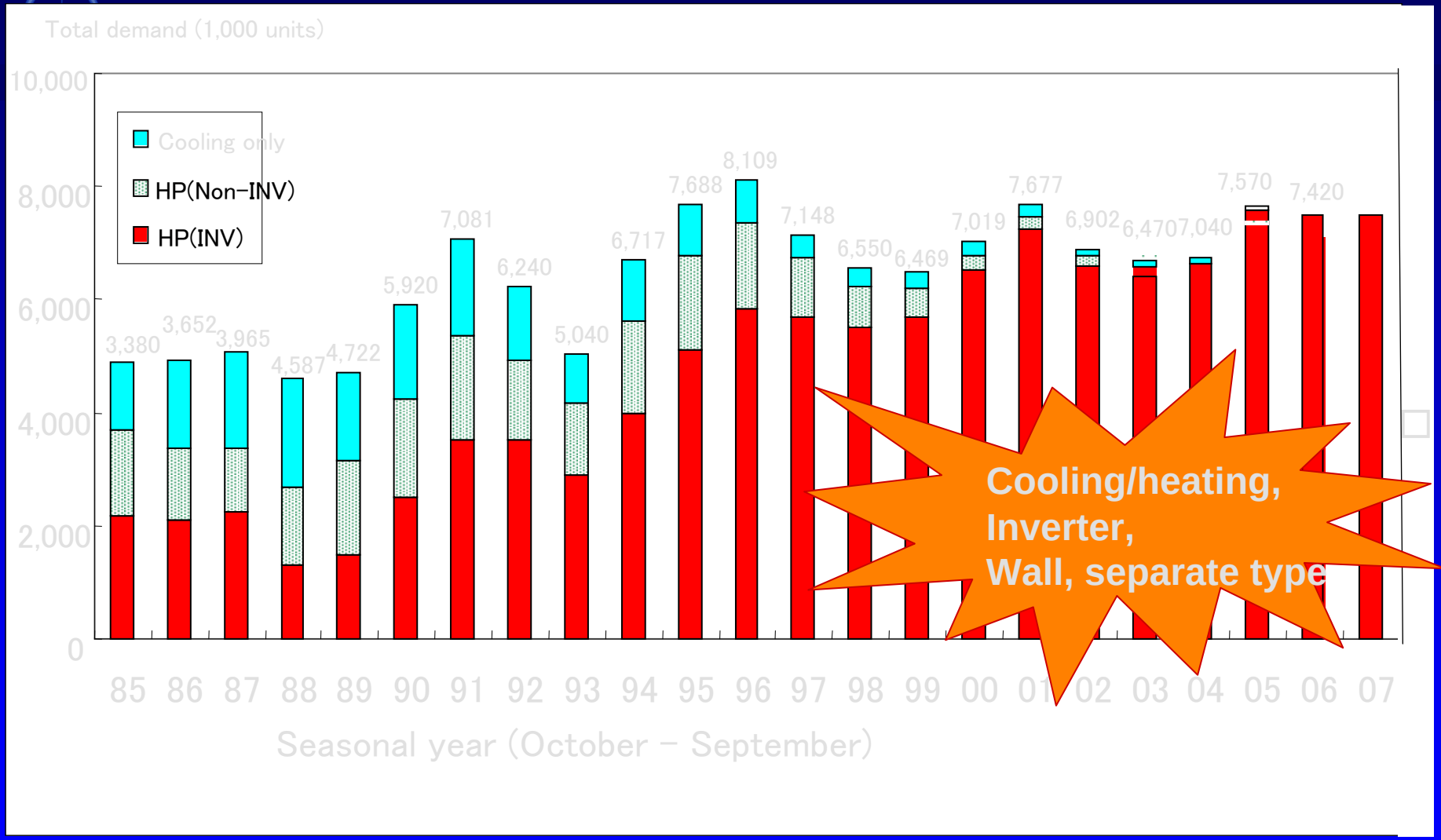
Demand for Air Conditioners



Source: Data reported by Mitsubishi Electric Co.

Japan's Energy-saving Standards
COP → APF

（Coefficient of Performance） （Annual Performance Factor）

COP (Coefficient of Performance)

COP shows cooling/heating capacity (kW) per 1 kW of power consumption. A higher figure represents higher efficiency of energy consumption and higher energy-saving capability.
（COP：Coefficient of Performance）

APF (Annual Performance Factor)

APE also shows cooling/heating capacity (kW) per 1 kW of power consumption. It takes into account not only power consumption at rated time but also load conditions such as buildings where air conditioners are used and purpose of use, outside air temperature while cooling or heating, and efficiency of the air conditioner depending on the differing capacities of inverter devices, thus making it possible to evaluate energy consumption performance against utilization.
（APF： Annual Performance Factor）

Adopting APF (Annual Performance Factor)

Energy-consumption Performance (Energy-saving law)

COP = (cooling rated COP + heating rated COP) / 2

APF = f (cooling rated COP, cooling median COP, heating rated COP, heating median COP, heating low-temperature COP, duration of outside air temperature)

Calculation methods matching the Japanese lifestyle and local environment!

Changes in design points through the revision of energy-saving standards

Life changes in line with change in air-conditioning capability

(Energy-saving standards appropriate to each locality/environment)

APF (Annual Performance Factor)

Standards for calculating duration of outside air temperature (Japan)

Outside air temperature	Japan/Tokyo Meteorological data		Preset temperature	27℃ for cooling/20℃ for heating
Duration	Cooling	3.6 months June 2 – Sept. 21	Operating hours	18 hours, 6:00 – 24:00
			Type of house	Average wooden house (facing south)
	Heating	5.5 months Oct. 28 – Apr. 14	Room space	Room space matching each machine

Aggregated cooling/heating capacity by cooling capacity

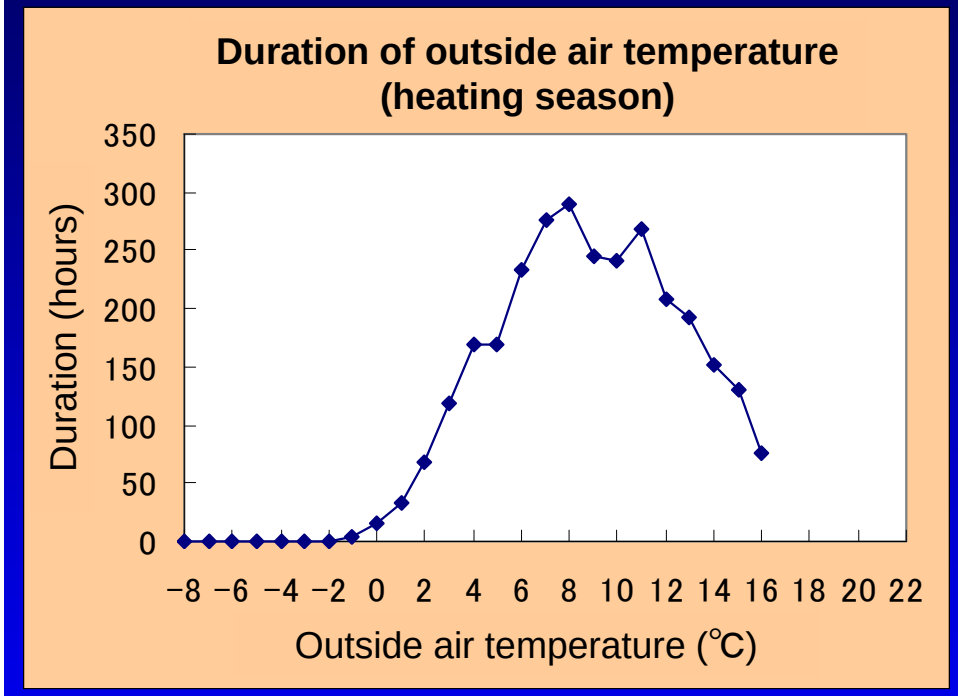
Cooling capacity (kW) (appellation)	2.2	2.5	2.8	3.6	4.0
Aggregated cooling/heating capacity (kWh)	4,408	5,010	5,611	7,214	8,015
Cooling capacity (kW) (appellation)	4.5	5.0	5.6	6.3	7.1
Aggregated cooling/heating capacity (kWh)	9,017	10,019	11,222	12,624	14,227

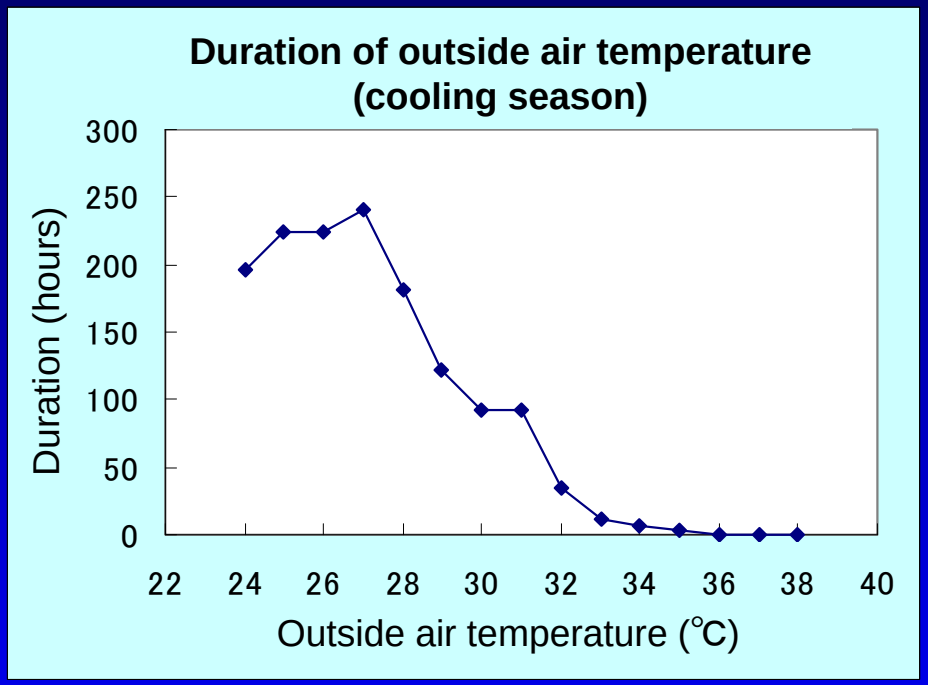
Power consumption during seasons = aggregated cooling/heating capacity / APF
Electricity cost = power consumption during each season x 22 yen x locational constant

Examples of locational constants

Sapporo (3.1), Sendai (1.6), Tokyo (1.0), Osaka (1.2), Fukuoka (1.1), Naha (0.6)

APF (Annual Performance Factor)





Total heating hours＝2,889 hrs

Σ（duration x difference in temperature）= 32,231

（Room temperature assumed 20℃）

Total cooling hours＝1,430 hrs

Σ（duration x difference in temperature）= 10,134

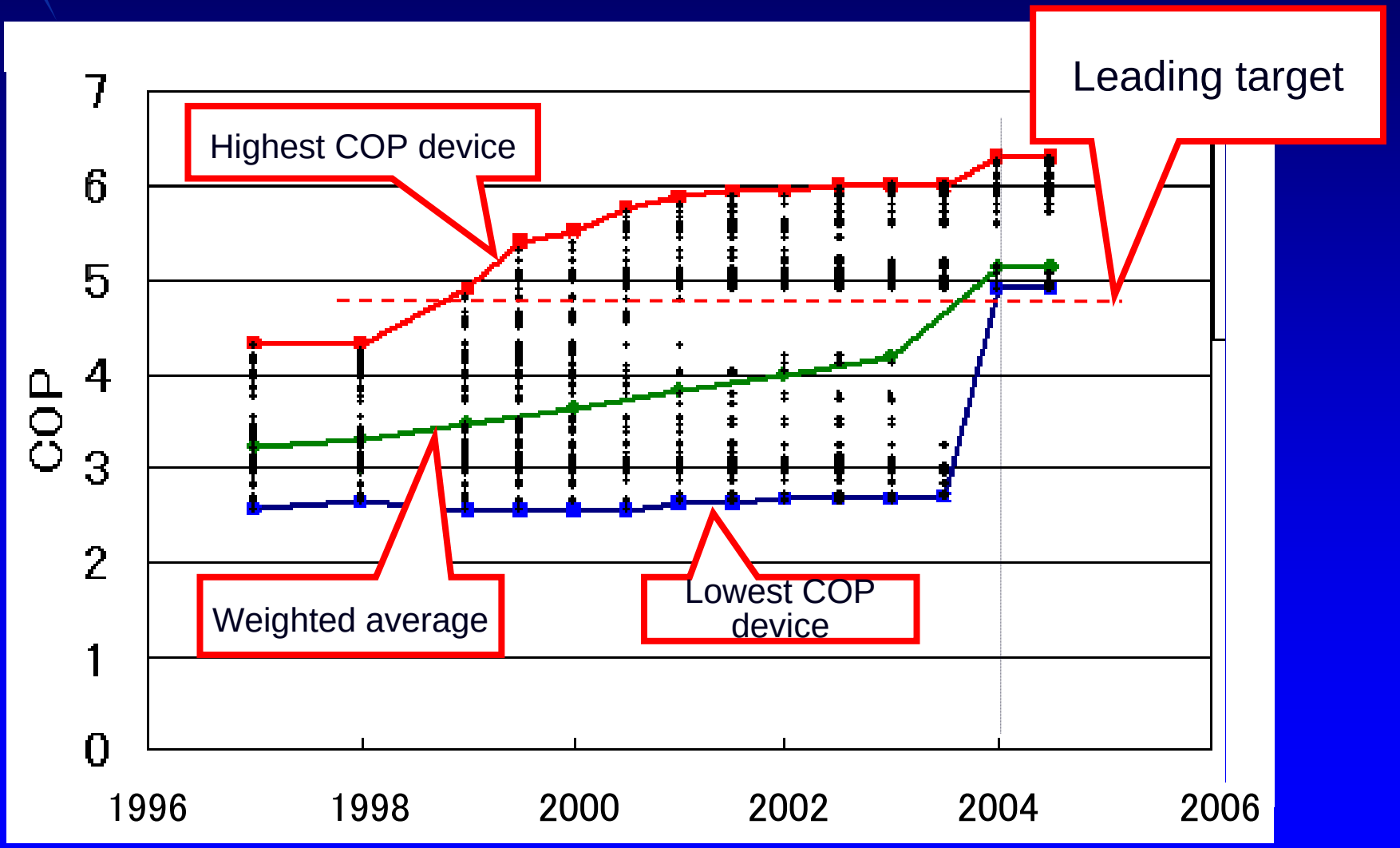
（Room temperature assumed 27 ℃）

Design point is on “median heating”.

Primary targets for air conditioner energy-savings （Excerpts）

Type of unit	Cooling capacity	Baseline energy consumption performance (COP)	Targeted year
Direct air-blowing, wall type (not including multi types for which an indoor device is controlled in each room)	2.5kW or less	5.27	2004 Refrigeration year
	2.5kW - 3.2 kW	4.90	
	3.2kW - 4.0 kW	3.65	
	4.0kW - 7.1 kW	3.17	2007 Refrigeration year
	Over 7.1kW	3.10	

Changes in distribution of air conditioner performance



2.8 kW cooling capacity class - data from JRAIA

Secondary targets for air conditioner energy-savings (Excerpts)

Targeted year: 2010

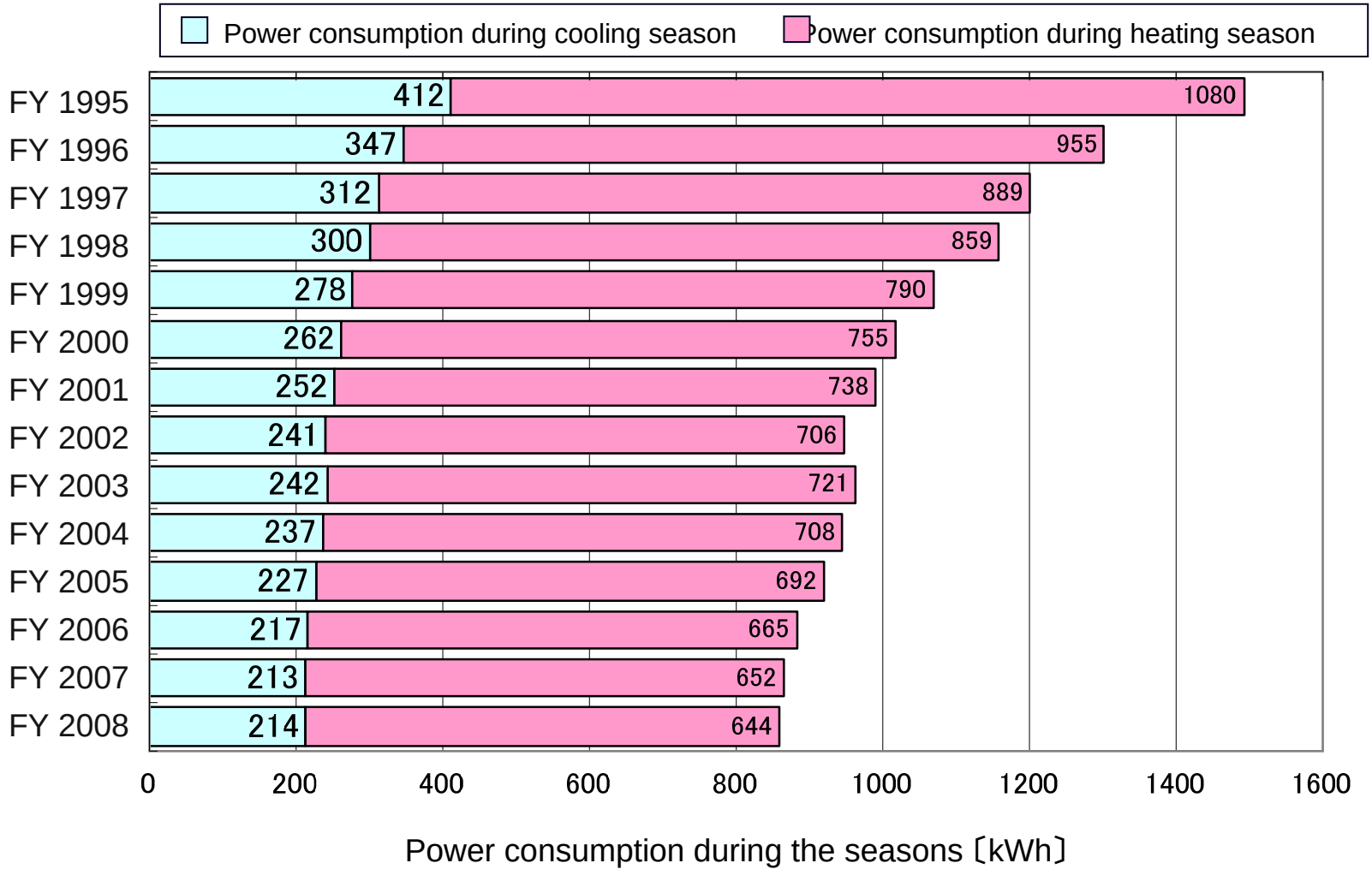
Category			Baseline energy consumption performance (APF)
Refrigeration capacity	Dimensional category	Category name	
3.2 kW or lower	Dimension-defined type	A	5.8 (←4.90)
	Dimension-free type	B	6.6 (←4.90)
3.2 kW – 4.0 kW	Dimension-defined type	C	4.9 (←3.65)
	Dimension-free type	D	6.0 (←3.65)

Under the heading Dimensional category, "dimension-defined type" refers to indoor devices that are less than 800 mm in width and 295 mm in height.

Others are categorized as dimension-free type.

Figures in parentheses show the relevant primary targets

Changes in energy-saving capabilities of air conditioners



Cooling & heating combined, wall, 2.8 kW cooling capacity, energy-saving type

Source: JRAIA

Problems with APF

APF (an indicator of actual air conditioner usage in Japan)

s1

- **The COP of inverter air-conditioners has the secondary feature of a convex upper shape**

  Lines where COP is reduced during low capacity are similar

  → Losing touch with actual operation during low capacity

- **Capacity ranges greater than rated capacity are estimated according to energy-saving capability at rated times**

  → Difference in power consumption/consumption current during actual operation (when operating for a short time)

- **Outside air temperature is assumed to be the same for rated time and median time**

  → Different from actual usage

- **Annual usage is assumed at 9.1 months; daily usage at 18 hours**

  → Longer than actual usage?

Labeling system for energy-saving

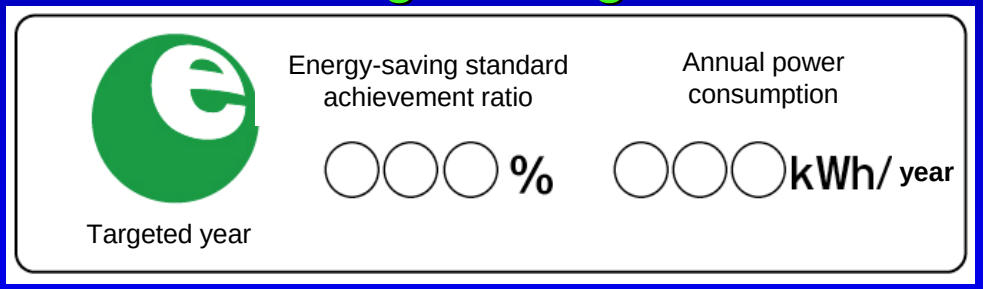
- Introduced in 2000 by Japanese Industrial Standards (JIS)
- Level of achievement of leading standards to be displayed
  → Useful when users select home appliances

Targeted appliances

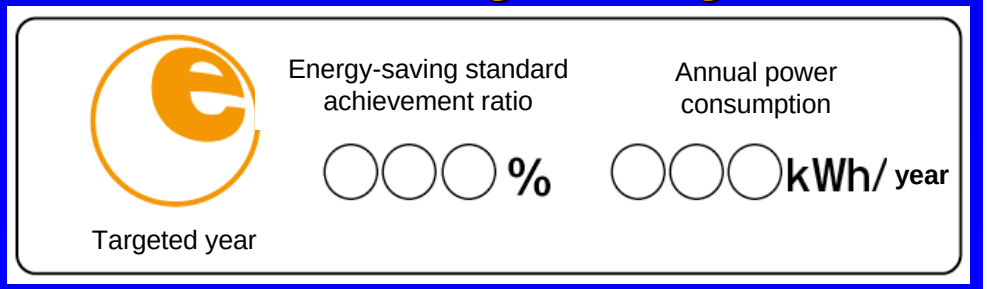
（Leading appliances）

- Air conditioners
- Fluorescent lighting fixtures
- TVs
- Refrigerator
- Rice cookers with thermos function
- Microwave ovens
- DVD recorders

Models attaining the target



Models not attaining the target



Unified energy-saving label

Retailers started using the unified energy-saving label in October 2006 as a system for showing energy-saving performance.

- Multistep assessment system to show relative energy-saving performance of marketed appliances by numbers of stars ★
- Standards are reviewed in April every year taking into consideration the energy-saving performance distribution of each type of appliance

Targeted appliances
- Air conditioners
- Refrigerators
- TVs

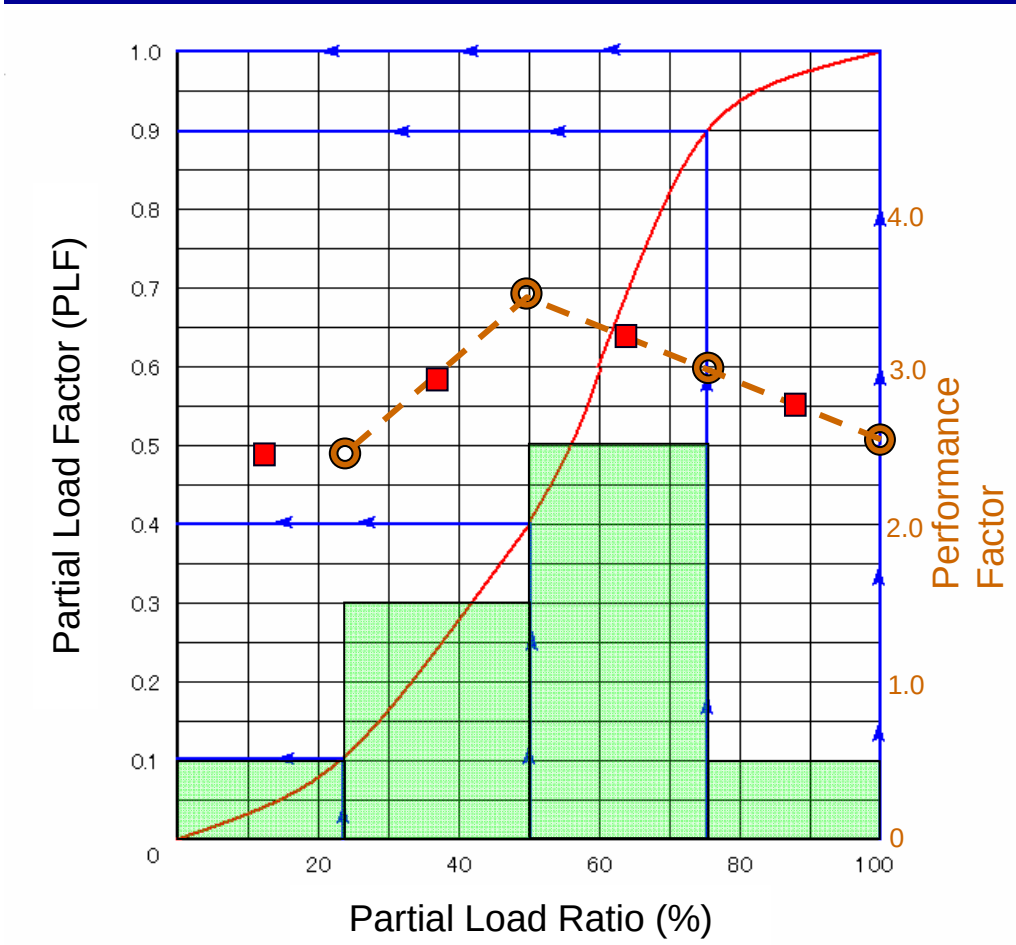
America's Energy-saving Standards: IPLV

IPLV（Integrated Part Load Value)

- Set up by ARI（Air conditioning & Refrigeration Institute)
- Seasonal performance coefficient weighted by annual generation frequency using COPs of several different loads and testing conditions
- An indicator similar to APF
- China and European countries are now considering adoption of these standards for evaluating air conditioning performance

American Energy-saving Standards: IPLV

Relationship between Partial Load Ratios and Partial Load Factors



IPLV calculation formula with 4 levels of partial load steps

PLV＝ (PLF1-PLF2)(COP1+COP2) / 2
+ (PLF2-PLF3)(COP2+COP3) / 2
+ (PLF3-PLF4)(COP3+COP4) / 2
+ PLF4･COP4

Test conditions at partial load steps (Chiller)

Step n	Partial load ratio	Air temperature at compressor intake
1	100%	35 ℃
2	75%	30 ℃
3	50%	25 ℃
4	25%	20 ℃
5	0%	15 ℃

Energy-saving standards suited to each region

The basic idea behind APF

$$\text{APF} = \frac{\text{Heat load at actual usage (cooling/heating times)}}{\text{Power consumption at actual usage}}$$

APF ≠ COP , APF ≠ (H･COP＋C･COP)／２
Representative value of actual heat load ≠ rated point,
Power consumption at actual usage ≠ rated point

As a result, in Japan, figures are calculated based on performance (rated, median, and low-temperature) and meteorological data for Tokyo, and difference from Tokyo is adjusted using locational constants.

In nature, IPLV is similar to APF

- **Loads are categorized in parts**
- **Test condition differs between partial loads**

Desirable energy-saving standards for air conditioners

- COP and SEER are incapable of assessing power consumption during actual use
- New energy-saving standards do not necessarily mean to choose either IPLV or APF
- Standards that are reasonable, valid, and suitable for housing/climate/usage of each country/region are sought

1) Applicable both to inverter and non-inverter devices

2) Applicable both to cooling regions and cooling/heating regions

3) Performance assessment points and outside air conditions meet international standards

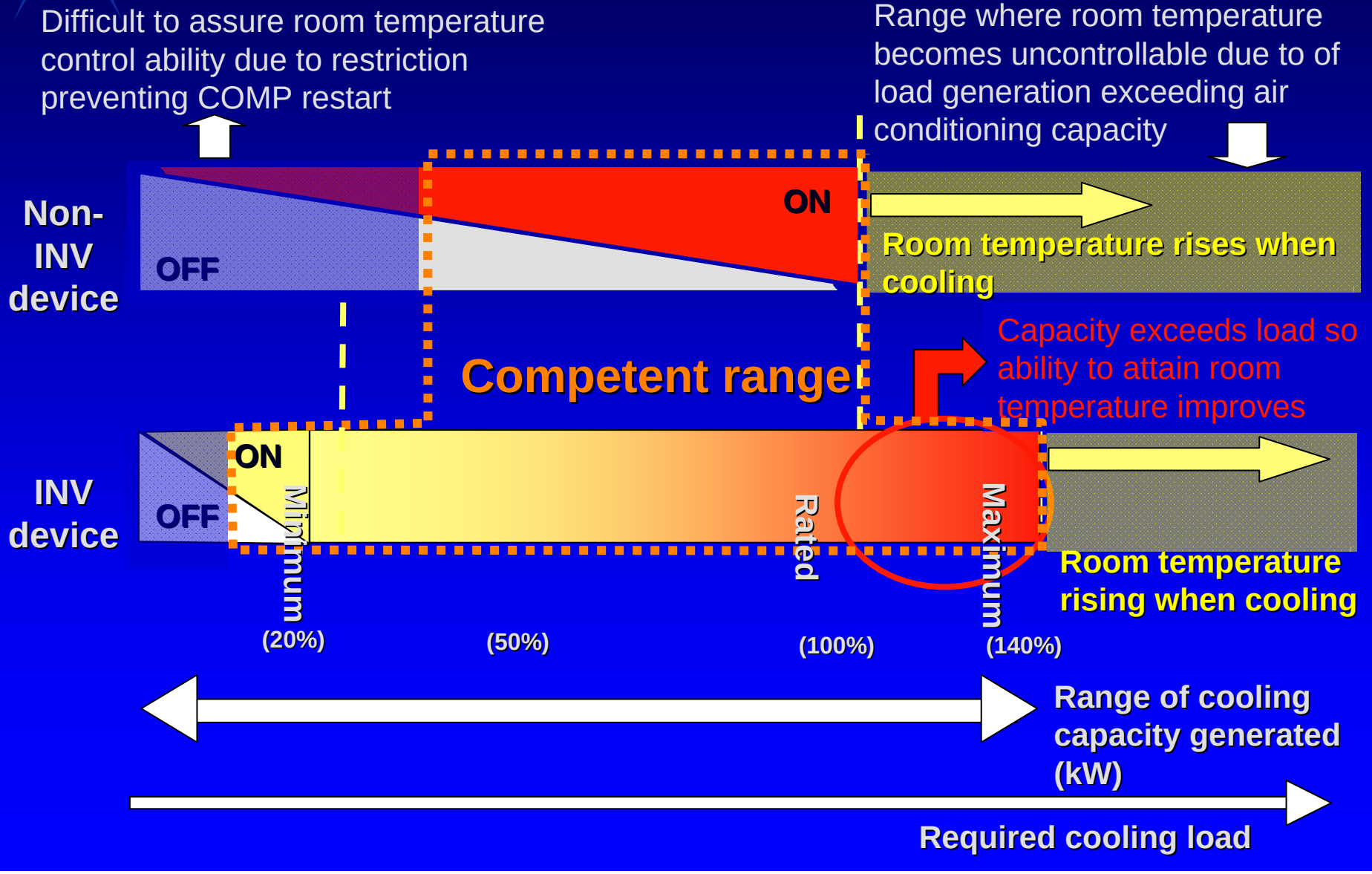
4) Up to three performance assessment points

5) Based on regional climate data and average housing

6) Within each region, should be adjusted using locational constants etc.

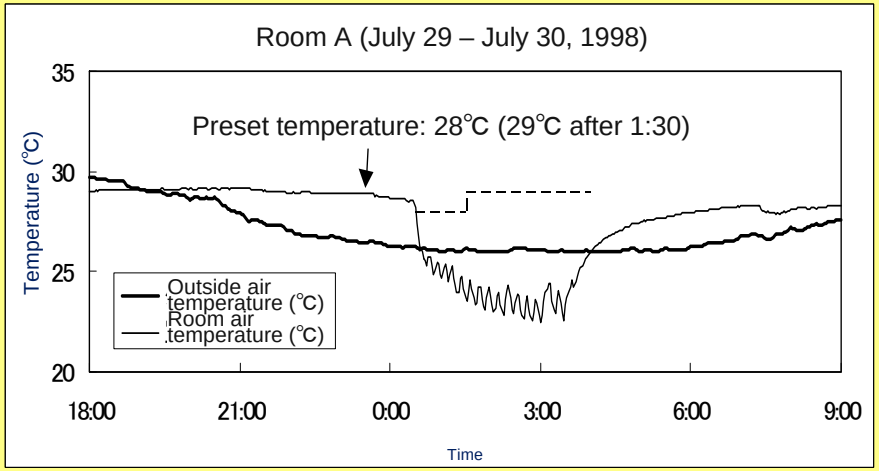
7) Periodically reviewed depending on development of air conditioners

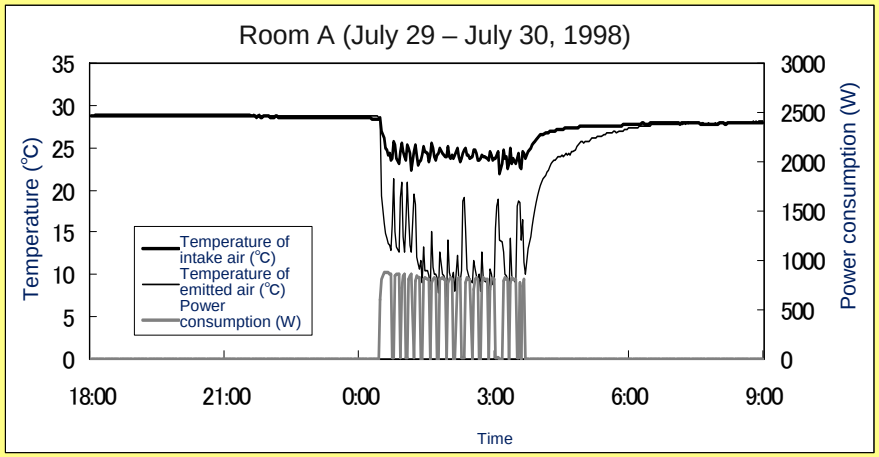
Comparing Inverter devices with Non-inverter devices



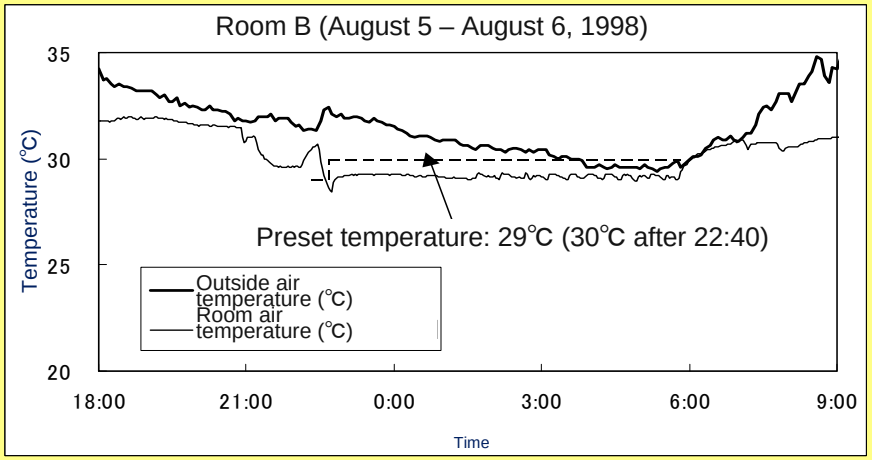
Operation of Inverter device (During sleep, in Nagoya, in 1998)

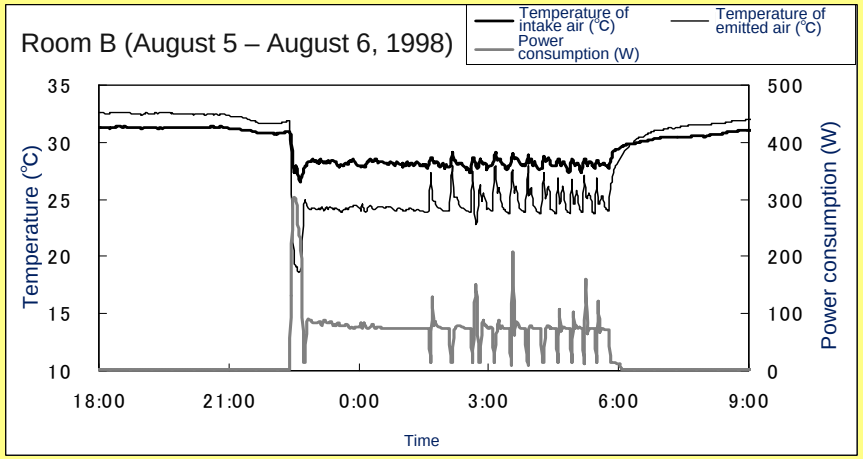
General device (Minimum power: 0.9 kW)





Test device (Minimum power: 0.5 kW)





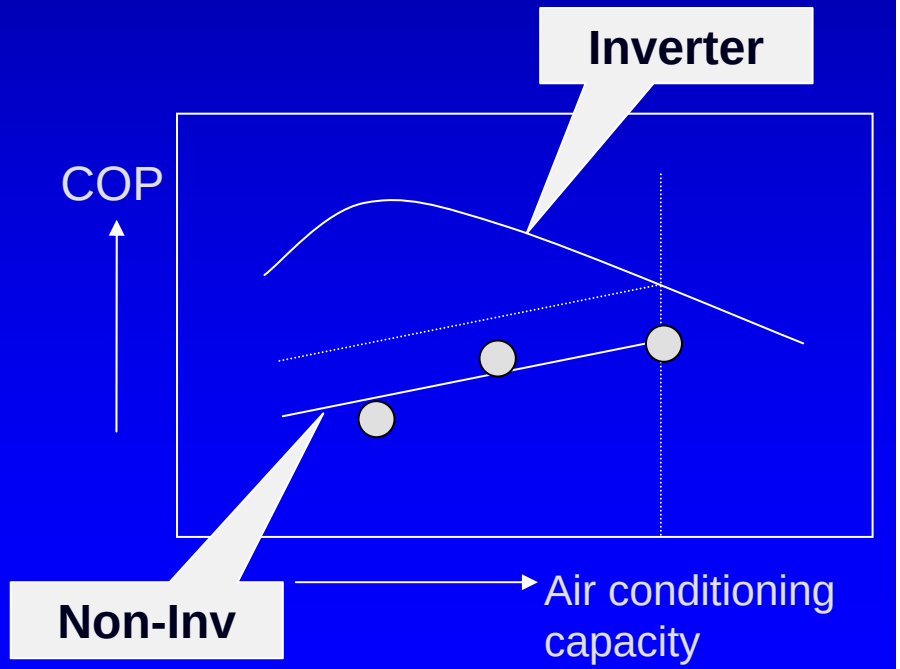
Application of new energy-saving standards

Assessment of cooling-only, cooling/heating, Non-INV, and INV devices is possible using a single set of energy-saving standards by metering constant-speed time of Non-INV devices and energy-saving performance when turning devices on or off.

1）Simulating operation characteristics caused by changes in outside air at model houses
→ Frequency and running rate under standard conditions

2）Metering energy-saving performance using air enthalpy method
→ Metering performance by running rate

3）Calculating power consumption by realized load
→ New energy-saving standards



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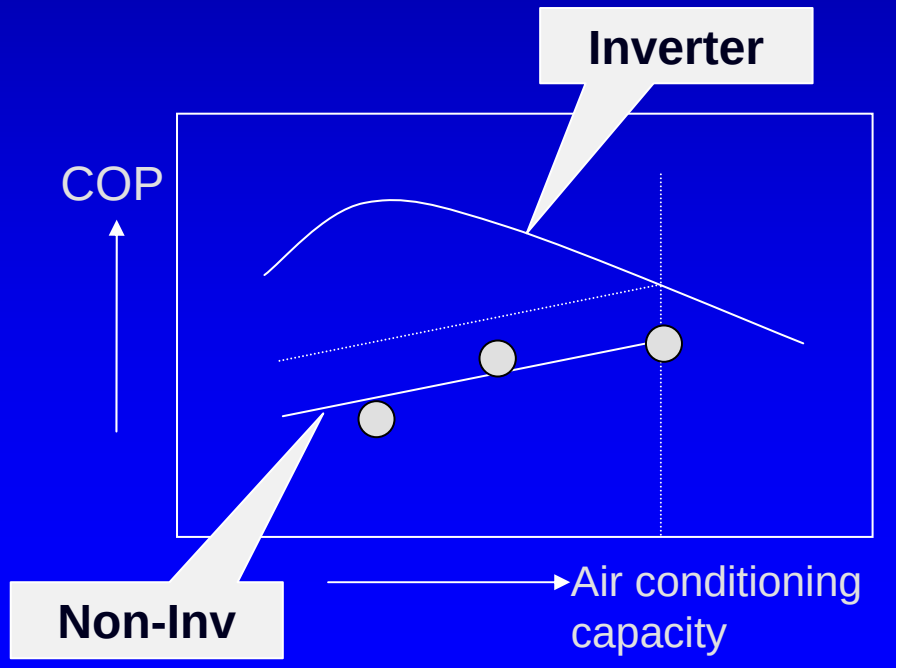

Points to note when conducting questionnaire survey

Points to note when conducting questionnaire survey

- When looking at the insulation ability of houses, etc, show model house structures → so respondents can choose.
- Specify a room space as an air-conditioned area (a closed space).
- For data that appears to show unbalanced air-conditioning load and capacity, conduct an additional survey on usage of air conditioners and categorize it as unique data with comments (eliminate it from the statistical data).
- Survey heat-generating appliances such as home appliances (estimate types of appliances and amount of generated heat)
- Check amount of clothing at home, and estimate sensation of warmth. → (Estimate clothing amount) → Estimate comfortable temperature
- Survey behavioral patterns per day/per week
  (at home/not at home, cleaning, washing, relaxation time at home, preparing meals, eating…)

Points to note when conducting Metering Survey

Points to note when conducting Metering Survey No. 1

1) When measuring temperature, meter outside air temperature, room temperature, and temperature at air intake of air conditioners.
Meter humidity of outside air and in the room if possible.
(units: ○.○℃,○○RH%)

・Outside air temperature: Measure at north side of building, which is in the shade all day.
Measure humidity if possible.

・Room temperature: Measure where the temperature is not influenced by air coming from air conditioners, and at places close to inhabitants.
Height: For heating: 5 – 10 cm above the floor; for cooling: 1.2 m above the floor

・Temperature at air intake: Set up at air intake of air conditioner where air is moving.

2) Power consumption of air conditioners (unit: W)

・When metering power consumption of air conditioners, sampling intervals should be 1 minute or less.

3) A questionnaire survey should be implemented.

Points to note when conducting Metering Survey

Points to note when conducting Metering Survey No. 2

4) How to estimate heat load

・When measuring the heat load of houses, do so when generated air conditioning capacity and heat load are balanced. Do not estimate it when the room temperature is within a non-controlled range just after the switch has been turned on.

・As for generated air conditioning capacity (kWh) at On/Off times, estimate generation capacity per hour using On-time, rated capacity (indicated value), and power consumption.

As for power consumption, calculate power consumption per hour (kWh) using On/Off cycle length and the relevant power consumption.

・As a survey on the preset temperature is necessary, record changes in preset temperature during operation.

・Another method is to estimate the heat load of houses through information about the characteristics of houses collected by questionnaire etc. and measured data such as room/outside temperature.

Energy-saving performance evaluation points

1) As for performance evaluation points, the more points you use, the more accurately you can measure power consumption. As COP is featured by upper-convex second-order characteristic, taking test cost into consideration, you should use up to three points.
2) Although inputting the minimum capacity may be a popular method, it makes accurate measurement difficult because minimum capacity is 0.2 – 0.5 kW-level. Let's consider more reasonable methods such as using simulation values.
3) It is desirable to internationally unify, through ISO etc, the capacity ratios and outside environment conditions of performance evaluation points. Each region/country chooses the relevant points out of an internationally unified system.

Conclusion

- Energy-saving standards for air conditioners should show the direction of their development and reflect people's lives in the country/region.
- When establishing new energy-saving standards, we should choose neither the US's IPLV nor Japan's APF. Rather, we should create new standards that are better suited to each country/region.
- Evaluation test points/test conditions should meet internationally agreed standards, with each country/region being able to choose appropriate ones for their situations.
- Due to development/test costs, evaluations should test a maximum of three points.
- Fair energy-saving standards and test facilities are needed so that air conditioners can compete fairly in the global market.
- Development of air conditioners entails the development of facilities to test air conditioning performance.
- Now might be the time when we have to consider new testing technologies that take into consideration high accuracy testing technology for low capacities and a test of the ability to create a certain environment that respects human senses.

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