The 8th IEA-Tsinghua Joint Workshop
"Making Buildings Zero-Carbon Ready by 2030 – Near-term Solutions for Heating Systems"
27th October 2022

Context for building heating systems and how their energy efficiencies are evaluated in a Building Energy Code of Japan

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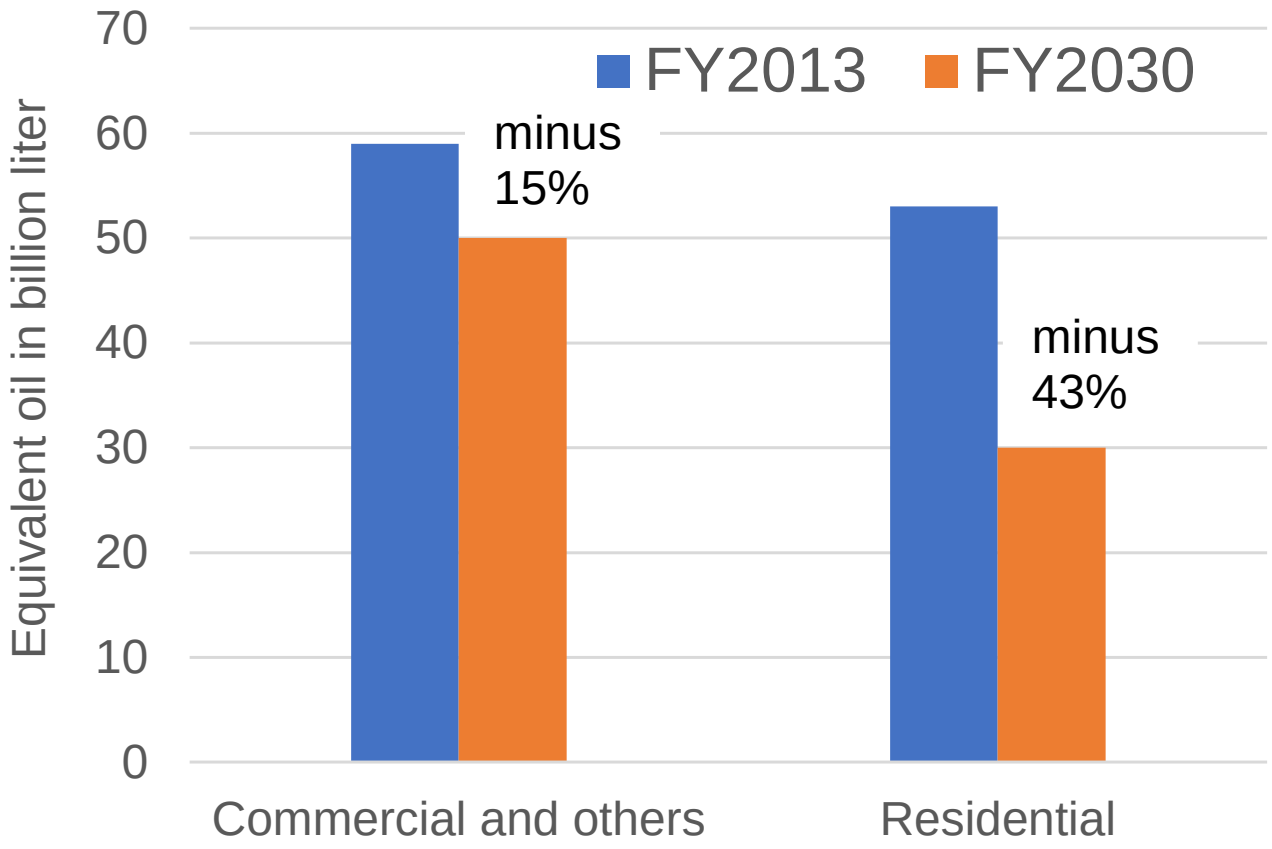
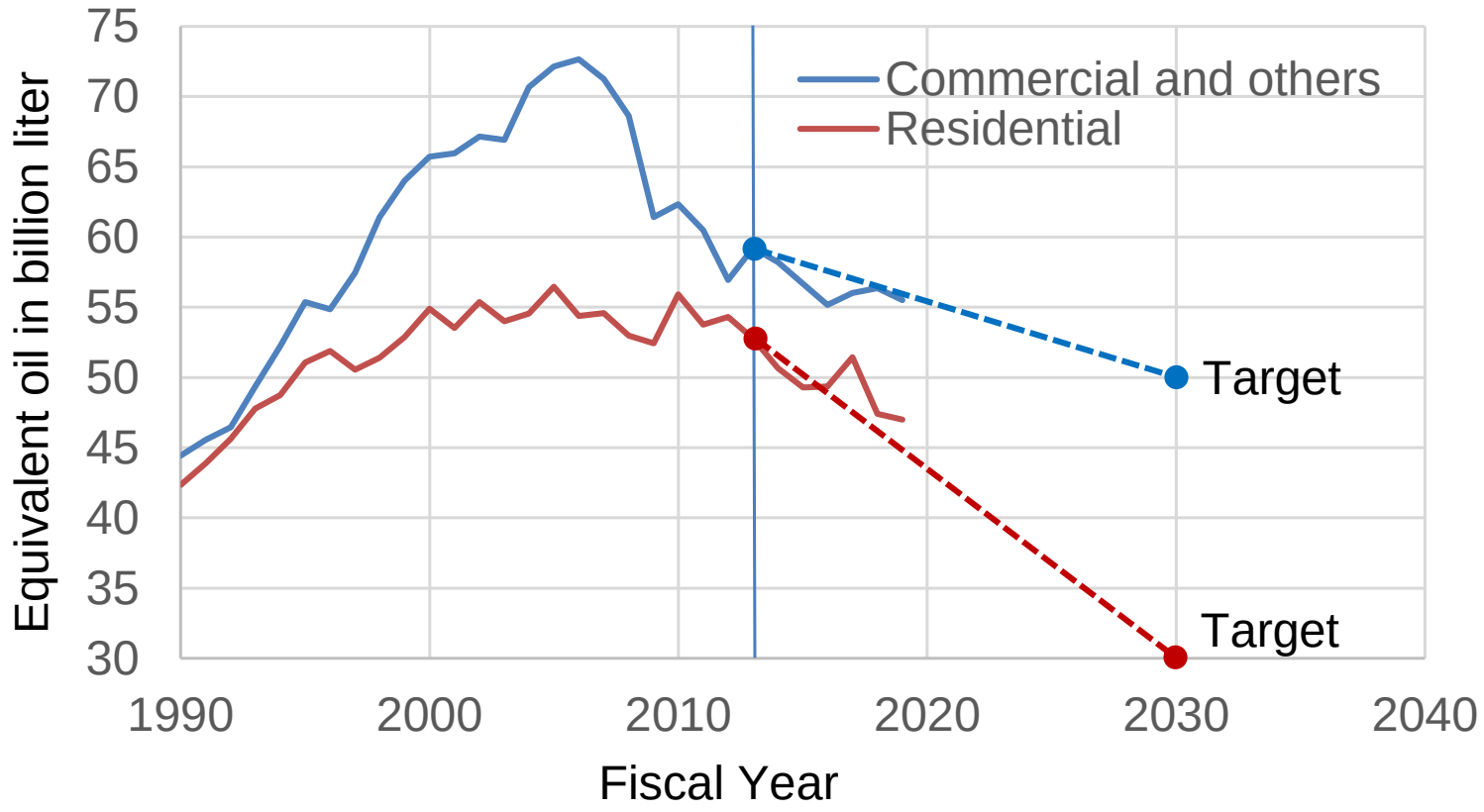
1. Reduction targets of end-use energy in FY2030 for buildings



Source (in Japanese): [20211022_03.pdf (meti.go.jp)]

1. Reduction targets of end-use energy in FY2030 for buildings

Transition of end-use energy (1990-2019) and targets in FY2030



Source (in Japanese): FY2019 Energy Supply and Demand Report (Revised Report) (meti.go.jp)

2. Present strategies for each category of buildings

2-1. Regulations (present)

Building categories	Regulations
1. Non-residential buildings (floor area is no less than 300m^2)	**Mandatory compliance with energy efficiency standards** for new construction, renovation or addition. In case of violation of provisions, construction clients are not able to start construction.
2. Residential buildings (floor area is no less than 300m^2)	**Obligation to notify a plan (calculation results) to Local authorities**. Local authorities will instruct or order, if the violation is not acceptable.
3. All buildings (floor area is less than 300m^2)	**Obligation of effort to comply plus obligation to explain calculated primary energy consumptions to building owner**
4. Standardized detached houses sold in lots 5. Standardized detached houses constructed by contract 6. Standardized apartment houses constructed by contract	**Housing top runner programs**, which mandate companies (supply scale is no less than each criterion) **to comply the average energy efficiency with higher standards by 10-25% within the period (five years)**

Source (in Japanese): Building Energy Efficiency Act (Act No.53 of July 8, 2015, last amended on June 14, 2019)
Order for Enforcement of Building Energy Efficiency Act (Order No.8 of 2016, last amended in 2020)
Ministry ordinance to define Building Energy Efficiency Standards (METI/MLIT Ordinance No.1 of 2016, last amended in 2020)

2. Present strategies for each category of buildings

2-2. Incentive Programs (present)

Programs	Contents and requirements
1. Certification of performance improvement plan	Floor space related to facilities for energy saving is not included in calculation of floor-area ratio, when receiving Local authorities' certificate of conformance with higher standards by 10 (residential) or 20% (non-residential)
2. Energy efficiency labelling of compliance	Building owners are able to label their buildings as the buildings, which meet energy efficiency standards when receiving Local authorities' certificate.
3. Energy efficiency labelling of rank for energy consumption and envelope performance (BELS)	Building owners are able to label energy efficiency of their buildings when evaluated by registered energy-saving review bodies. BELS (Building-Housing Energy-efficiency Labelling System) is needed to apply subsidies such as ZEH and ZEB.
4. Subsidy for ZEH and ZEBs	ZEH is defined as 20% higher energy consumption standard without PV and design energy consumption cancelled with PV, and envelope with higher thermal performance by 11-31%. ZEB is defined as 50% higher energy consumption standard without PV and design energy consumption cancelled with PV. **ZEB Oriented is defined as 30% or 40% higher energy consumption standard.**

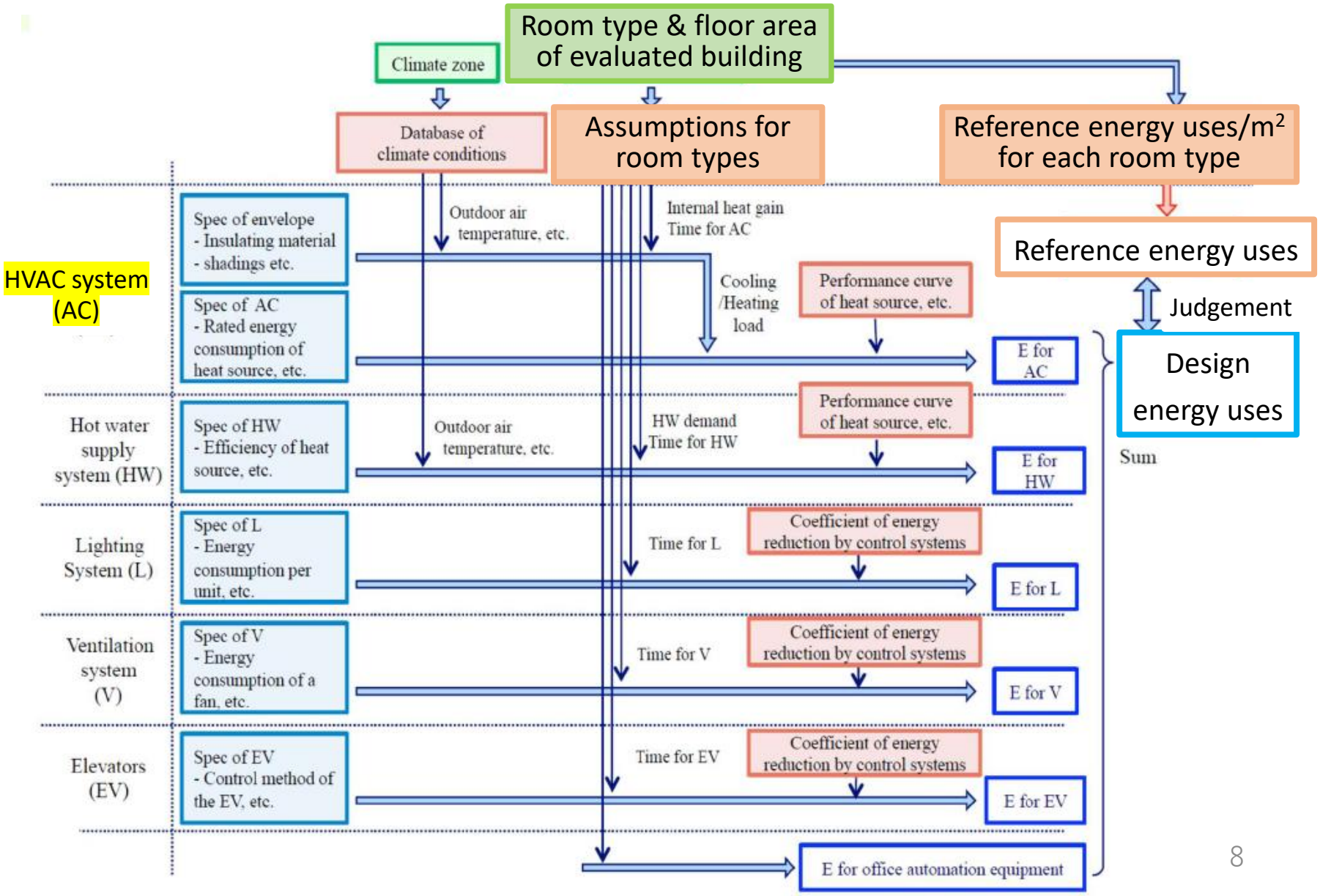
Source (in Japanese): Housing Bureau, MLIT

3. Planned strategies toward higher standards in 2030 (future)

year	2022-2029	2030	2050
Residential	**1. Compliance with standards is planned to be mandatory in around 2025** 2. Upgrading Performance Improvement plan to ZEH level 3. Addition of Top runner program for condominium apartment (BEI=0.9) 4. Upgrading Top runner standards 5. Low interest loan and subsidy for ZEH, ZEH+ and LCCM 6. Promotion of energy retrofit	**1. Upgrading Standards by 20% for energy consumption and standards or envelope thermal performance** 2. In 2030 at the latest, various standards are planned to be upgraded.	**Carbon Neutral in building sectors is realized.** In average, building stock has energy efficiency of ZEH and ZEB levels. PV is installed in 60% of newly built detached houses.
Non-residential	**1. Compliance with standards is planned to be mandatory for buildings with floor area less than 300m^2 in around 2025** 2. Upgrading mandatory standards by 20% for large and mid size buildings 3. Upgrading Performance Improvement plan to ZEB Oriented level 4. Promotion of energy retrofit	**1. Upgrading standards to ZEB Oriented for large or mid size buildings, and to 20% higher level for small buildings.** 2. Further upgrading Performance Improvement plan.	
Renewables	Promotion of PV, solar heat collector, standardization for biomass stove, etc.		

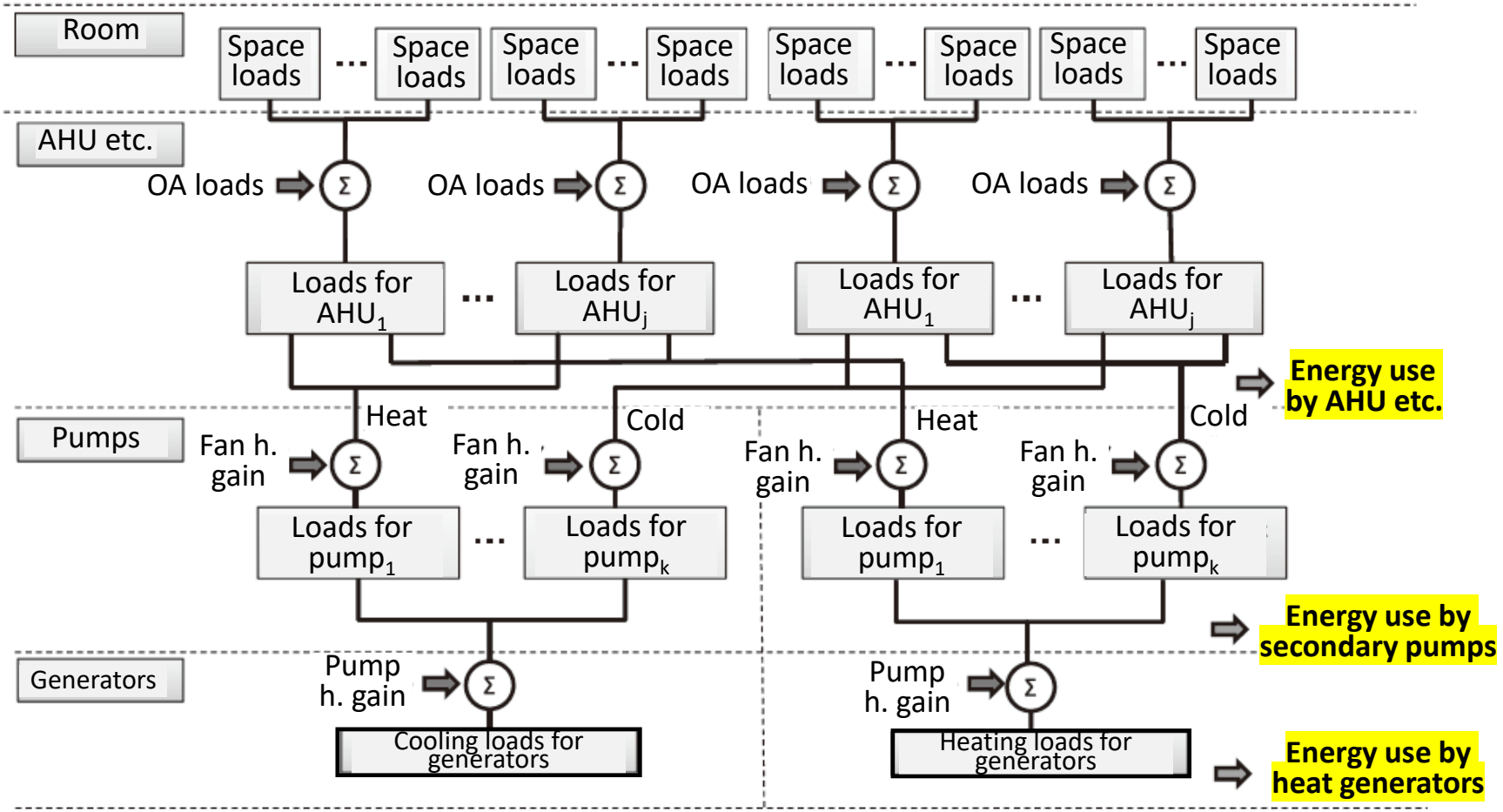
Source (in Japanese): Roadmap by Council on energy conservation in buildings toward decarbonized society, Aug. 2021

4. Overall structure of energy use calculation for non-residential buildings



5. Process for calculating energy use by HVAC system

Flow of heating and cooling needs (loads) calculation and energy use calculation for fans, pumps and heat/cold generators



6. Key characteristics of the HVAC energy use calculation method

- Space heating and colling needs (loads) are heavily influenced by conditions of room (space) usage such as schedule, internal heat gains and outdoor air intake.
- Standard conditions for 210 room types for 9 building types are prepared.
- The format of the conditions is standardized as ISO 18523-1, which includes the Japanese standard conditions as an informative appendix.

Example: List of room type for hotel building (Ht-1 to Ht-31)

Table C.2 — Categories of space or zone for hotel building

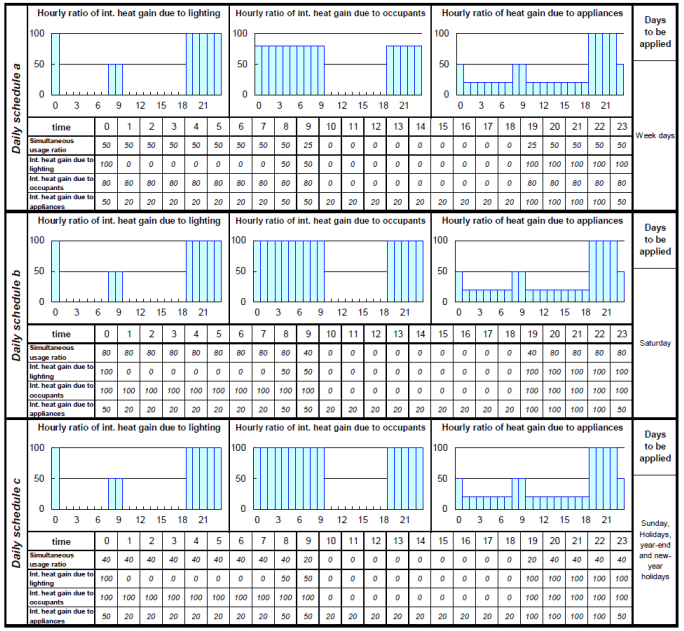
Ht-1 **Guest room**
Ht-2 Bath room inside guest room
Ht-3 Front desk open all day
Ht-4 Office room open all day
Ht-5 Corridor open all day
Ht-6 Lobby open all day
Ht-7 Lavatory open all day
Ht-8 Smoking room open all day
Ht-9 **Banquet hall**
Ht-10 **Conference hall**
Ht-11 **Wedding ceremony hall**
Ht-12 Restaurant
Ht-13 Lounge
Ht-14 Bar
Ht-15 Shop
Ht-16 Staff canteen
Ht-17 Changing room
Ht-18 Front desk open not all day
Ht-19 Office room open not all day
Ht-20 Corridor open not all day
Ht-21 Lobby open not all day
Ht-22 Lavatory open not all day
Ht-23 Smoking room open not all day
Ht-24 Kitchen
Ht-25 Indoor parking garage
Ht-26 Machine room
Ht-27 Electric room
Ht-28 Kitchenette with hot water server
Ht-29 Storage room
Ht-30 Printing room
Ht-31 Garbage storage room

Example: Schedule and condition for guest room (Ht-1) of hotel building

Category	No.	Ht-1	Building	Hotel building	Space/ZONE	Guest room

General	Space heating & cooling						Ventilation for unconditioned space		Lighting		Domestic hot water
Annual schedule	Operation hours	Ref. heat gain Lighting	Ref. int. heat gain Occupants	Ref. occupancy density	Ref. heat gain Appliances	Ventilation requirement	Operation hours	Ventilation requirement	Operation hours	maintained average illuminance	Total number of days
A	[hours/yr.]	[W/m2]	[W/m2]	[Person/m2]	[W/m2]	[m3/h-m2]	[hours/yr.]	[m3/h-m2]	[hours/yr.]	[lux]	[day]
	5475	15.0	6.4	0.1	4.0	4.0	0	0.0	2920	300	365

Total number of days of each daily schedule [day]	Time of start & end for normal operation (hours)				Set-point	Patterns	Normal operation Temp.(deg) rate(/h)		The case operation Temp.(deg) rate(/h)		Time of start & end (hours)				Ventilation requirement rate	Time of start & end (total hours)				Height of working plane	Total daily usage
a	241	a	19	10	(15)	Heating season	w1	22	40	-	-	a	-	-	(0)		a	19	10	(8)		
b	51	b	19	10	(15)	Cooling season	s1	26	50	-	-	b	-	-	(0)	[1/h]	b	19	10	(8)	[m]	[Lperson-day]
c	73	c	19	10	(15)	Intermediate season	m1	24	50	-	-	c	-	-	(0)	-	c	19	10	(8)	0	165.0



6. Key characteristics of the HVAC energy use calculation method

- Heat and cold generator's energy efficiency is estimated taking **the partial load ratio** at each hour into consideration.
- Characteristics of all kinds of heat and cold generator are modeled with;
  1) rated energy efficiency (COP),
  2) default function of the input energy with the partial load ratio as the independent parameter,
  3) default function of the maximum capacity with the heat source temperature as the independent parameter,
  4) default function of the maximum input energy with the heat source temperature as the independent parameter, and
  5) default function of the input energy with the temperature of outflowing fluid temperature as the independent parameter.

Example: Default functions for air source heat generators (for heating)

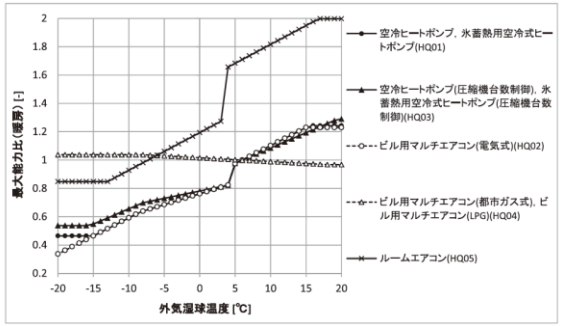


図 2.1D.5　空冷式熱源の暖房運転時の最大能力比特性

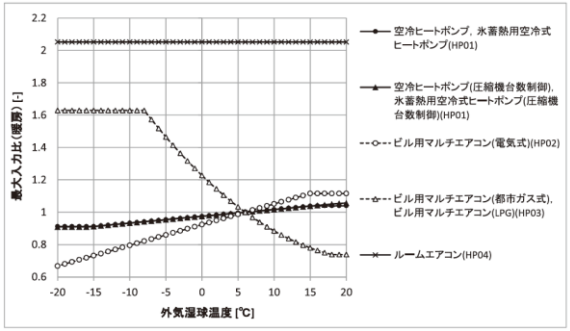
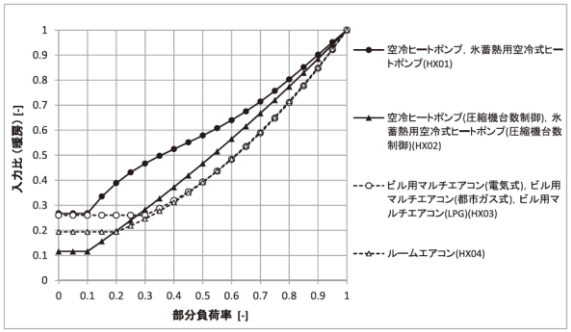


図 2.1D.6　空冷式熱源の暖房運転時の最大入力比特性



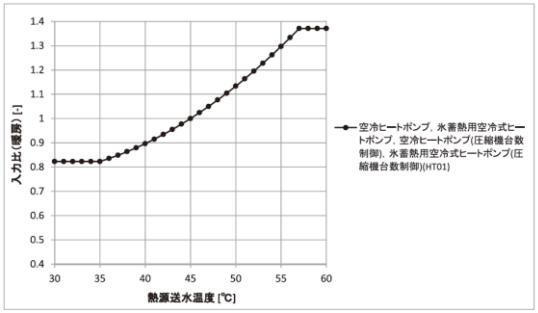
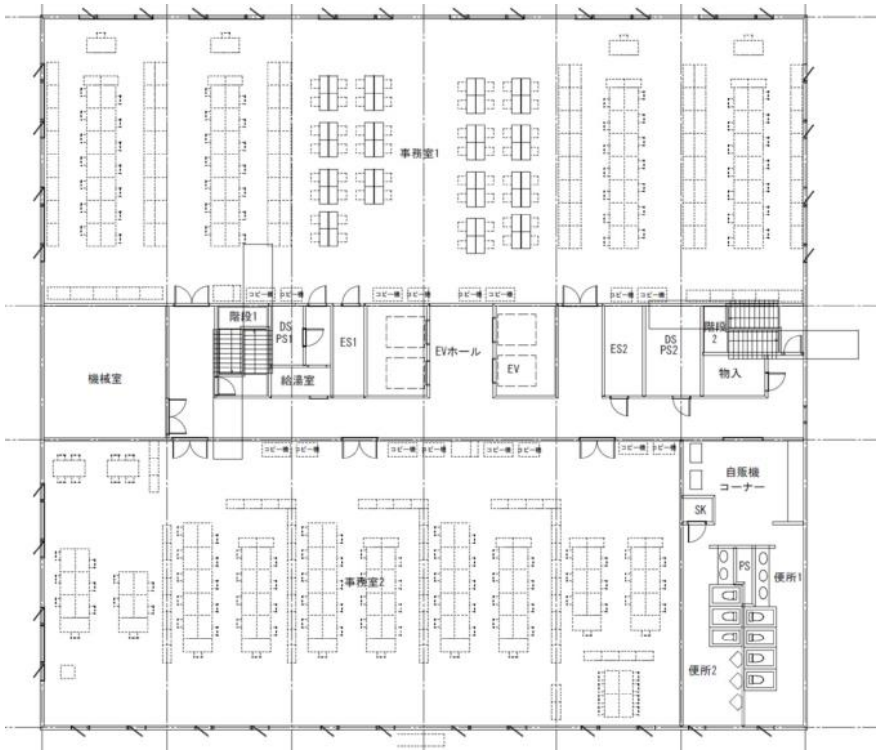
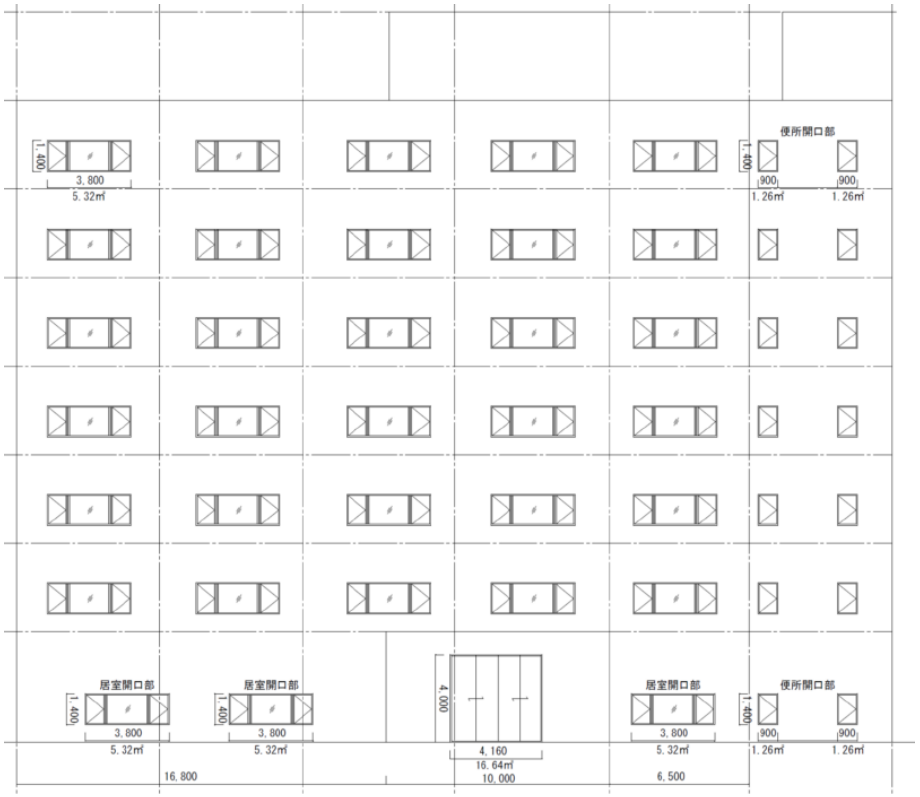


図 2.1D.8　空冷式熱源の暖房運転時の送水温度特性

7. Case studies

- Seven story office building
- Two landscape office rooms on each floor
- Located in Tokyo
- Total floor area 10360 m^2





7. Case studies (specifications for Case 1 – Case 5)

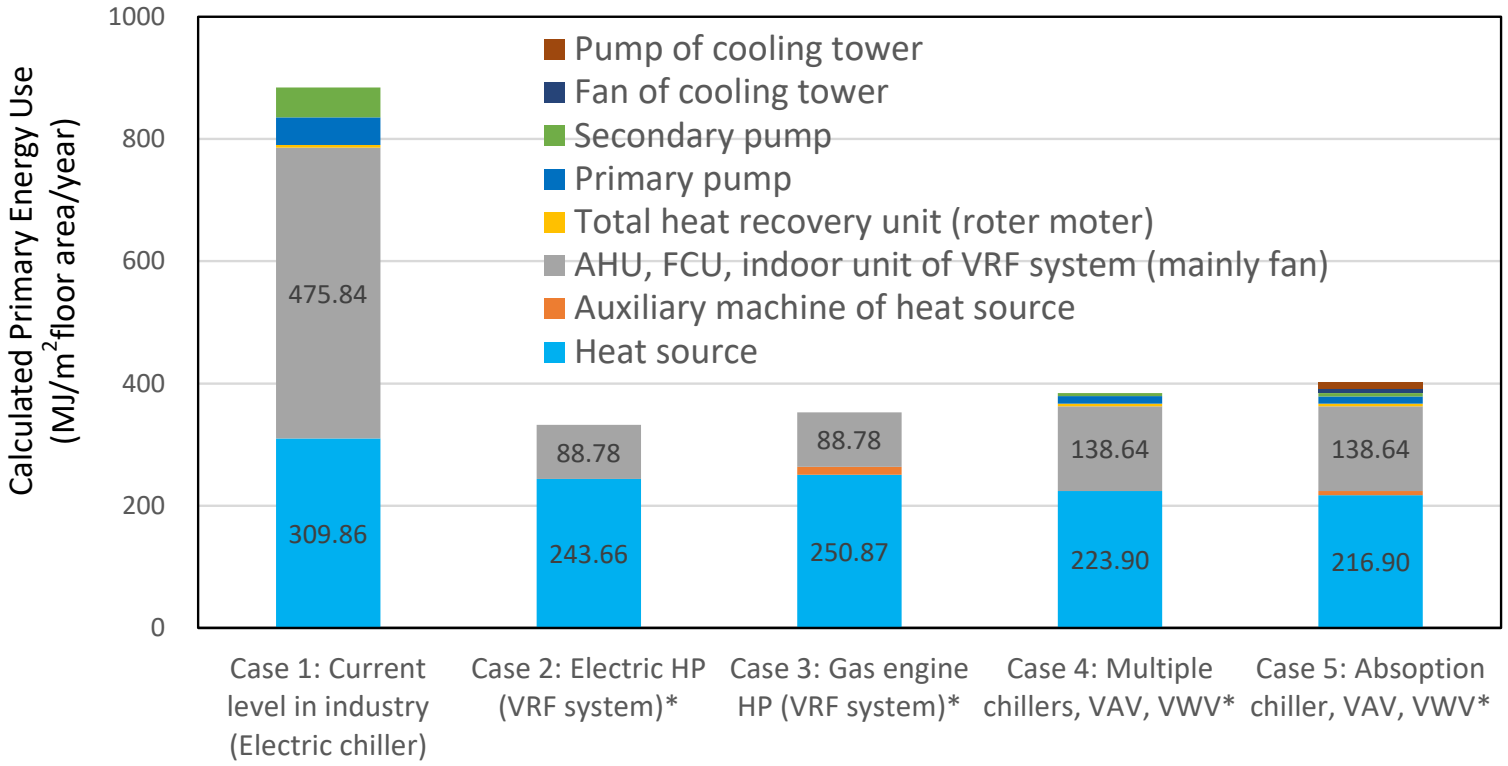
Case number	Building envelope				Building services		
	Opaque		Window		HVAC & Ventilation	Lighting	Service hot water
	Standard	Improved	Standard	Improved			
Case 1	✓		✓		Two water chilling units with ai handling units and rotary total heat exchangers. The specifications and sizes of the HVAC system and its components follow the ones, which are used when determining the reference energy uses. It means the result of the calculation becomes nearly equal to the reference energy use for the Case 1 building.	Maintained illuminance: 750 lx. Florescent lamp without energy-saving control	Automatic hot water faucets in rest rooms. Heat generators are instantaneous electric heaters.
Case 2		✓		✓	Electric VRF systems and energy recovery units are installed. Mechanical exhaust ventilation systems in machine and electric rooms are provided with temperature dependent on-off control. Sizing of VRF outdoor and indoor units are carried out according to a popular design standard.	Task-ambient lighting. Maintained illuminance: 400 lx. LED. Automatic controlled blinds and illuminance control for daylighting.	As above.
Case 3		✓		✓	Gas engine driven VRF systems and energy recovery units are installed. The same as Case 2 for the control of mechanical exhaust ventilation systems in machine and electric rooms. Sizing of VRF outdoor and indoor units are carried out according to an appropriate design standard.	As above.	As above.
Case 4		✓		✓	Sizing of the heat and cold generation system, pumps and AHU/FCU is carried out according to an appropriate design standard. Five water chilling units, three secondary pumps, AHU/FCU and rotary toral heat exchangers with better balance between supply and exhaust are installed.	As above.	As above.
Case 5		✓		✓	Sizing is carried our as Case 4. Two absorption chillers are installed. For AHU/FCU and rotary total heat exchangers are the same as Case 4.	As above.	As above.

7. Case studies (Sizing results for Case 2 – Case 5)

	Heat and cold generator type	Total capacity (kW) / number of units		Total rated input energy (primary basis, in kW)		Rated COP in primary energy basis	
		cooling	heating	cooling	heating	cooling	heating
Case 1	Water chilling unit (air source)	1072 / 2 units	1166 / 2 units	897	924	1.19	1.26
Case 2	VRF (electric)	894 / 16 outdoor units	1028 / 16 outdoor units	720	977	1.24	1.05
Case 3	VRF (gas)	940 / 16 outdoor units	1058 / 16 outdoor units	847	818	1.11	1.29
Case 4	Water chilling unit (air source)	870 / 5 units	870 / 5 units	722	704	1.20	1.24
Case 5	Absorption chiller (gas, variable cooling water volume)	1054 / 2 units	796 / 2 units	843	938	1.25	0.85

Primary energy factor: 9760 kJ/kWh(electricity)

7. Case studies (Results. Calculated primary energy use)

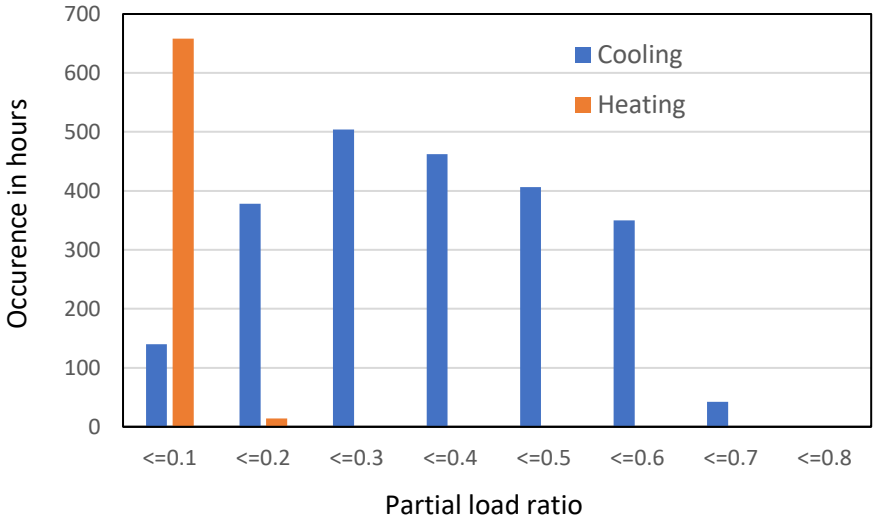


* For Case 2 to Case 5, improved building envelope is assumed, even though its contribution is not as large as HVAC systems, partly because climatic condition is rather mild.

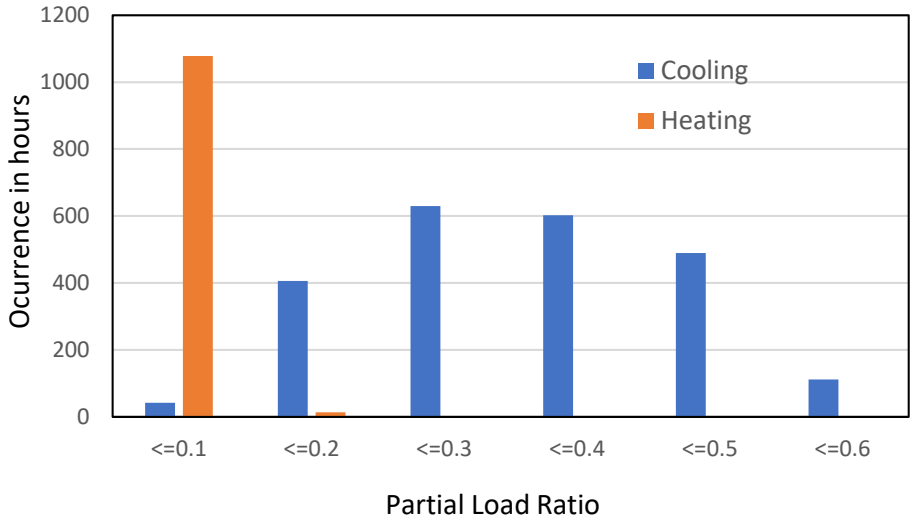
Primary energy factor: 9760 kJ/kWh(electricity)

- Energy use for AHU fans and secondary pumps can be reduced by following the sizing practice. Especially fan power for AHU should be carefully sized.
- Energy use for heat and cold generators can be reduced by a proper sizing and sequence control of generators with a divided capacity.

7. Case studies (Results. Calculated primary energy use)



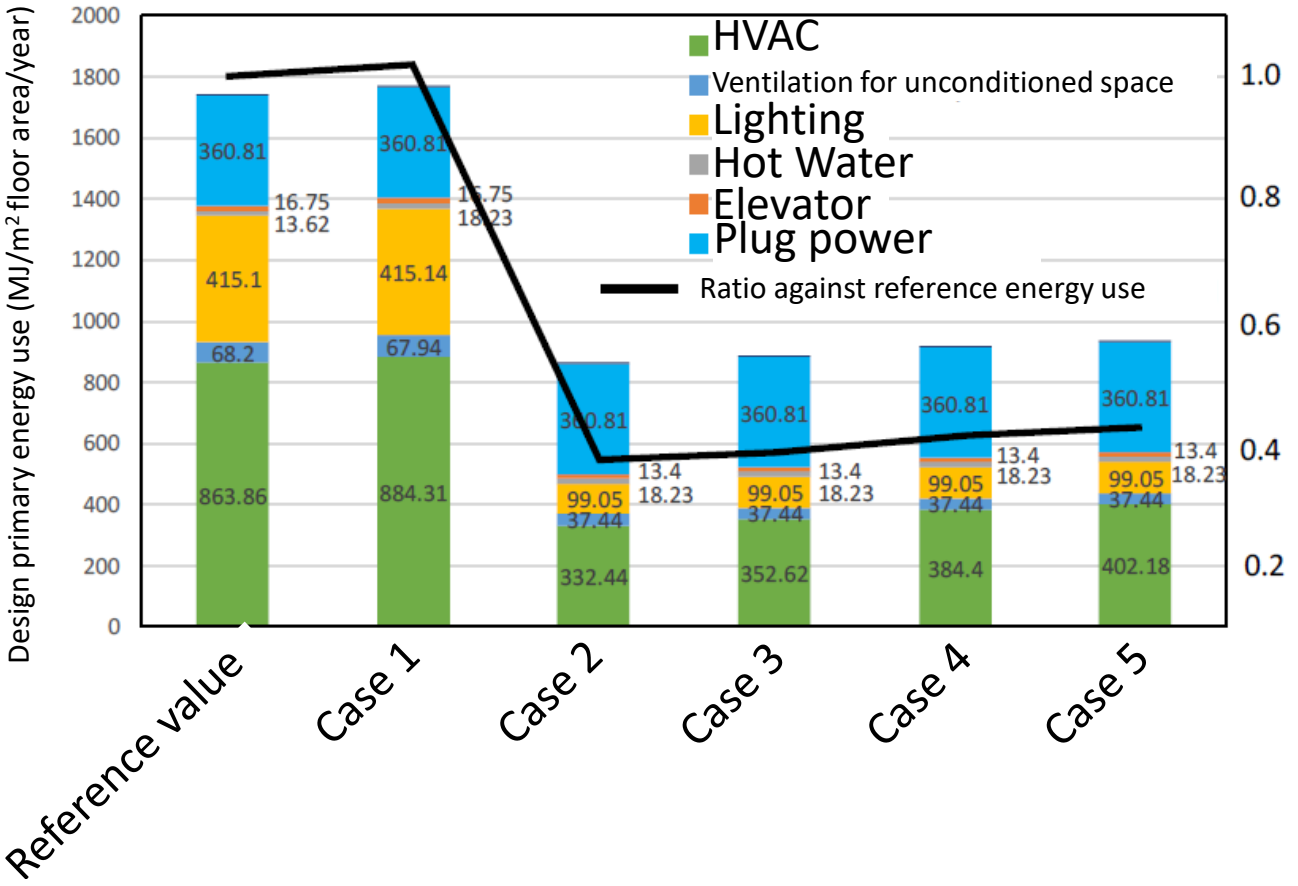
Case 2
Outdoor Unit of Variable Refrigerant Flow for an office room with 597 m^2 floow area (located in Tokyo)
Capacity (rated COP): 0.118kW/m^2 (3.39) for cooling, 0.133kW/m^2 (2.96) for heating



Case 4
Air-source Water Chilling Units (180kW×4+150kW×1) for air-conditioned space with 7436 m^2 floor area in a 7-story office building
Capacity: 0.117 kW/m^2 for cooling and heating
Rated COP: 3.22 (cooling) 3.38 (heating) for 180kW unit, 3.50 (cooling) 3.54 (heating) for 150kW unit

- The above two figures for distributions of partial load ratio for Case 2 and Case 4 show the partial load ratio remains mostly below 0.5 even if a proper sizing has been carried out.
- Remarkable difference between cooling and heating should be taken care of.

7. Case studies (Results. Calculated primary energy use)



Total calculated primary energy use for Case 1 to Case 5

- It is feasible to design buildings with BEI (building energy index) below 0.5 (compliant with requirement for ZEB Oriented=0.6 for office) for office buildings in mild climatic regions in Japan.

8. Still existing issues

- The following energy-saving techniques have not yet been evaluated mainly due to the lack of design standards and specifications:

VWV control system (beside discharge pressure control)	under development
VAV control system (beside discharge pressure control)	as above
CO_2 based outdoor-air intake control system	as above

- Characteristic functions for heat and cold generators with improved energy efficiency especially under low partial load ratio conditions

- Better harmonization between standards in the world of heating/cooling equipment and those in the world of buildings with the equipment integrated in themselves (especially important for more accurate evaluation tools for building energy codes)

Thank you for your kind attention.