Imperial College London – The University of Tokyo
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OPTIMAL DESIGN METHOD FOR DISTRIBUTED ENERGY SYSTEM UTILIZING WASTE HEAT BY MEANS OF GENETIC ALGORITHMS

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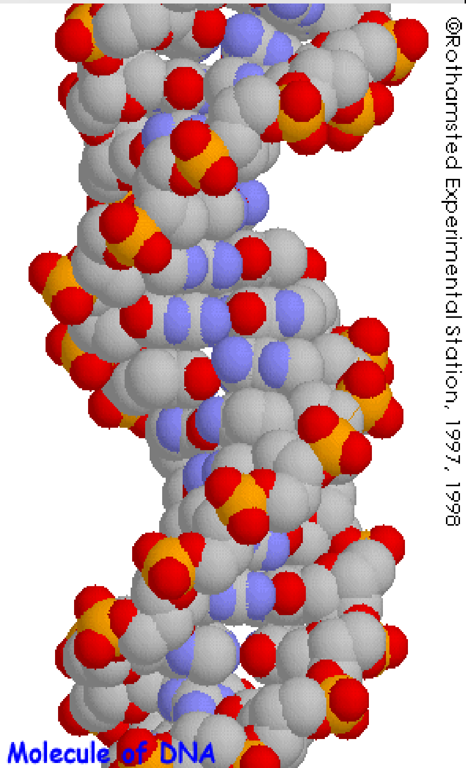


Contents of This Presentation

- Development of Optimal Design Method for Building Energy System Using Genetic Algorithms
- Optimal Design for Distributed Energy System utilizing Waste Heat from CGS by Genetic Algorithms.
- Optimization Energy System of Building Complex (composed of office and apartment) Using Genetic Algorithms

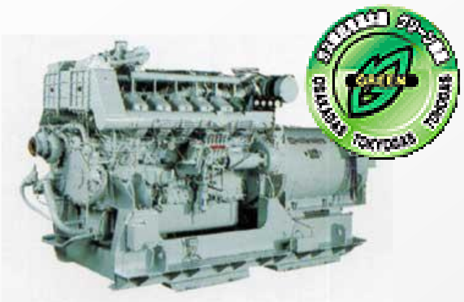
Contents of This Presentation

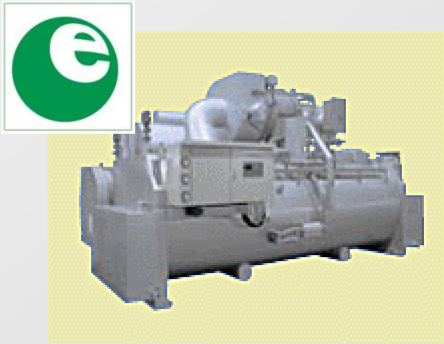
- Development of Optimal Design Method for Building Energy System Using Genetic Algorithms
- Optimal Design for Distributed Energy System utilizing Waste Heat from CGS by Genetic Algorithms.
- Optimization of Energy System of Building Complex Using Genetic Algorithm

Background

Energy Saving is very important problem in the building section.

In the resent years, efficiency of each building equipment has been improved very much.



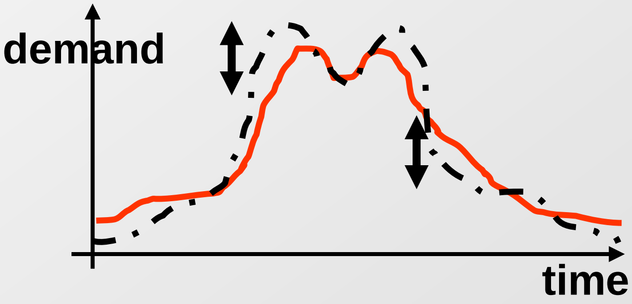


On the other hand, energy systems of buildings have been becoming very complex and appropriate design or operation planning are not conducted yet.
(Designed or operated still empirically)

Problems in Designing Energy Systems

①Difficulty of predicting Energy Demand.

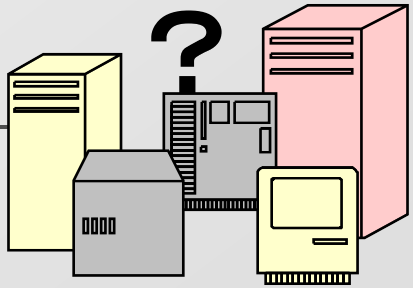
∗Energy Loss caused by too excess capacity.



②Design Complexity

∗<u>enormous combinations.</u>

∗<u>different operations in same System.</u>



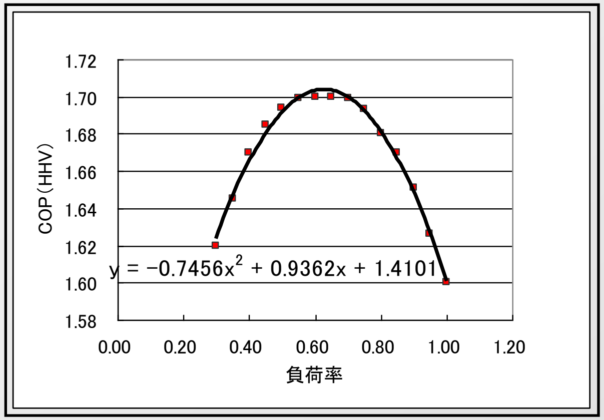
➡ **<u>Design Method for Optimal Energy Systems must be established!</u>**

Previous Researches

＊Optimization by using linear program.

ex) Ito, G.Sundberg, etc.

However,
“inverter control” techniques.
non-linear functions.



➡ Difficulty in accurate System Design using LP.

Objectives of this Research

＊Optimal Design Method for Building and Urban Energy System by using GA, which can optimize “capacity of each equipment” and its “operation planning” simultaneously.

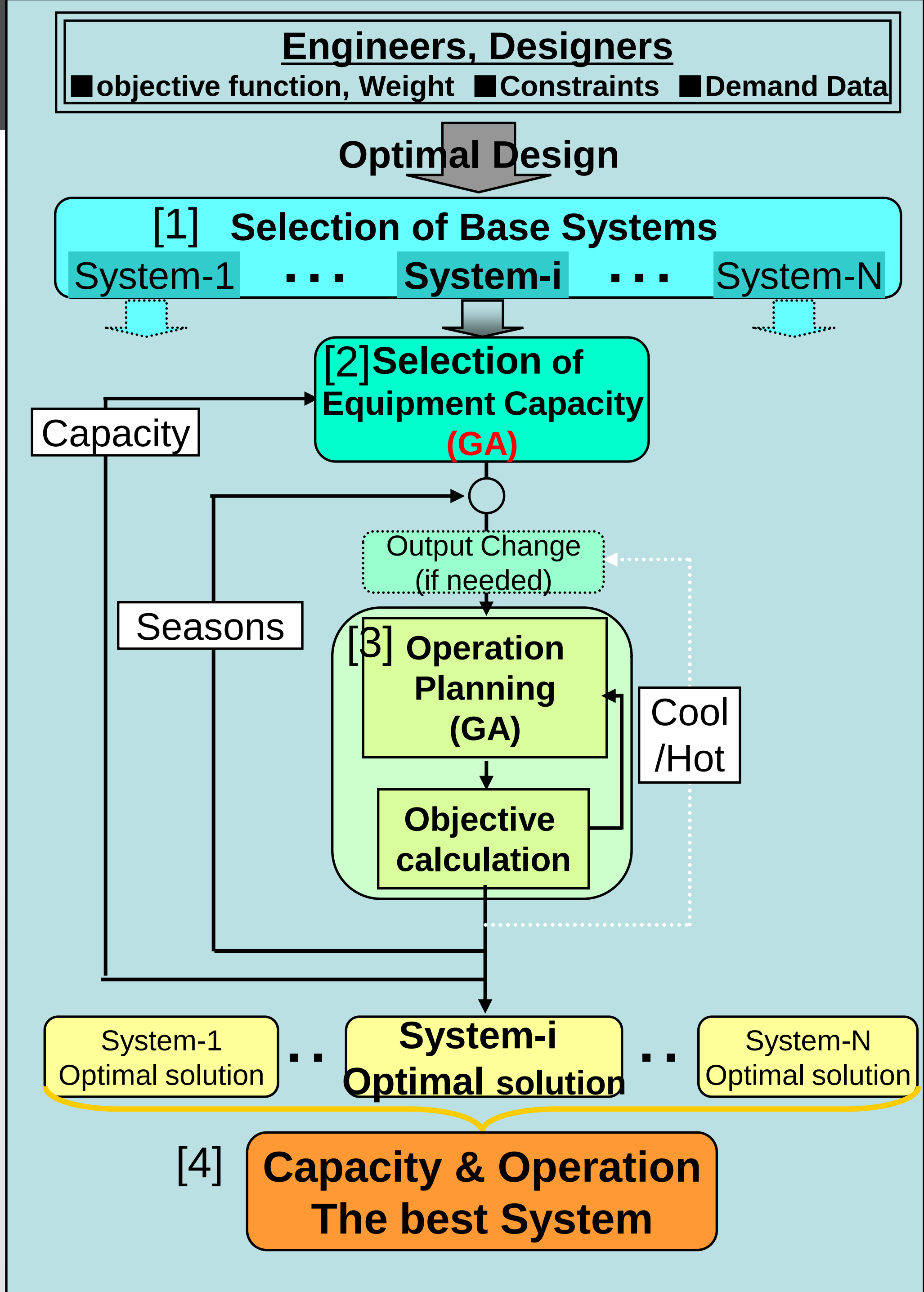
Optimal Design
Method Outline

①Selection of
Base Systems
(Combi. of equipment.)

②Selection of
Equipment Capacity
(GA)

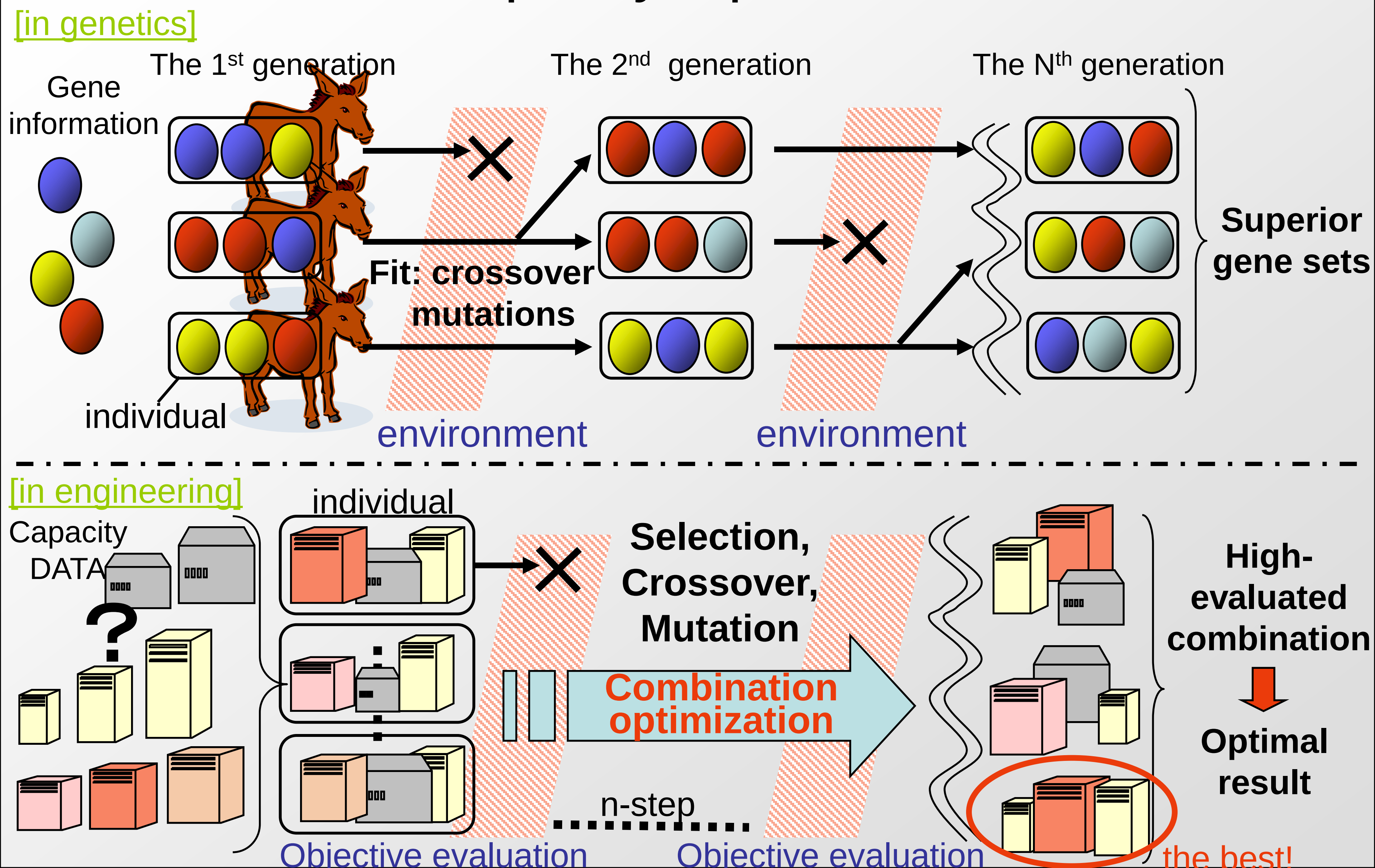
③Operation Planning
(GA)

④the Best System

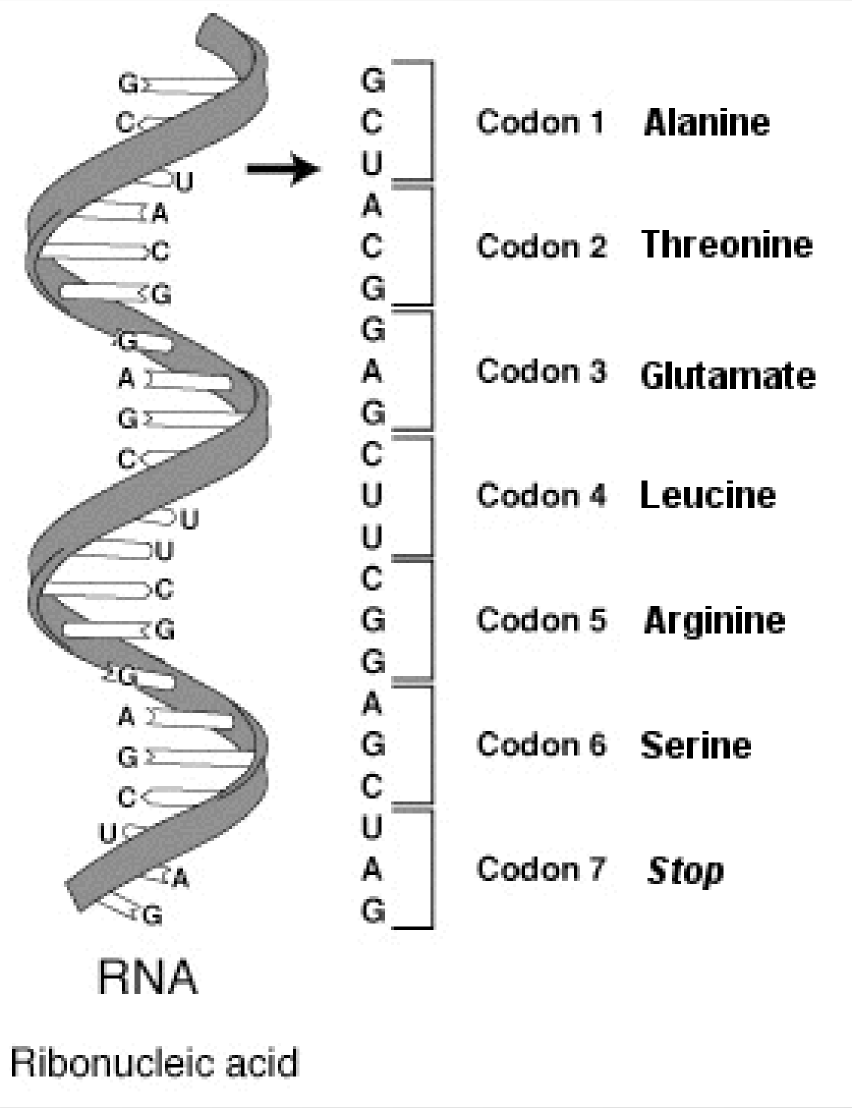


Optimization by using genetic Algorithms

- ex. Capacity Optimization -

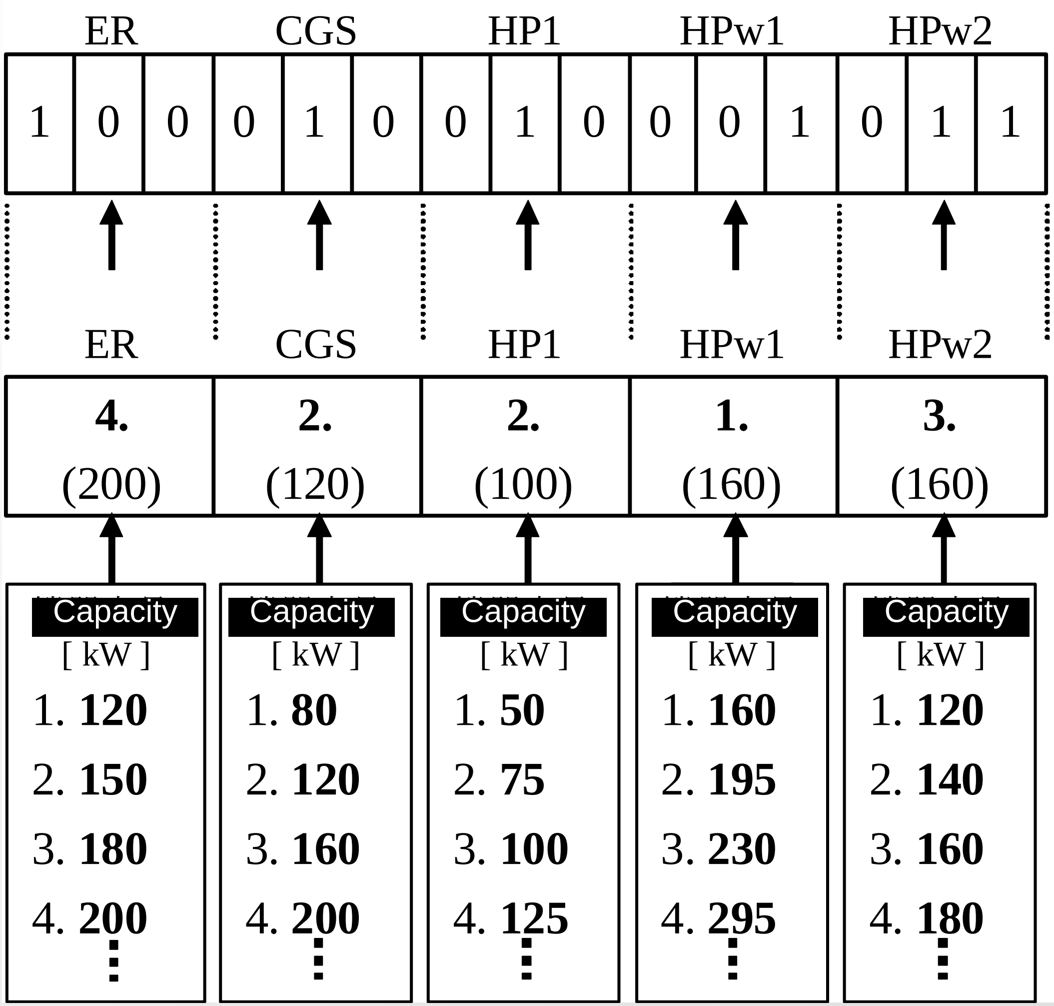


Description of Chromosome



Description of Chromosome

- For Selection of Equipment Capacity



Chromosome
(binary system)

Here

ER : Turbo Refrigerator

CGS : Cogeneration System

HP : Heat Pump

HPw : Heat Pump for Hot Water

Choice of Capacity is according to line-up of equipments

Description of Chromosome

- For Selection of Operation Planning

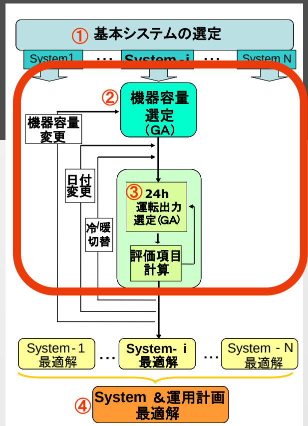
Hours	0	1	2	3	4	5	6	7	8	9	10	11
α	0	0	0	0	0	0	1.0	1.0	1.0	0.2	0.2	1.0

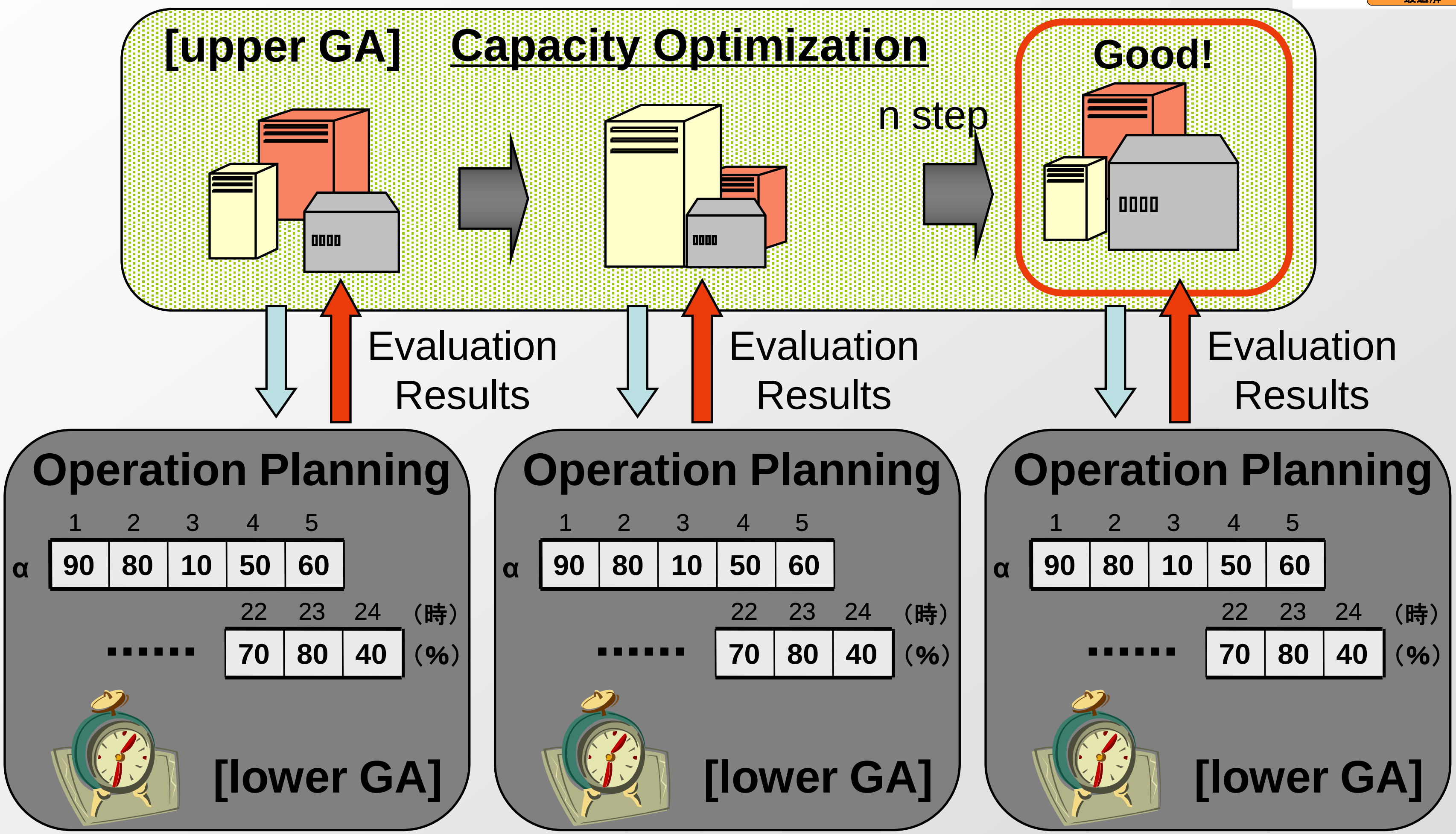
Chromosome

	12	13	14	15	16	17	18	19	20	21	22	23
....	0.2	0.2	0.2	0.2	1.0	0.4	0.6	1.0	1.0	0	0	0

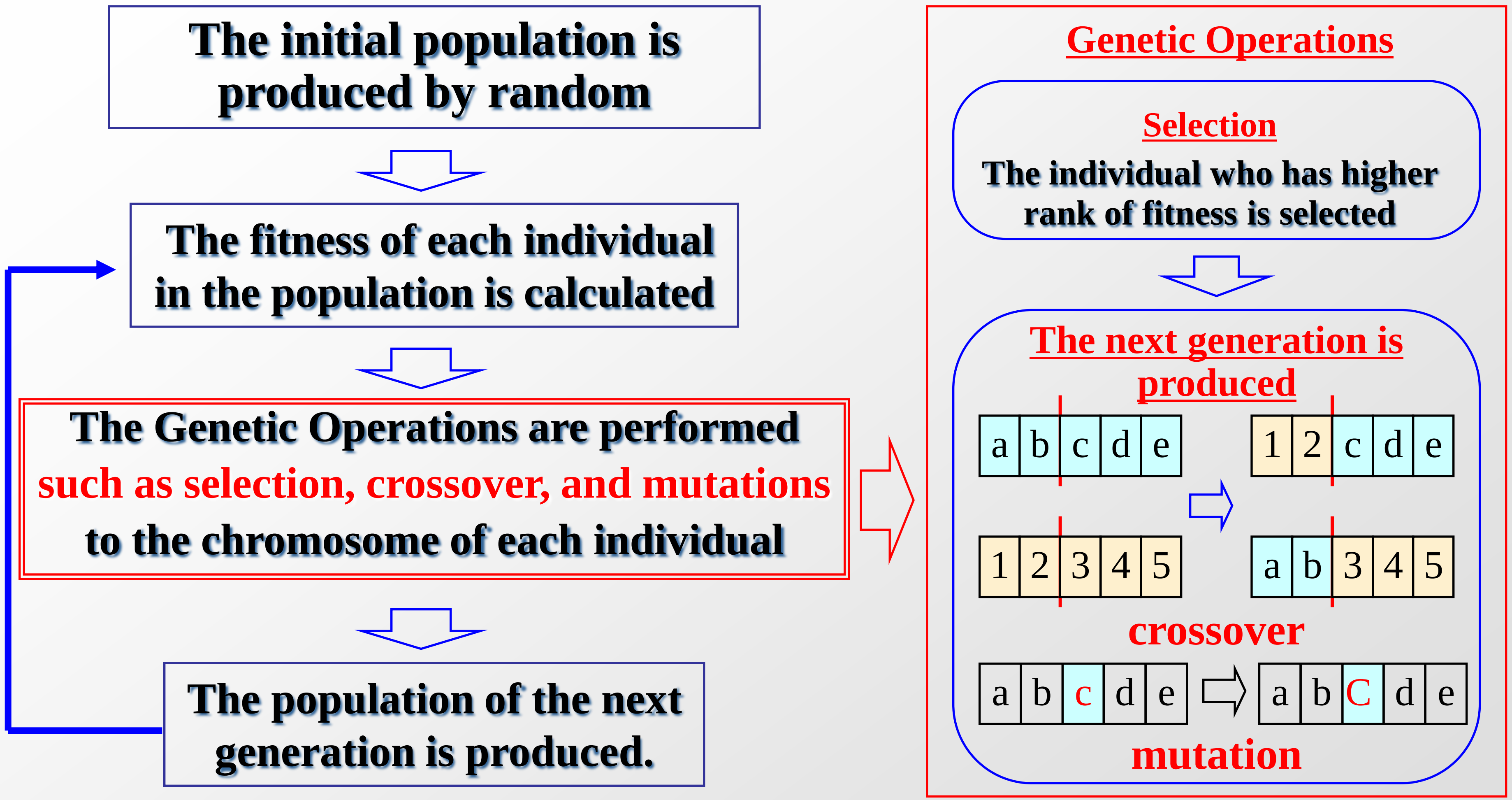
但し、α : Operating rate (0.0~1.0)

2-layers Optimization
Capacity & Operation





The Fundamental Flow of the GA



- It is considered that the excellent parents have high possibility of producing the excellent children. If the process is repeated many generations, it is possible that we can find the optimum individual.

Experimental Analysis

Purpose:

Validation of the proposed method by comparison with the exact solution.

Target and Conditions

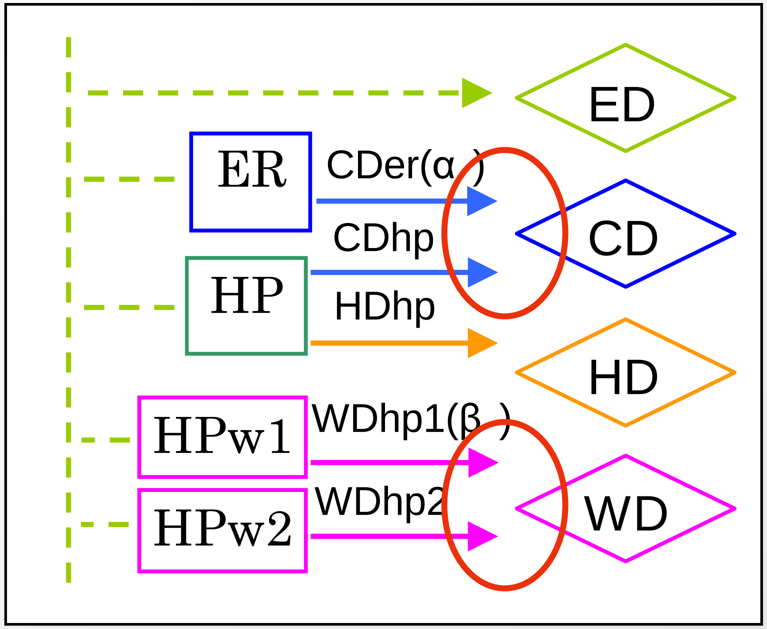
○ Building　: Hospital 40,000㎡

○ Date　: a representative day, in Aug.(24hours)

○Demand Data: the default data for HOSPITAL in "Computer Aided Simulation for Cogeneration Assessment & Design III" (CASCADE III)

(released by 空気調和衛生工学会)

○ Objective System

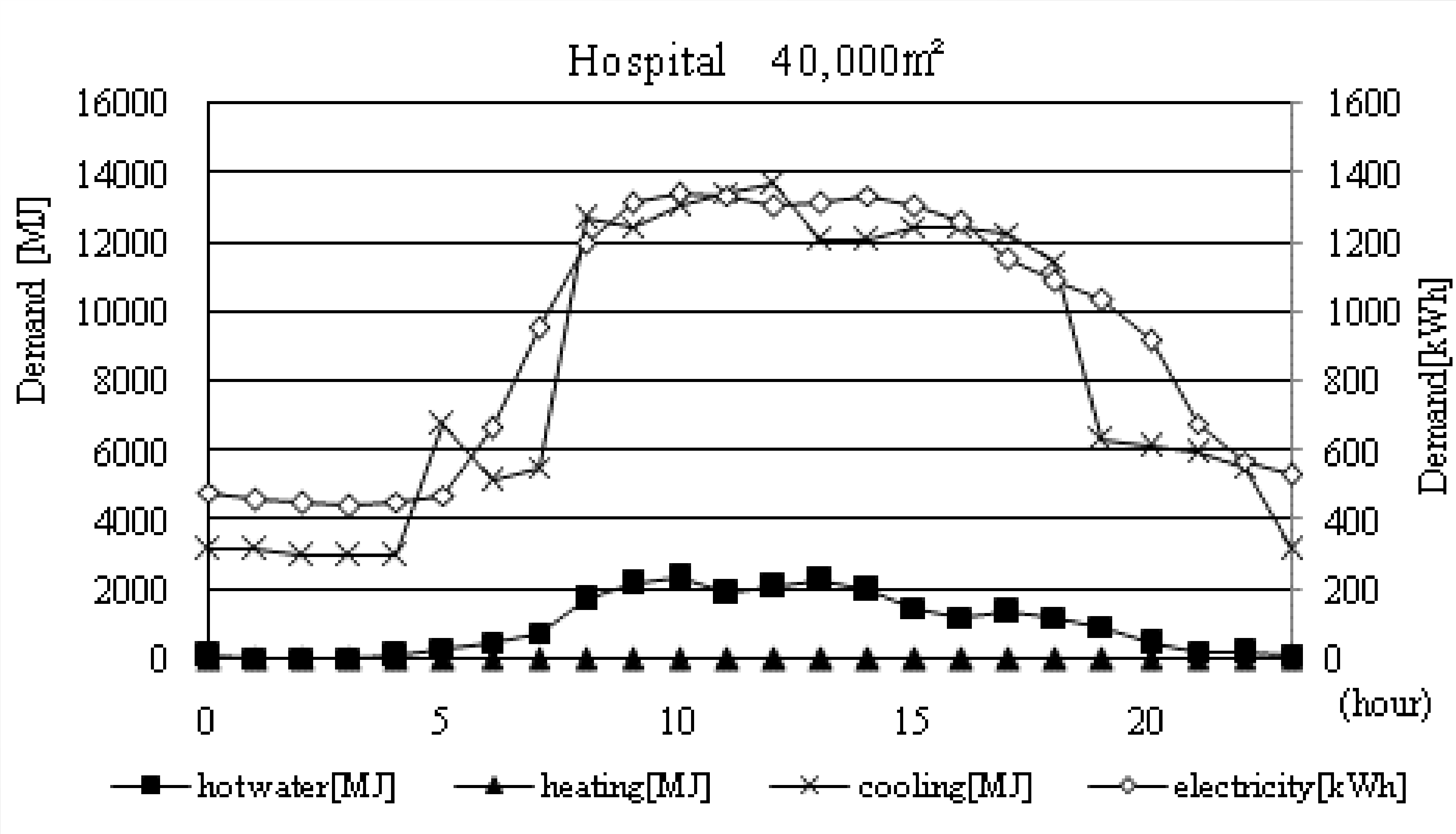


ED: Elec. Dem.　CD :Cooling Dem.
HD: Heating Dem.　WD: Hot Water Dem.

■objective functions

> an amount of CO_2 emisson and Energy consumption

Target and Conditions



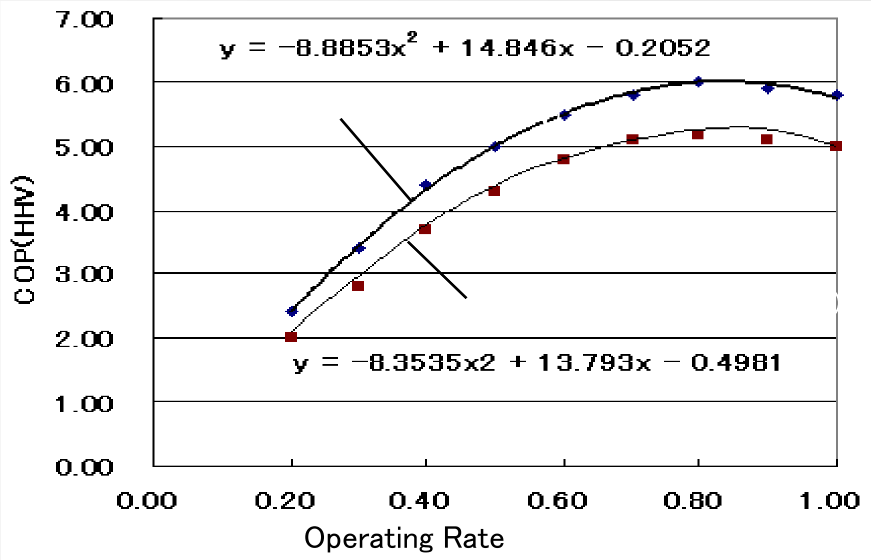
Demand Data: the default data for HOSPITAL in "Computer Aided Simulation for Cogeneration Assessment & Design III" (CASCADE III)

Objective Function

- Energy Consumption

$$E = \frac{\alpha Q}{COP(\alpha)} \text{ [kW]}$$

Q: Heat Load



COP of Equipment under for Operating Rate

- CO2 Emission

- Life Cycle Cost etc.

In this study, energy consumption and CO2 emission will be minimized.

Variables

Capacity	
Turbo Refrigerator （ER）	2280 [kW] (Fixed)
Cooling/Heating HP (HP)	1600 [kW] (Fixed)
Hot Water HP1 (HPw1)	550, 600 [kW]
Hot Water HP2 （HPw2）	150, 200 [kW]
Operation Planning（ Load Factor ）	
Operation of ER	α_i (i=0_23): (0 , 0.4 , 0.6 , 0.8 , 1.0)
Operation of HPw1	β_i (i=0_23): (0 , 0.4 , 0.6 , 0.8 , 1.0)

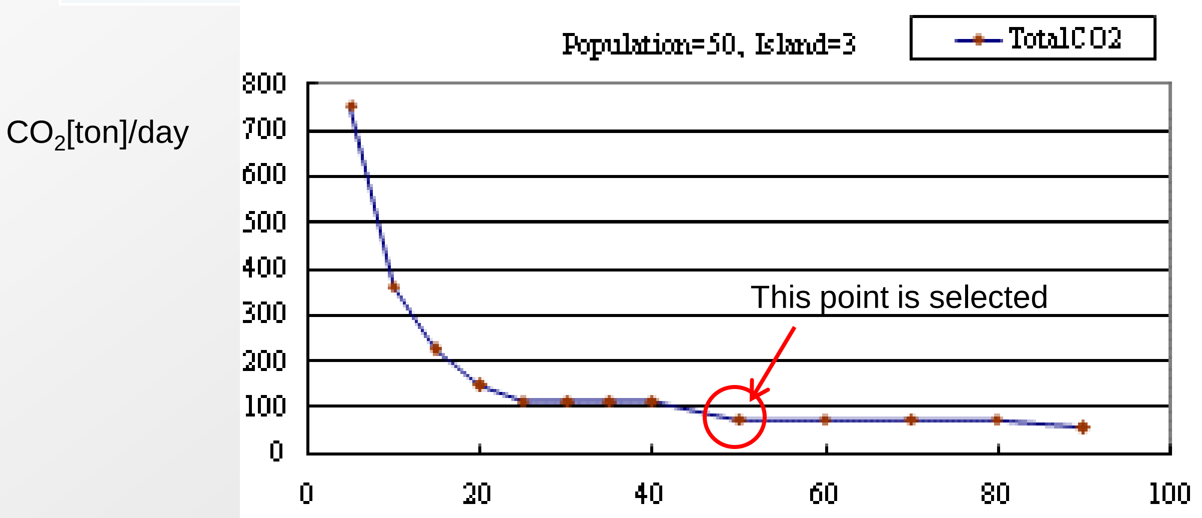
ex. Chromosome shape (Operation Planning)

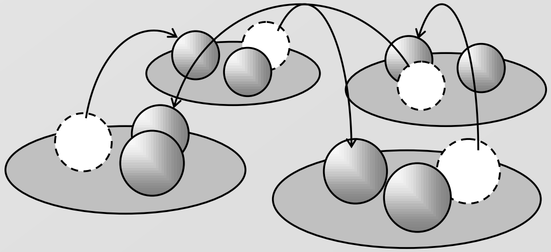
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Operation of ER	**α**	0	1.0	0	0.6	0	1.0	0	1.0	0.6	0.4	0.6	0.6	0.6	0.4	0.4	0.4	0.4	0.4	0.4	1.0	1.0	1.0	1.0	0

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Operation of HPw1	**β**	0.6	0	0.8	0	0	1.0	1.0	0.4	0.6	0.4	0.6	0.6	0.6	0.4	0.4	0	0.4	0	0.4	1.0	0.8	0.6	1.0	0

GA Parameters

Parameter	Selection of equipment	Selection of operation planning
Size of Sub Population	5	50
Number of Island	2	3
Population size	10	150
Number of Generations	20	60
Rate of Migration	0.5	0.5
Interval of Migration	5	5
Rate of Crossover	1	1
Rate of Mutation	0.03	0.01

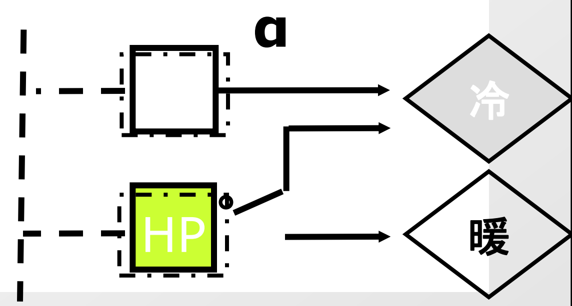




Analysis and Limitation Conditions

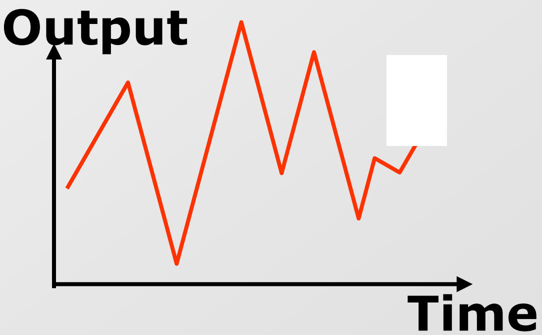
＊Automatic Change for Cooling/Heating

If Heating Demand is 0 for 24 hours,
HP is changed for Cooling Operation.



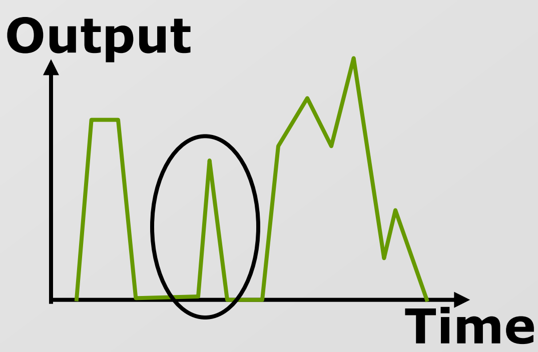
＊Avoiding Radical Change of Output

Penalty on Over 60% hourly Change



＊Avoiding Frequent ON/OFF Operation

Penalty on Operation Less than 2 Hours



Results

Selected Capacity

Equipment	Capacity
Turbo Refrigerator (ER)	2280 (kW)
Cooling/Heating HP (HP)	1600 (kW)
Hot Water HP 1 (HPw1)	550 (kW)
Hot Water HP 2 (HPw2)	150 (kW)

Selected Operation Program

α

time	0	1	2	3	4	5	6	7	8	9	10	11
α	0	0	0	0	0	1.0	1.0	1.0	0.6	0.4	0.6	0.6

....	12	13	14	15	16	17	18	19	20	21	22	23
	0.6	0.4	0.4	0.4	0.4	0.4	0.4	1.0	1.0	1.0	1.0	0

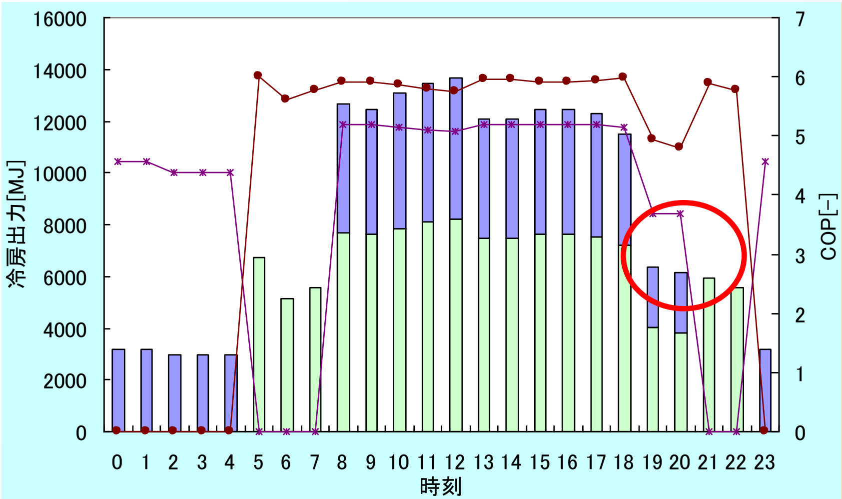
β

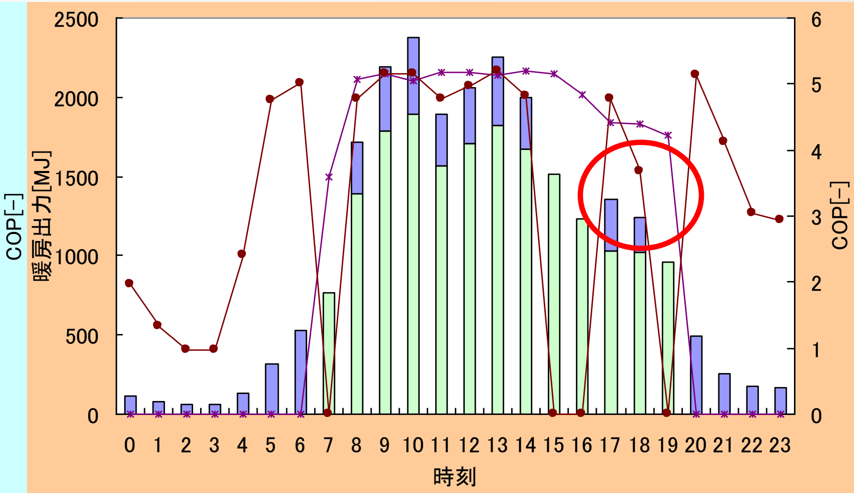
time	0	1	2	3	4	5	6	7	8	9	10	11
β	0	0	0	0	0	0	1.0	1.0	1.0	0.2	0.2	1.0

....	12	13	14	15	16	17	18	19	20	21	22	23
	0.2	0.2	0.2	0.2	1.0	0.4	0.6	1.0	1.0	0	0	0

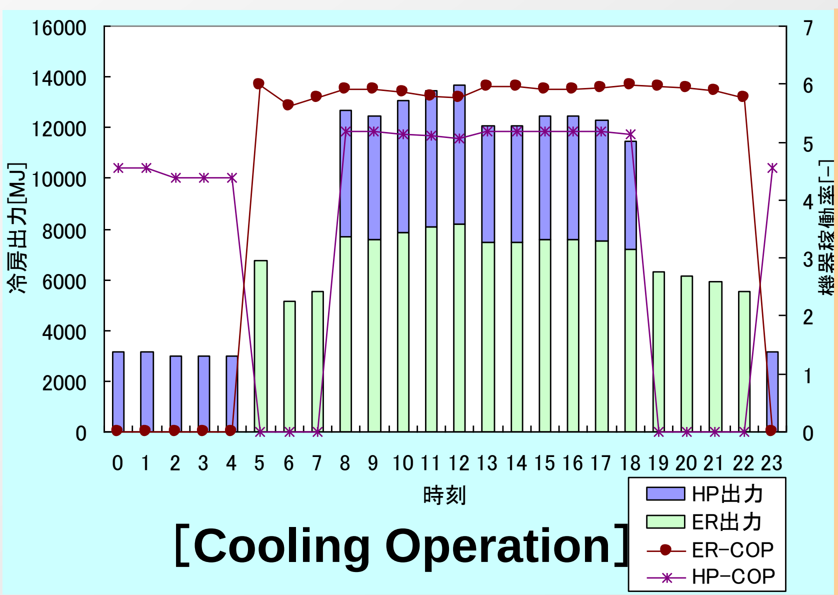
Analysis Results

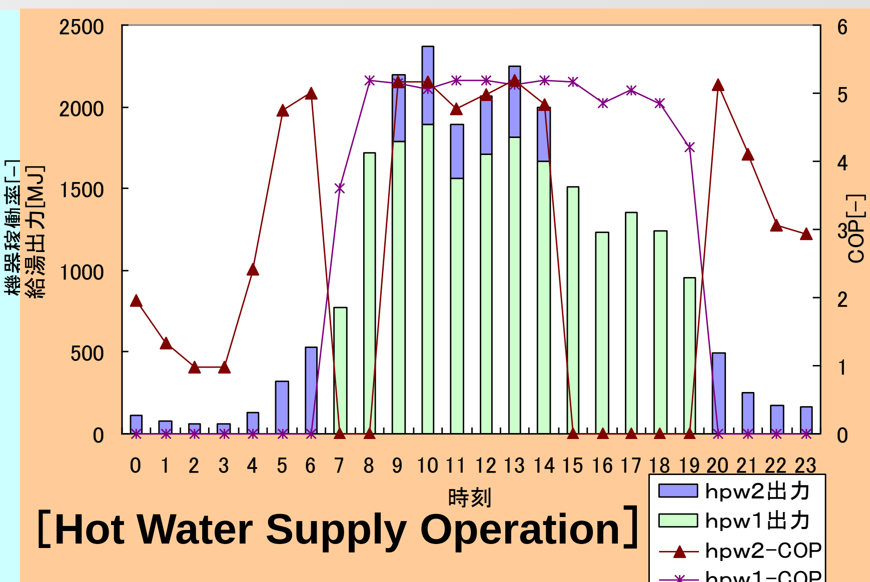
The Method Proposed Here





Results of Entire Inquiry: Exact Solution





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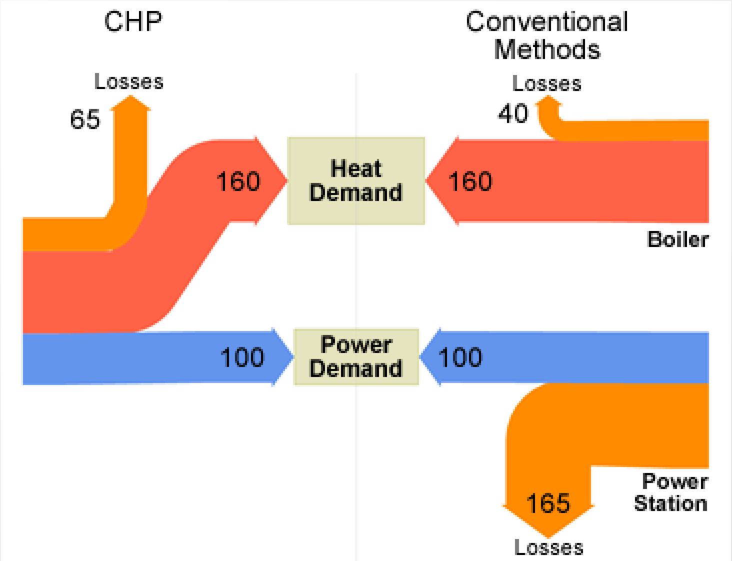
Distributed Energy System based on CGS

Cogeneration System (also combined heat and power, CHP) is the use of a heat engine or a power station to simultaneously generate both electricity and useful heat. It is one of the most common forms of energy recycling.

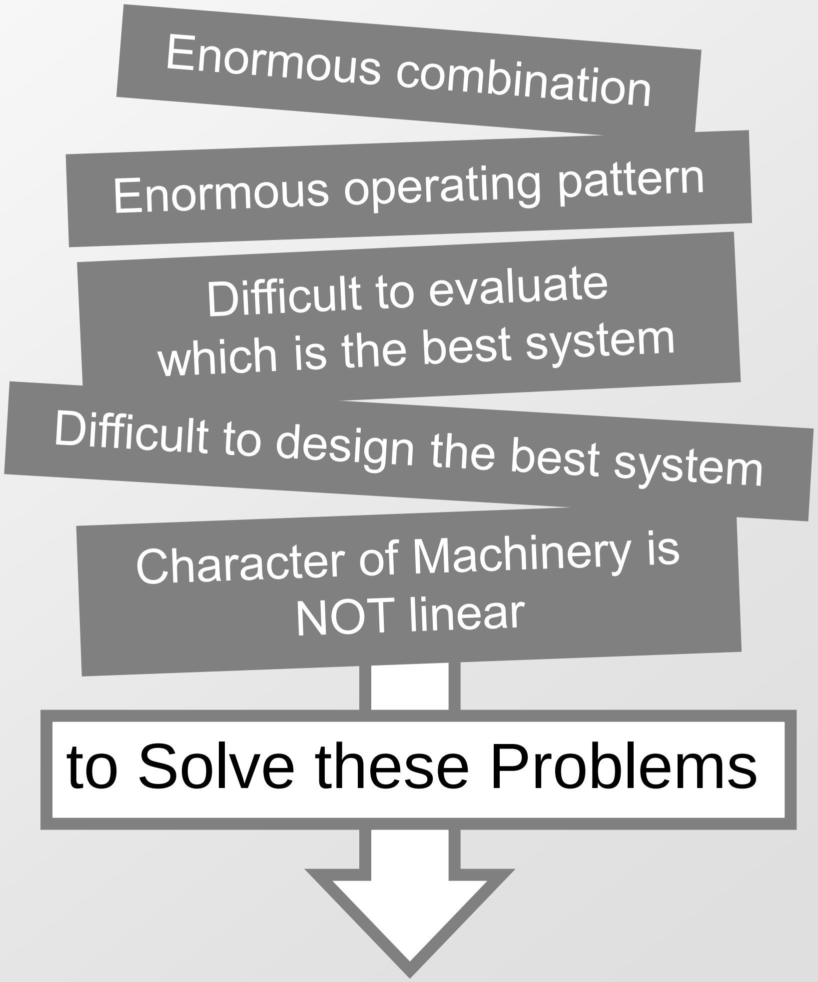


However, the energy efficiencies of the actual CGS are often lower than expected.

Purpose

The reasons why the energy efficiency of CGS is so low, are considered as.

1. Failure in prediction of heat demand.
2. Failure in optimum combination of equipment.
3. Failure in optimum operation planning
4. Low efficiency of power generation

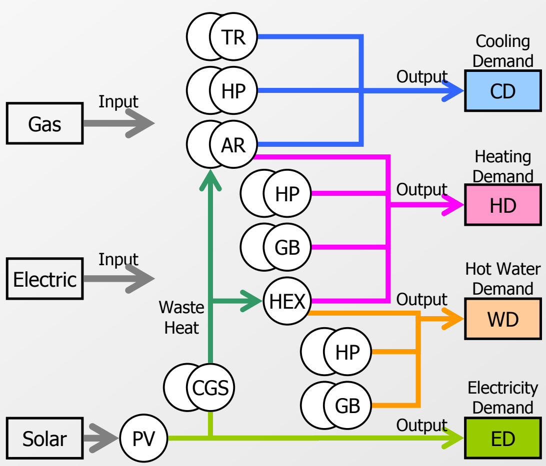


Using
Genetic Algorithm

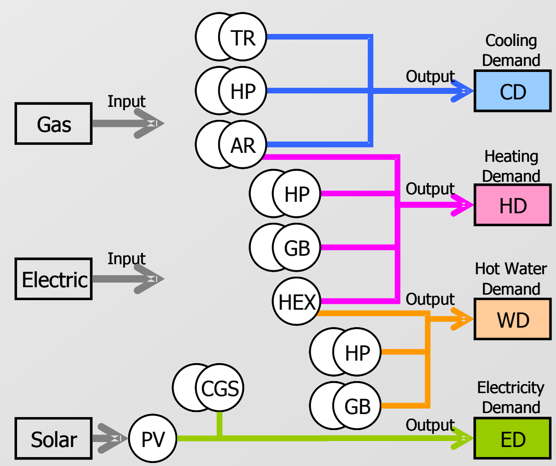
CASE STUDY

Building Type	Hospital
Building Size	20,000m^2 (Tokyo)
Optimize Method	Multi Island Genetic Algorithm（MIGA）
Objectives	Minimization of Primary Energy Consumption
Demand Data	Default Data of CASCADEIII
Comparison	Waste heat Usage（Case1 and Case2）

Case1：Waste Heat Available



Case2：Waste Heat NOT Available



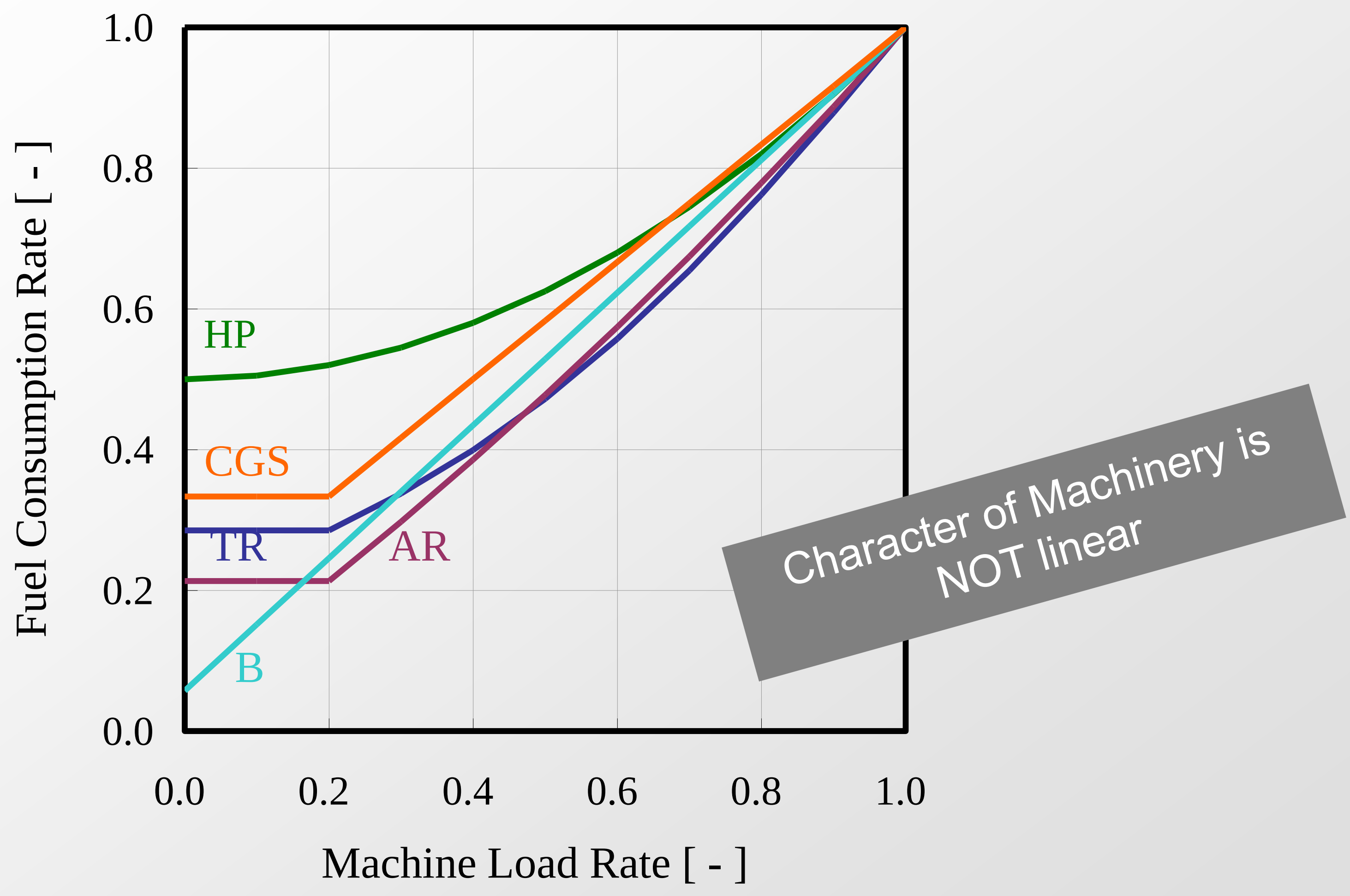
Type of Equipment

			COP		Input		Output			
			C	H	GAS	ELE	CD	HD	WD	ED
AR	Absorption Refrigeration Machine	[RT]	1.10	0.92	○		○	○		
TR	Turbo Refrigeration Machine	[RT]	2.50	---		○	○			
EHP	Electrical Heat Pump System	[HP]	2.04	1.98		○	○	○	○	
GHP	Gas Heat Pump System	[HP]	1.41	1.39	○		○	○	○	
GB	Gas Boiler	[kw]	---	0.91	○			○	○	
CGS	Co-Generation System	[kw]	*1)		○		○	○	○	○

Commercial Electricity：9.97MJ/kWh　　Commercial Gas：3.6MJ/kWh

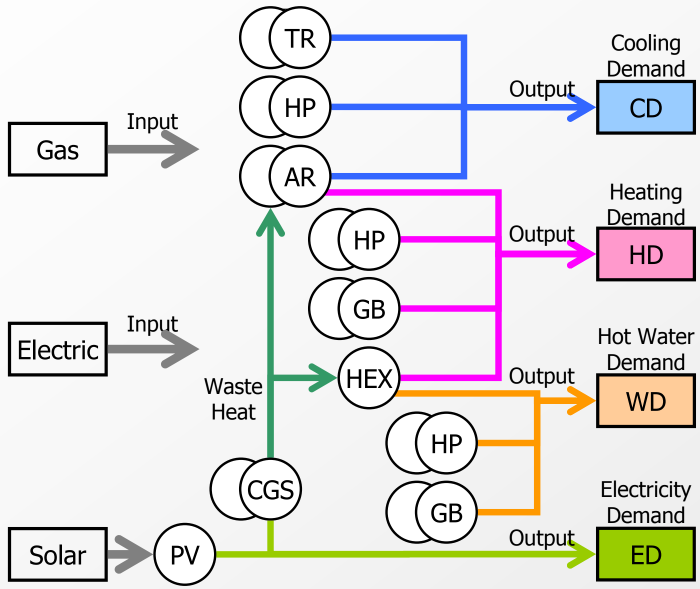
*1) Small CGS（～300kw）：0.33, Large CGS（350kw～）：0.38

Machinery Performance



the value of the machinery database of the CEC/AC calculation program "BECS/CEC/AC for Windows" published by Institute for Building Environment and Energy Conservation (IBEC)

Coding of chromosome



Packaging System combination as gene information

Chromosome coding

1	2	3	4	5	6	7	8	9	10	11	12
Cool Heat Supplier							Hot Heat Supplier				
AR1 USRT	AR2 USRT	TR1 USRT	TR2 USRT	HPc1 HP	HPc2 HP	eneHP G/E	GBh1 kw	GBh2 kw	HPh1 HP	HPh2 HP	eneHP G/E

Machinery division

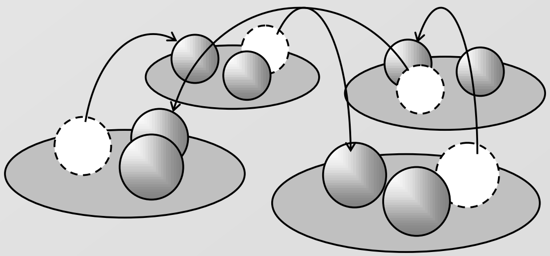
……

13	14	15	16	17	18	19	20
Hot Water Supplier					Electricity Supplier		
GBw1 kw	GBw2 kw	HPw1 HP	HPw2 HP	eneHP G/E	CGS1 kw	CGS2 kw	PV m^2

7,12,17th：Fuel of HP

GA Parameters

Size of Sub-Population	50
Number of Islands	5
Population Size	250
Number of Generations	100
Total Individual Size	25,000
Rate of Crossover	1.0
Rate of Mutation	0.10
Rate of Migration	1



Design Variables

			1	2	3	4	5	6	7	8
AR	Absorption Refrigeration Machine	[RT]	0	30	40	50	100	120	180	200
TR	Turbo Refrigeration Machine	[RT]	0	125	150	200	215	250	300	320
EHP	Electrical Heat Pump System	[HP]	0	8	10	13	16	20	25	32
GHP	Gas Heat Pump System	[HP]	0	8	10	13	16	20	25	32
GB	Gas Boiler	[kw]	0	58	87	116	151	186	232	291
CGS	Co-Generation System	[kw]	0	115	200	230	300	350	480	600
PV	Photovoltaic Power System	[m^2]	0	50	100	150	200	500	750	1,000

Result of Machinery Combination (Case 1)

Waste Heat Available

Cool Heat Supplier				Cool and Hot		Hot Heat Supplier				Hot Water Supplier				Electricity Supplier		
TR1	TR2	HP1	HP2	AR1	AR2	GB1	GB2	HP1	HP2	GB1	GB2	HP1	HP2	CGS1	CGS2	PV1
[USRT]	[USRT]	[HP]	[HP]	[USRT]	[USRT]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[m2]
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	125	8	8	30	30	58	58	8	8	58	58	8	8	115	115	50
150	150	10	10	40	40	87	87	10	10	87	87	10	10	200	200	100
200	200	13	13	50	50	116	116	13	13	116	116	13	13	230	230	150
215	215	16	16	100	100	151	151	16	16	151	151	16	16	300	300	200
250	250	20	20	120	120	186	186	20	20	186	186	20	20	350	350	500
300	300	25	25	180	180	232	232	25	25	232	232	25	25	480	480	750
320	320	32	32	200	200	291	291	32	32	291	291	32	32	600	600	1,000

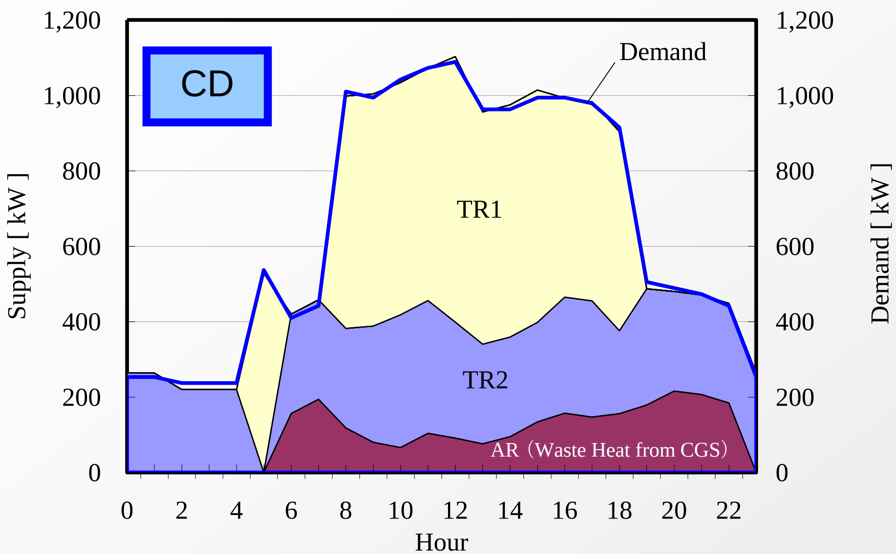
Result of Machinery Combination (Case 2)

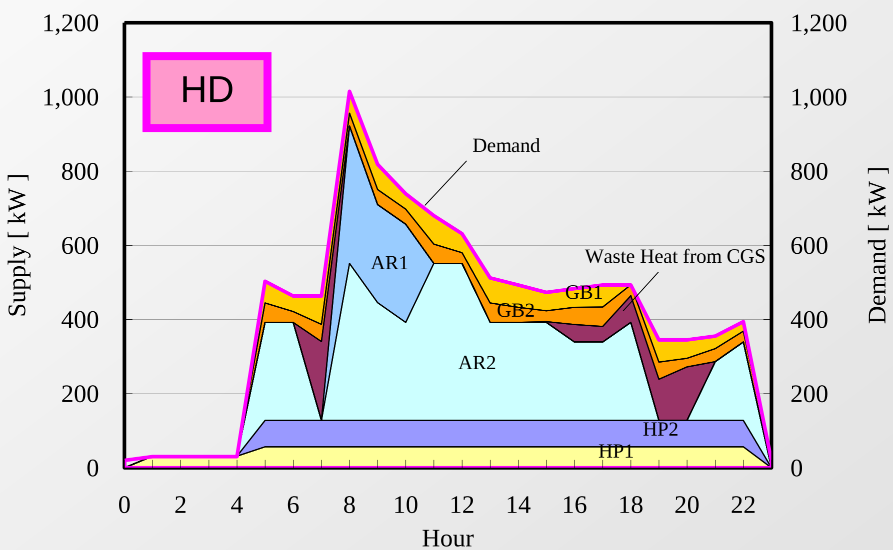
Waste Heat NOT Available

Cool Heat Supplier				Cool and Hot		Hot Heat Supplier				Hot Water Supplier				Electricity Supplier		
TR1	TR2	HP1	HP2	AR1	AR2	GB1	GB2	HP1	HP2	GB1	GB2	HP1	HP2	CGS1	CGS2	PV1
[USRT]	[USRT]	[HP]	[HP]	[USRT]	[USRT]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[m2]
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	125	8	8	30	30	58	58	8	8	58	58	8	8	115	115	50
150	150	10	10	40	40	87	87	10	10	87	87	10	10	200	200	100
200	200	13	13	50	50	116	116	13	13	116	116	13	13	230	230	150
215	215	16	16	100	100	151	151	16	16	151	151	16	16	300	300	200
250	250	20	20	120	120	186	186	20	20	186	186	20	20	350	350	500
300	300	25	25	180	180	232	232	25	25	232	232	25	25	480	480	750
320	320	32	32	200	200	291	291	32	32	291	291	32	32	600	600	1,000

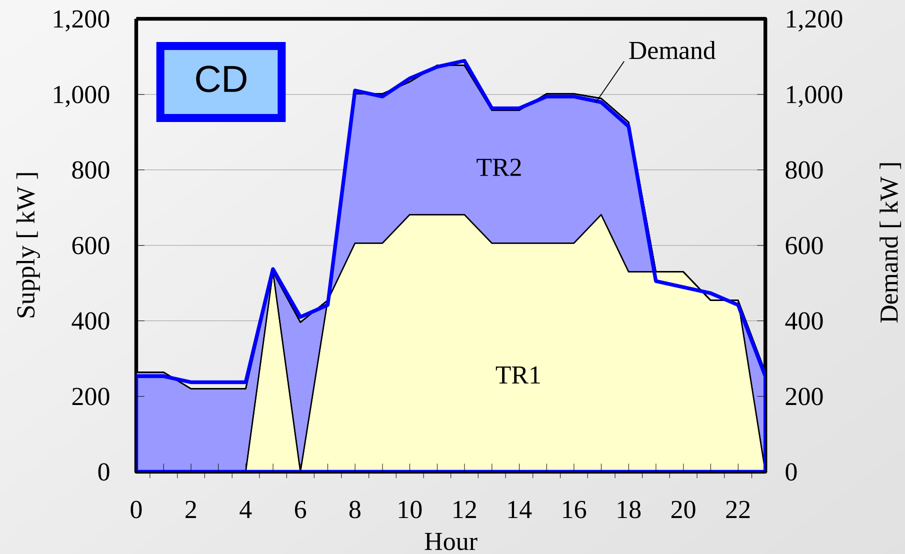
Operation Pattern Comparison

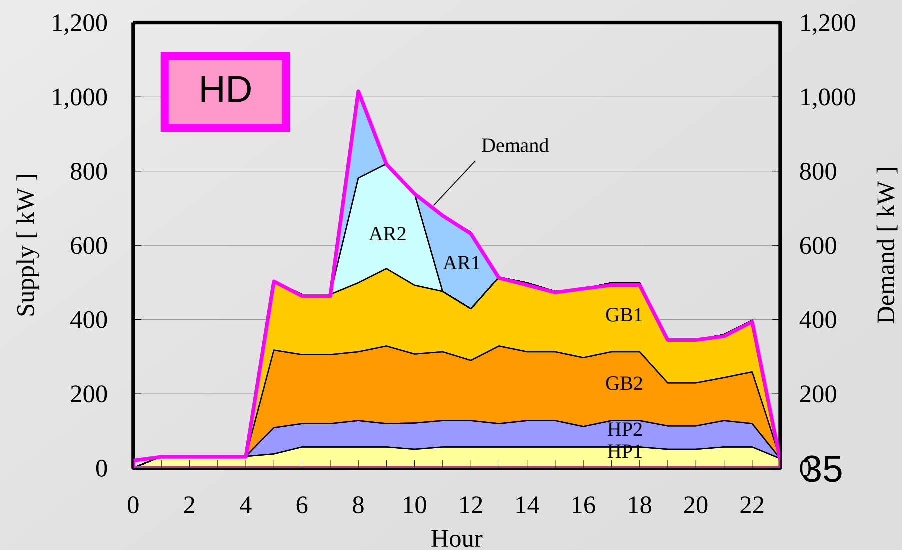
Case1: Waste Heat Available





Case2: Waste Heat NOT Available

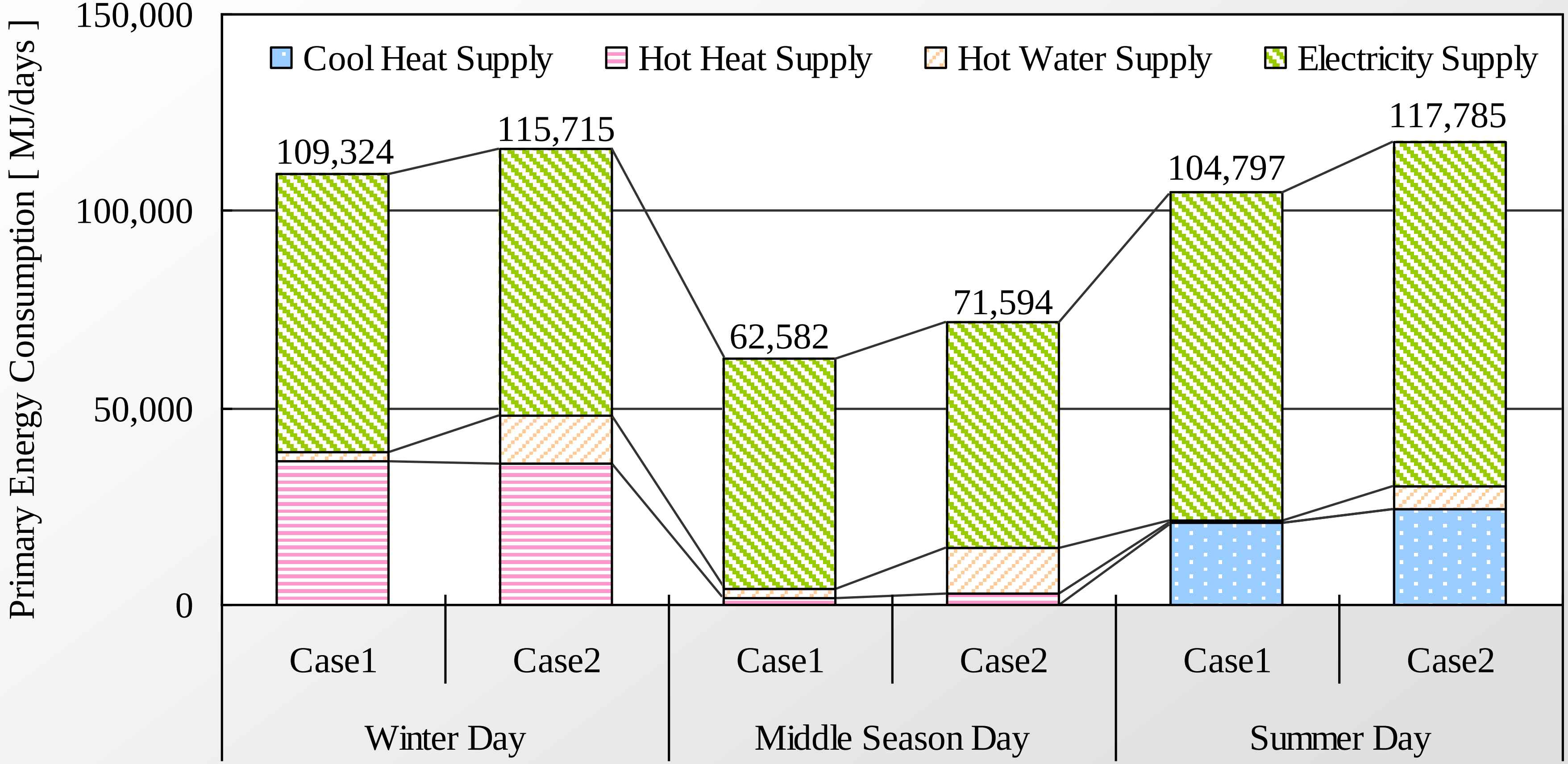




Primary Energy Consumption

Case1: Waste Heat Available

Case2: Waste Heat NOT Available



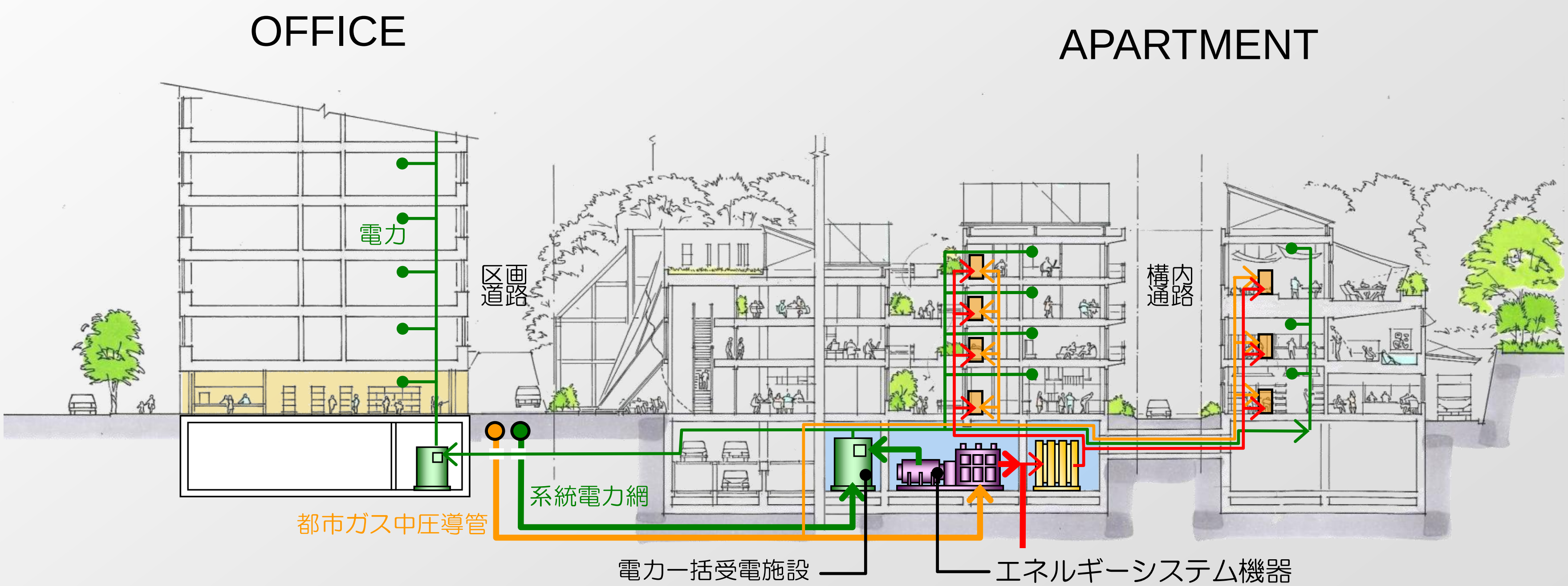
Waste Heat Available | Waste Heat NOT Available | Waste Heat Available | Waste Heat NOT Available | Waste Heat Available | Waste Heat NOT Available

Contents of This Presentation

- Development of Optimal Design Method for Building Energy System Using Genetic Algorithms
- Optimal Design for Distributed Energy System utilizing Waste Heat from CGS by Genetic Algorithms.
- Optimization Energy System of Building Complex (composed of office and apartment) Using Genetic Algorithms

Case Study

		OFC OFFICE	APT APARTMENT
延床面積	[m^2]	15,800	33,600
最大需要（電力）	[kW]	499	340
最大需要（冷熱）	[kW]	1134	0
最大需要（温熱）	[kW]	531	143
最大需要（給湯）	[kW]	0	330

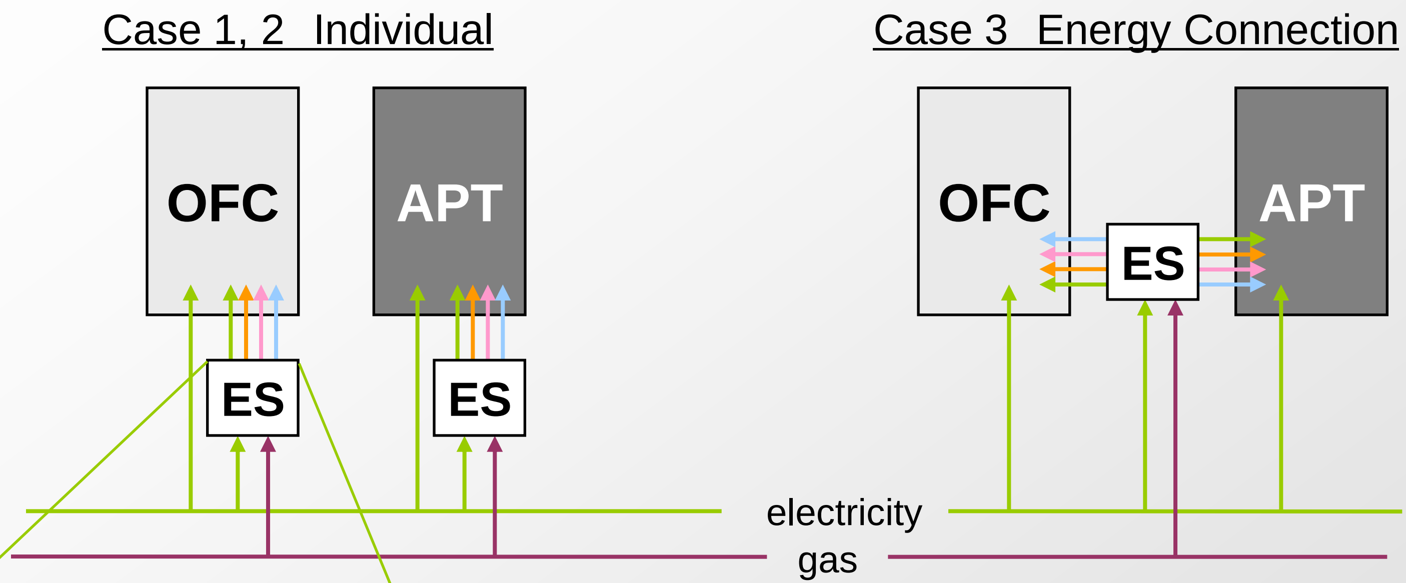


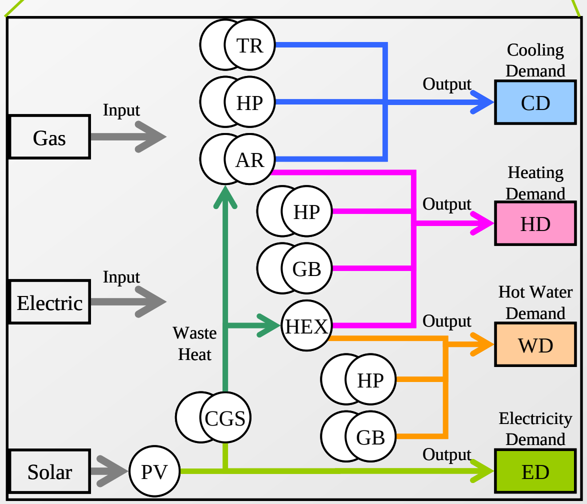
Cases

Case	Combination	Operation	Building	REMARK
Case *-0	Manual	Manual	Individual	Basecase of Individual Building
Case *-1	Manual	Optimization	Individual	Optimized only Operation
Case *-2	GA Optimization	Optimization	Individual	Optimized including CGSs
Case *-3	GA Optimization	Optimization	Individual	Optimized NOT including CGSs
Case 3-0	Manual	Manual	Connected	Basecase of Energy Connection
Case 3-2	GA Optimization	Optimization	NOT Connected	Sum up the results of Case *-2
Case 3-3	GA Optimization	Optimization	NOT Connected	Sum up the results of Case *-3
Case 3-4	GA Optimization	Optimization	Connected	Optimized Energy Connection

* : Case 1 or 2

Energy Supply Flow

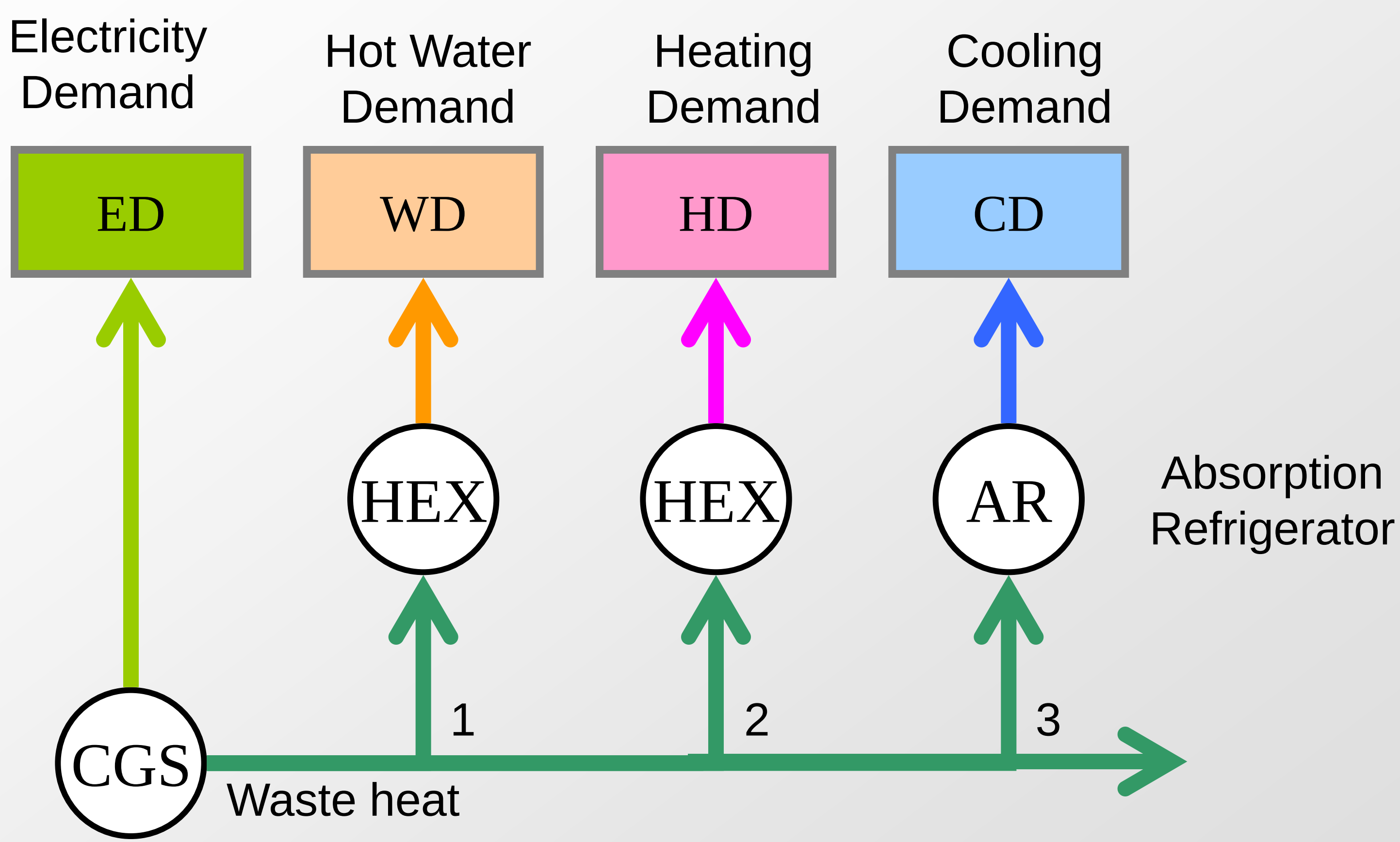




Energy System

- Transferring Heat Loss is 5%
- Each building doesn't have its own machinery in Energy Center Case

Waste heat supply



Result: Combination and Objective

		Cool heat supply				ool and H		Hot heat supply				Hot water supply				Electricity supply			OBJECTIVE			
		HP1 [HP]	HP2 [HP]	TR1 [USRT]	TR2 [USRT]	AR1 [USRT]	AR2 [USRT]	GB1 [kw]	GB2 [kw]	HP1 [HP]	HP2 [HP]	GB1 [kw]	GB2 [kw]	HP1 [HP]	HP2 [HP]	CGS1 [kw]	CGS2 [kw]	PV1 [m2]	Winter Day [MJ/day]	Middle Day [MJ/day]	Summer Day [MJ/day]	Total [MJ/3days]
Office	Case1-0	0	0	0	0	180	180	0	0	0	0	0	0	0	0	0	0	0	83,679	83,667	133,083	300,429
	Case1-1	0	0	0	0	180	180	0	0	0	0	0	0	0	0	0	0	0	86,306	80,967	120,046	287,319
	Case1-2	250	200	8	16	0	180	186	116	0	0	0	0	0	0	350	0	1,000	76,430	69,409	85,560	231,399
	Case1-3	125	250	8	13	—	—	—	—	40	10	—	—	0	0	—	—	1,000	78,172	67,607	87,226	233,005
Apartment	Case2-0	0	0	0	0	0	0	186	186	0	0	116	116	0	0	0	0	0	80,489	63,064	54,992	198,545
	Case2-1	0	0	0	0	0	0	186	186	0	0	116	116	0	0	0	0	0	79,448	61,113	52,131	192,692
	Case2-2	0	0	0	0	0	0	0	0	32	16	186	58	32	25	0	0	1,000	72,000	55,653	50,231	177,884
	Case2-3	0	0	0	0	—	—	—	—	40	10	—	—	100	50	—	—	1,000	71,418	56,294	51,499	179,211
Energy Connection	Case3-0	0	0	0	0	180	180	186	186	0	0	116	116	0	0	350	350	0	143,657	131,911	148,604	424,172
	Case3-2																		148,430	125,061	135,792	409,283
	Case3-3																		149,590	123,901	138,725	412,216
	Case3-4	0	320	32	10	0	200	232	291	32	32	58	0	13	8	0	350	1,000	139,648	109,787	129,598	379,034

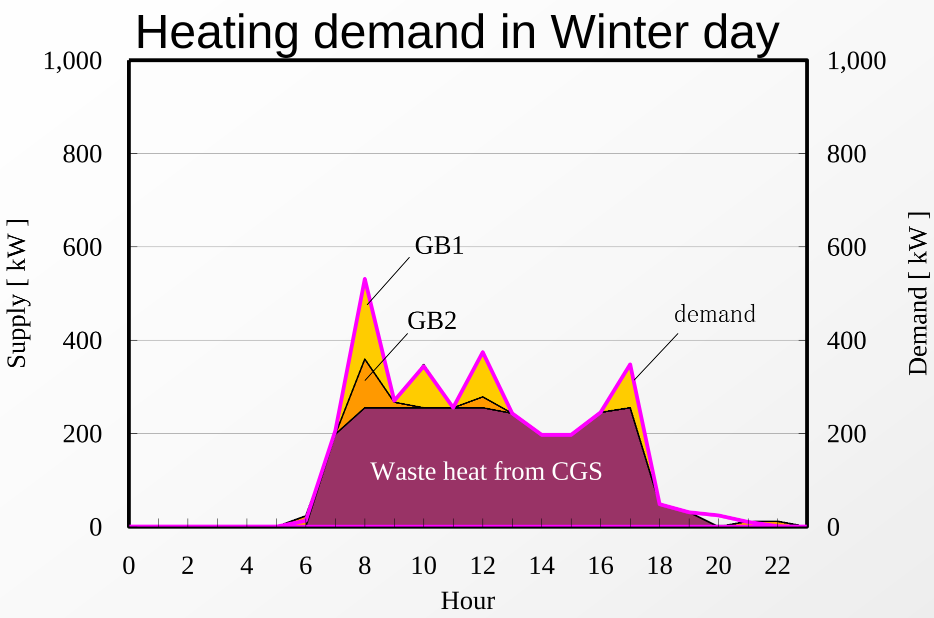
OFFICE Cases (Individual)

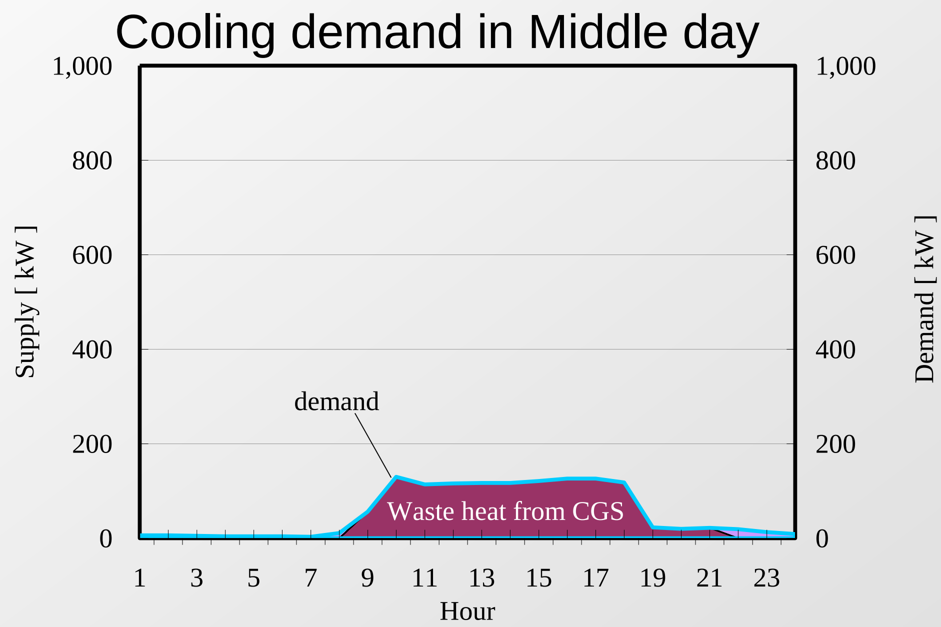
Case1-2: GA Optimization

Cool heat supply				Cool and Hot		Hot heat supply				Hot water supply				Electricity supply		
TR1	TR2	HP1	HP2	AR1	AR2	GB1	GB2	HP1	HP2	GB1	GB2	HP1	HP2	CGS1	CGS2	PV1
[USRT]	[USRT]	[HP]	[HP]	[USRT]	[USRT]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[m2]
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	125	8	8	30	30	58	58	8	8	58	58	8	8	115	115	50
150	150	10	10	40	40	87	87	10	10	87	87	10	10	200	200	100
200	200	13	13	50	50	116	116	13	13	116	116	13	13	230	230	150
215	215	16	16	100	100	151	151	16	16	151	151	16	16	300	300	200
250	250	20	20	120	120	186	186	20	20	186	186	20	20	350	350	500
300	300	25	25	180	180	232	232	25	25	232	232	25	25	480	480	750
320	320	32	32	200	200	291	291	32	32	291	291	32	32	600	600	1,000

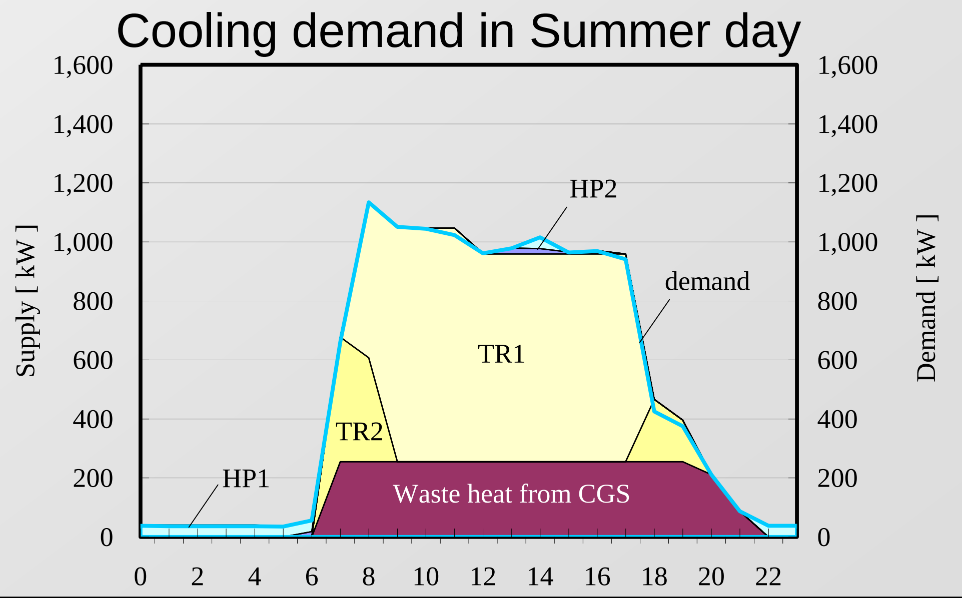
Case1-0, 1-1（Combination by Manual）

Operation; OFFICE（Case1-2: GA optimization）





- Base load is supplied by waste heat in each season
- All of Cool heat demand is supplied by waste heat in Middle season
- TRs supply cool heat for daytime peak



OFFICE (no CGS Case)

Case1-3: GA optimization

Cool heat supply				Cool and Hot		Hot heat supply				Hot water supply				Electricity supply		
TR1	TR2	HP1	HP2	AR1	AR2	GB1	GB2	HP1	HP2	GB1	GB2	HP1	HP2	CGS1	CGS2	PV1
[USRT]	[USRT]	[HP]	[HP]	[USRT]	[USRT]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[m2]
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	125	8	8	30	30	58	58	8	8	58	58	8	8	115	115	50
150	150	10	10	40	40	87	87	10	10	87	87	10	10	200	200	100
200	200	13	13	50	50	116	116	13	13	116	116	13	13	230	230	150
215	215	16	16	100	100	151	151	16	16	151	151	16	16	300	300	200
250	250	20	20	120	120	186	186	20	20	186	186	20	20	350	350	500
300	300	25	25	180	180	232	232	25	25	232	232	25	25	480	480	750
320	320	32	32	200	200	291	291	32	32	291	291	32	32	600	600	1,000
		40	40					40	40			40	40			
		50	50					50	50			50	50			
		64	64					64	64			64	64			
		100	100					100	100			100	100			

Case1-2

APARTMENT Case (Individual)

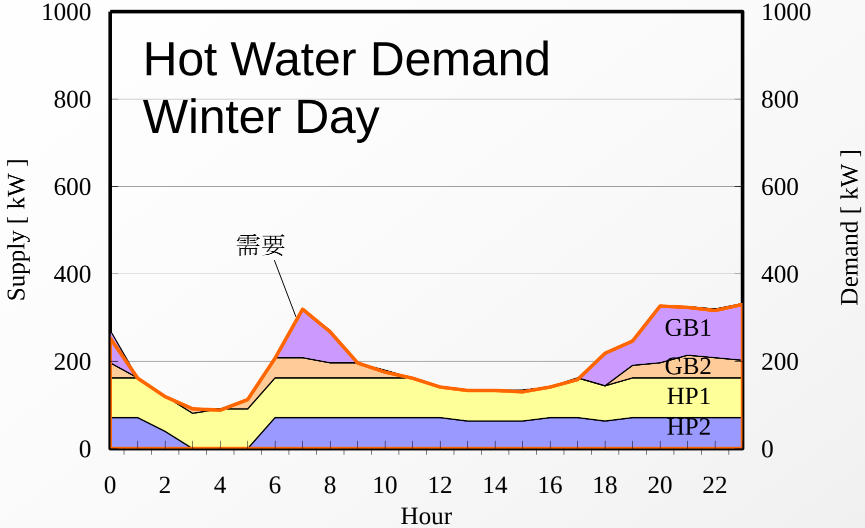
Case2-2: GA optimization

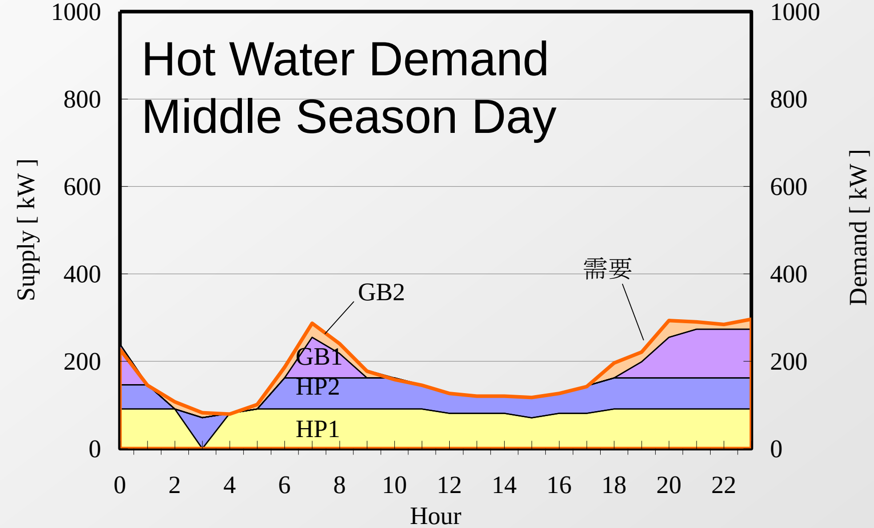
Cool heat supply				Cool and Hot		Hot heat supply				Hot water supply				Electricity supply		
TR1	TR2	HP1	HP2	AR1	AR2	GB1	GB2	HP1	HP2	GB1	GB2	HP1	HP2	CGS1	CGS2	PV1
[USRT]	[USRT]	[HP]	[HP]	[USRT]	[USRT]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[m2]
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	125	8	8	30	30	58	58	8	8	58	58	8	8	115	115	50
150	150	10	10	40	40	87	87	10	10	87	87	10	10	200	200	100
200	200	13	13	50	50	116	116	13	13	116	116	13	13	230	230	150
215	215	16	16	100	100	151	151	16	16	151	151	16	16	300	300	200
250	250	20	20	120	120	186	186	20	20	186	186	20	20	350	350	500
300	300	25	25	180	180	232	232	25	25	232	232	25	25	480	480	750
320	320	32	32	200	200	291	291	32	32	291	291	32	32	600	600	1,000

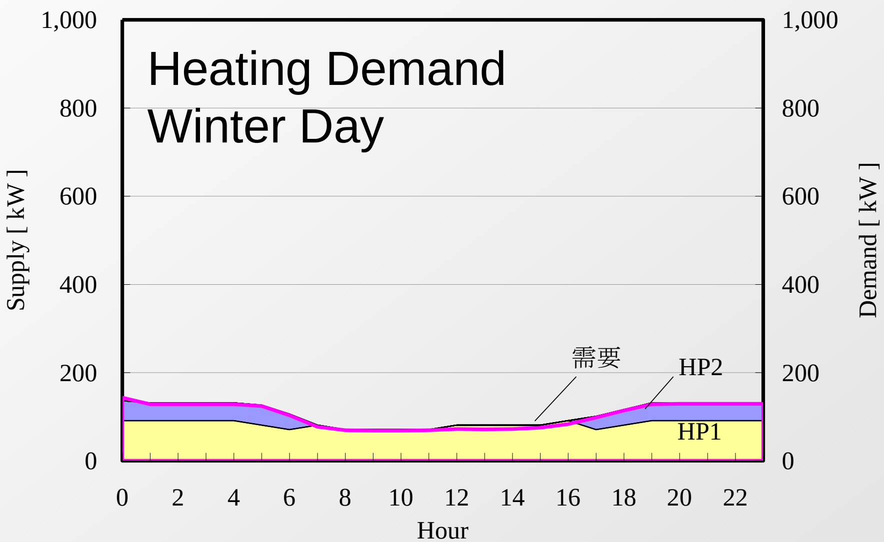
Case2-0, 2-1（Combination by Manual）

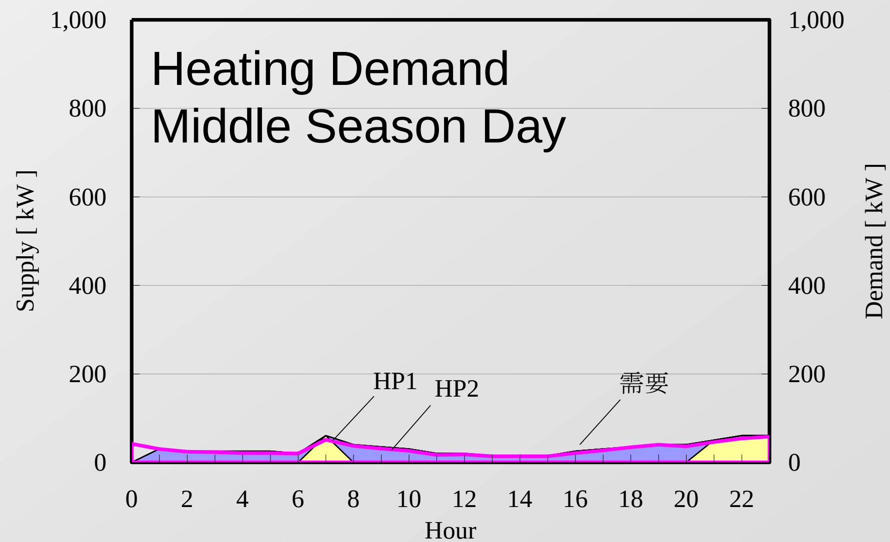
•Because of small demand, CGS is not selected. (Efficiency of Small CGS is lower than Large CGS)

Operation; APARTMENT（Case2-2 : GA optimization ）









- Base load is supplied by HPs in Hot water demand

APARTMENT (no CGS Case)

Case2-3: GA optimization

Cool heat supply				Cool and Hot		Hot heat supply				Hot water supply				Electricity supply		
TR1	TR2	HP1	HP2	AR1	AR2	GB1	GB2	HP1	HP2	GB1	GB2	HP1	HP2	CGS1	CGS2	PV1
[USRT]	[USRT]	[HP]	[HP]	[USRT]	[USRT]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[m2]
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	125	8	8	30	30	58	58	8	8	58	58	8	8	115	115	50
150	150	10	10	40	40	87	87	10	10	87	87	10	10	200	200	100
200	200	13	13	50	50	116	116	13	13	116	116	13	13	230	230	150
215	215	16	16	100	100	151	151	16	16	151	151	16	16	300	300	200
250	250	20	20	120	120	186	186	20	20	186	186	20	20	350	350	500
300	300	25	25	180	180	232	232	25	25	232	232	25	25	480	480	750
320	320	32	32	200	200	291	291	32	32	291	291	32	32	600	600	1,000
		40	40					40	40			40	40			
		50	50					50	50			50	50			
		64	64					64	64			64	64			
		100	100					100	100			100	100			

Case2-2

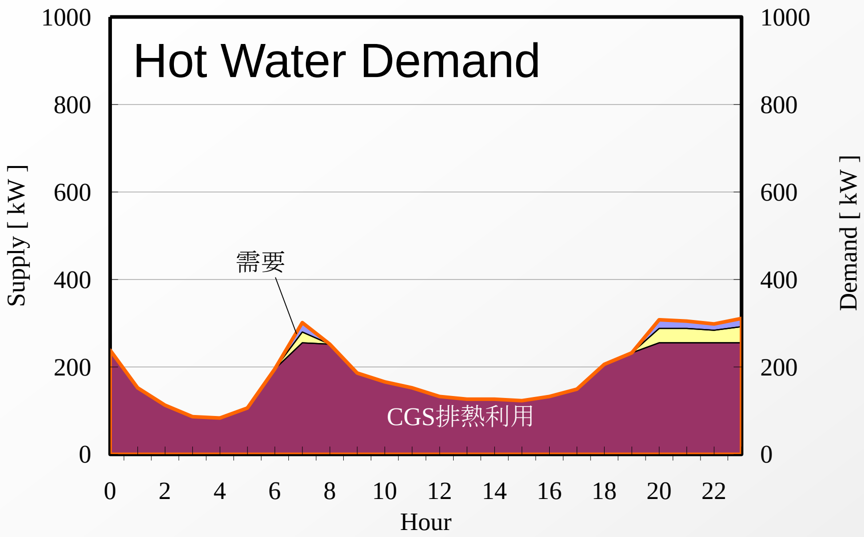
Energy Connection Case

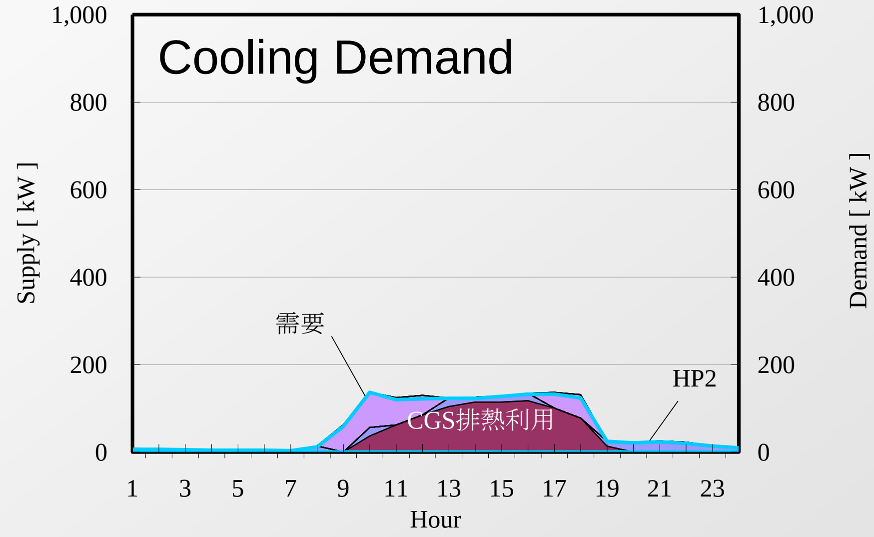
Case3-4

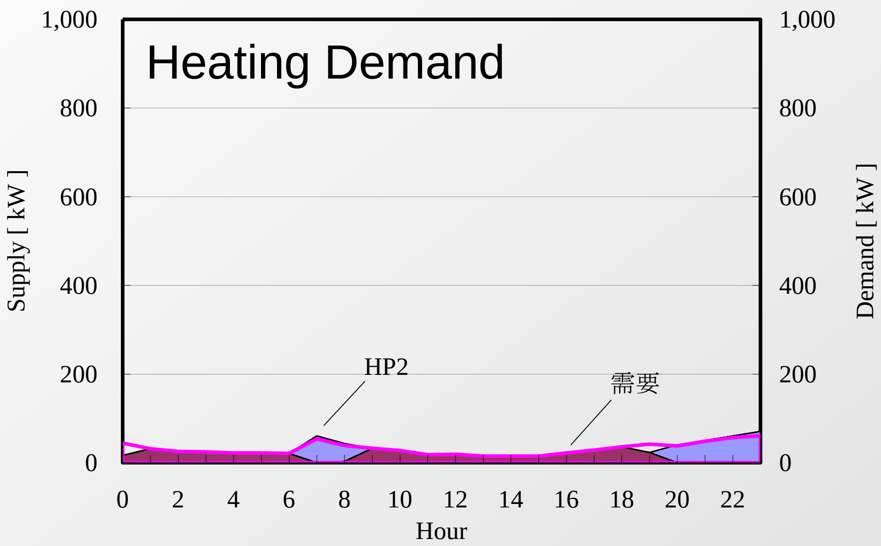
Cool heat supply				Cool and Hot		Hot heat supply				Hot water supply				Electricity supply		
TR1	TR2	HP1	HP2	AR1	AR2	GB1	GB2	HP1	HP2	GB1	GB2	HP1	HP2	CGS1	CGS2	PV1
[USRT]	[USRT]	[HP]	[HP]	[USRT]	[USRT]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[HP]	[HP]	[kw]	[kw]	[m2]
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	125	8	8	30	30	58	58	8	8	58	58	8	8	115	115	50
150	150	10	10	40	40	87	87	10	10	87	87	10	10	200	200	100
200	200	13	13	50	50	116	116	13	13	116	116	13	13	230	230	150
215	215	16	16	100	100	151	151	16	16	151	151	16	16	300	300	200
250	250	20	20	120	120	186	186	20	20	186	186	20	20	350	350	500
300	300	25	25	180	180	232	232	25	25	232	232	25	25	480	480	750
320	320	32	32	200	200	291	291	32	32	291	291	32	32	600	600	1,000

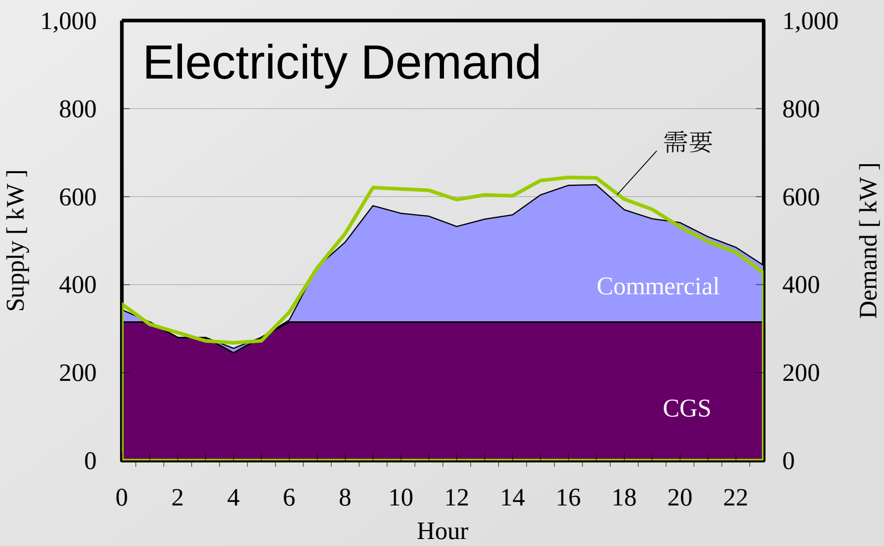
Case3-0

Operation in Middle Season Day

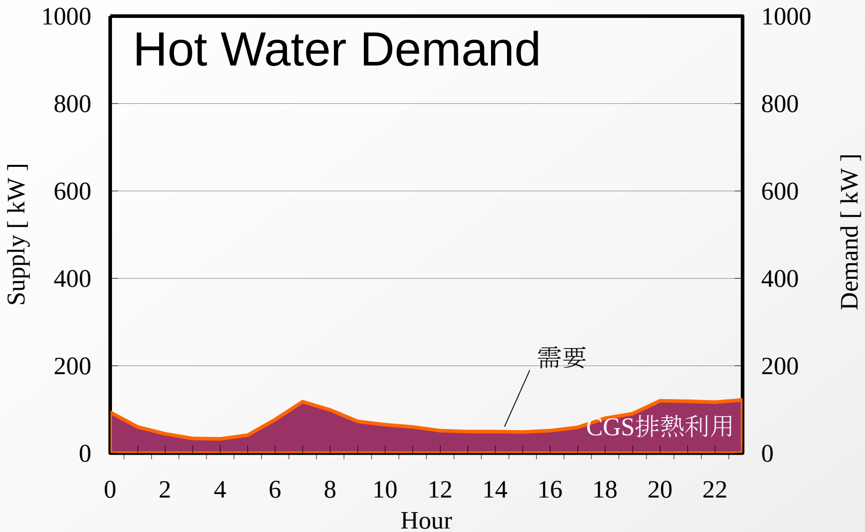


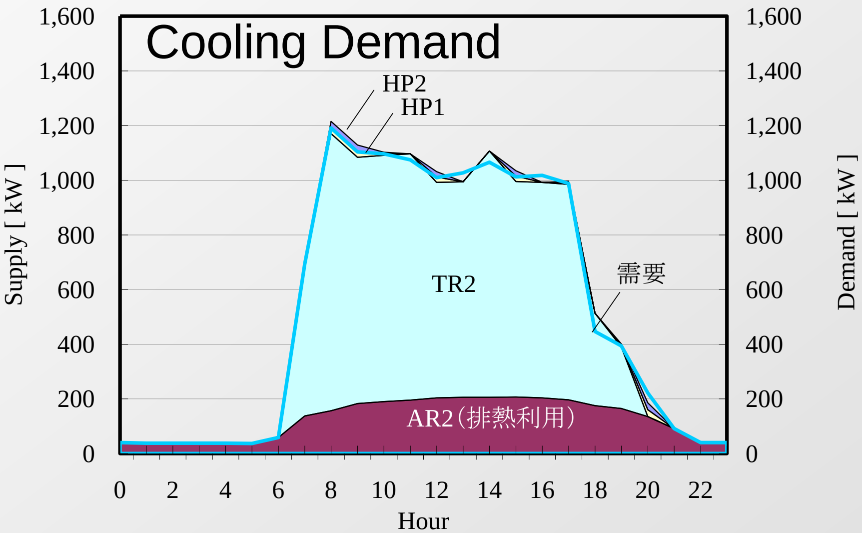




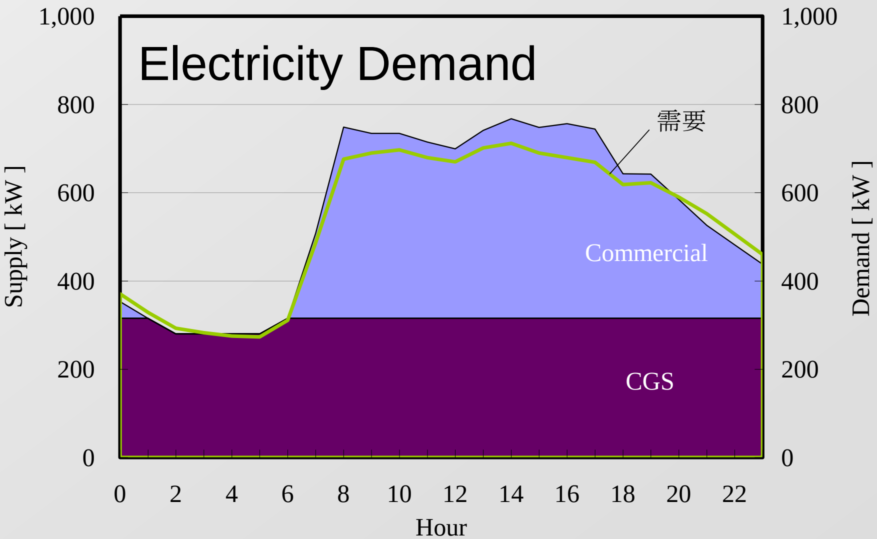


Operation in Summer Day

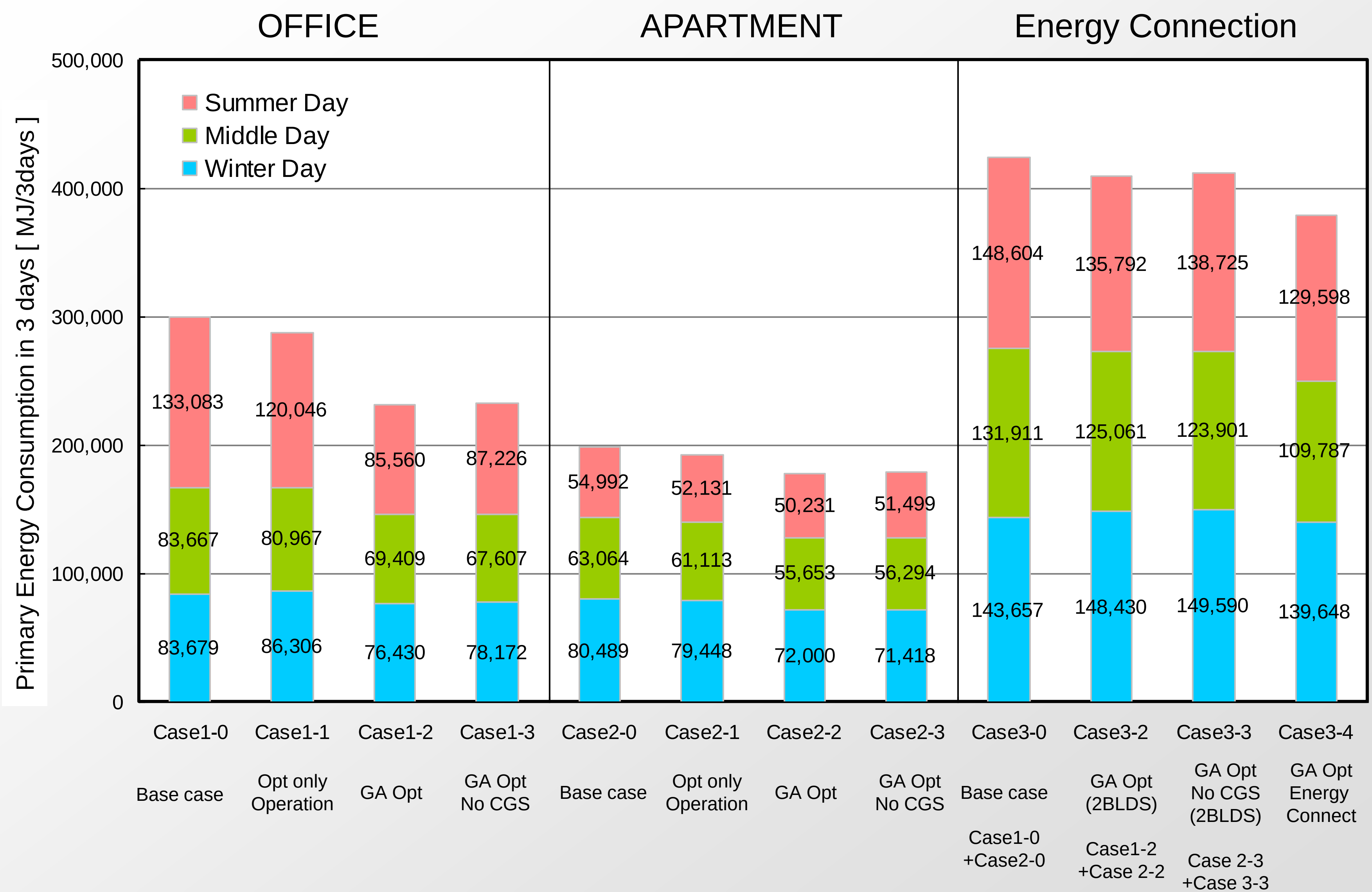




- All of Hot Water Demand is supplied with Waste heat from CGS
- Base load of Cool Heat Demand is supplied by Waste heat demand
- About 40% of peak load is supplied by CGS in Electricity Demand



Primary Energy Consumption



CONCLUSIONS

(1) New Optimal Design Method for Building Energy System which optimizes system type, its capacity and its operation planning simultaneously, has been proposed.

(2) Using the above method, the optimum system and operation planning for CGS are selected and the energy efficiency of this system is confirmed.

(3) Toward adapting the design method for practical use, evaluation of optimal combination considering economical factor is needed, for example, using Multi-Objective Genetic Algorithm (MOGA).

Thank you for your attention!

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