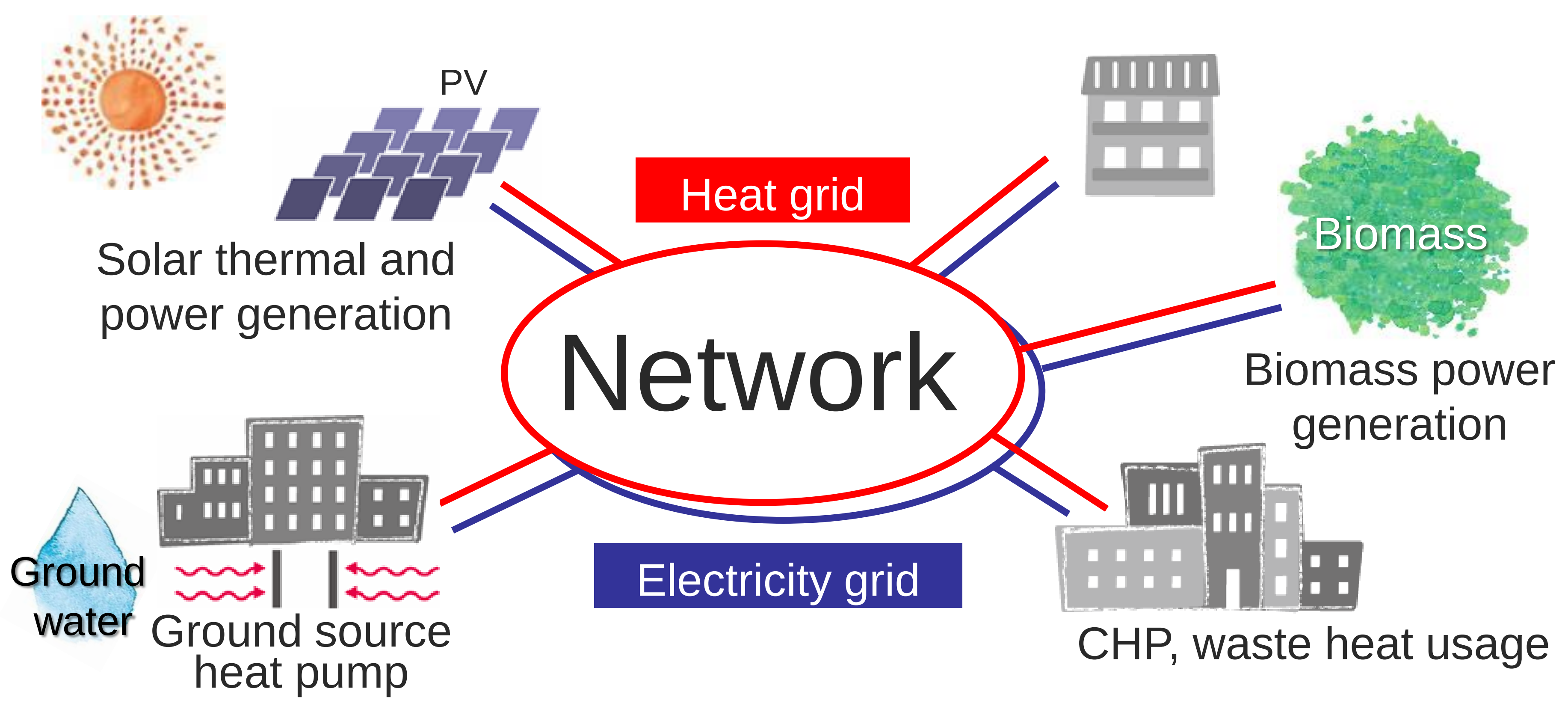
Development of planning optimization method for distributed energy system using GA

Objectives

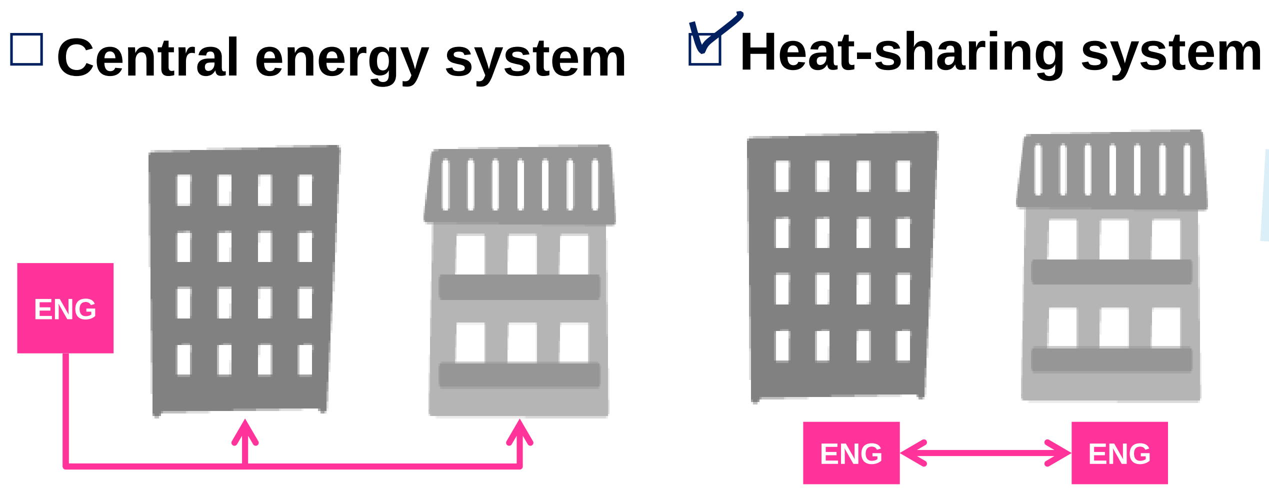
Distributed energy system



This concept promote to introduce renewable energy in districts.

Ex) Hachinohe city, Kita-kyushu city and so on.

Although this concept could improve the efficiency and resilience of the city, it is not easy to decide an optimal solution. Thus, a optimization method is significant.



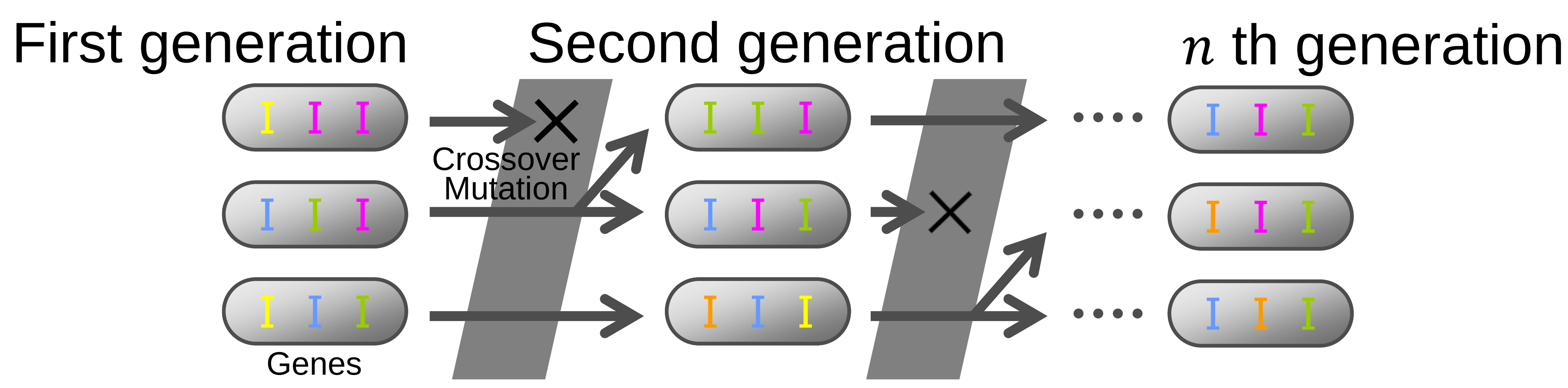
- Many combinations of machines
- Complex heat balances
- Many combinations of operating schedules
- Hard to plan an optimal system
- Evaluation of a suggested plan is not easy
- Nonlinear characteristics

Key factor is an optimization method

Genetic algorithm

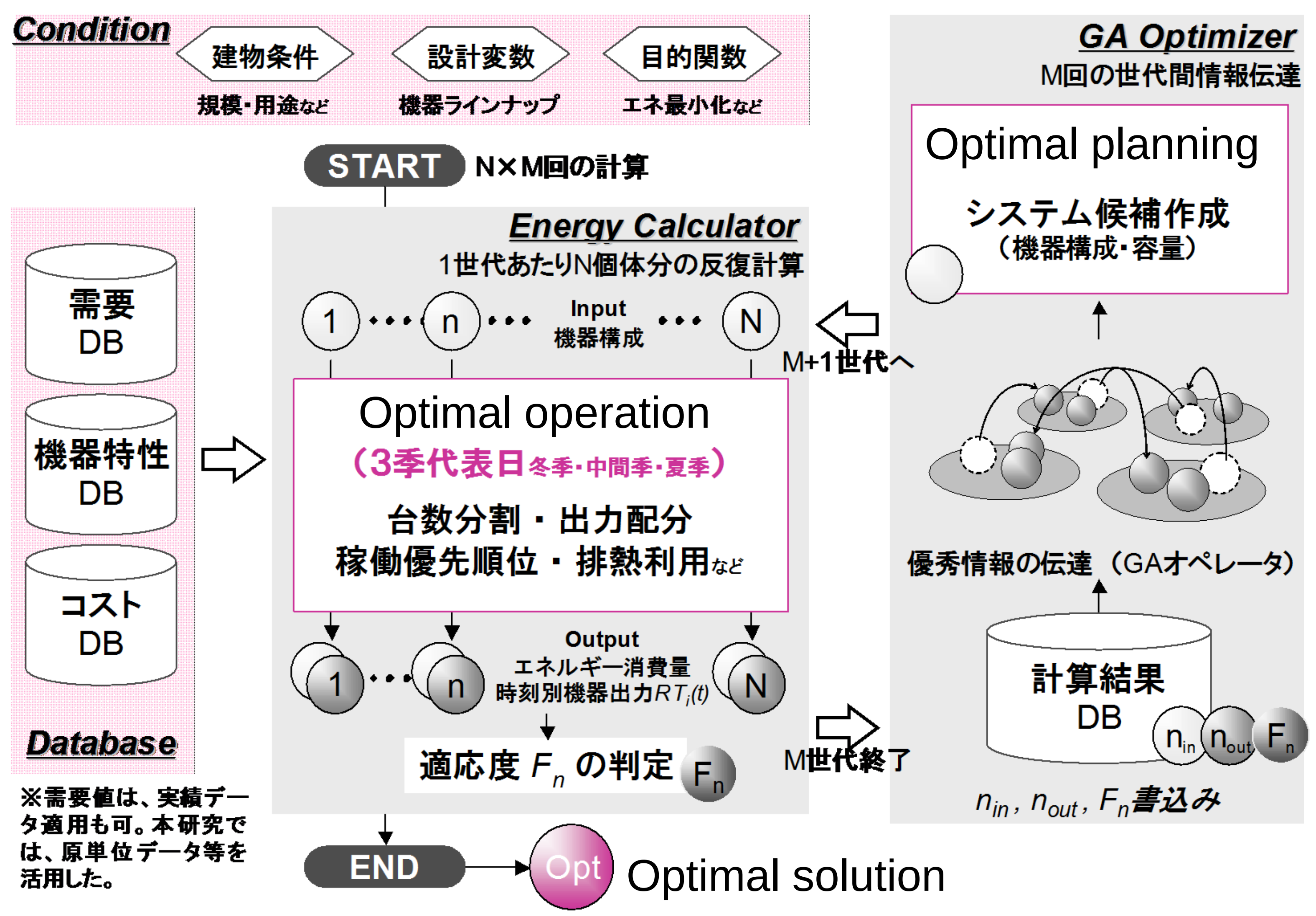
Genetic algorithm (GA)

This algorithm mimics animals behavers and evolution to find a better solution



- This method is the best for finding a better solution when there are many combinations.
- Nonlinear configuration is one of the suitable condition when using GA.

Conceptual diagram of optimization method



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Multi-objective optimization of energy consumption and saving costs

We developed an optimization method (objective function is primary energy consumption)

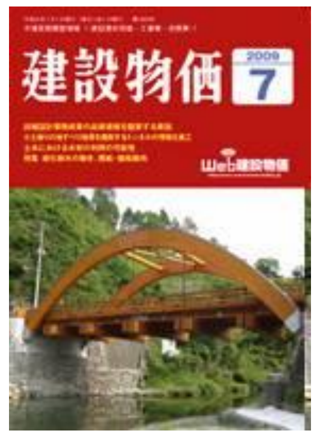
Initial costs

Machine prices

- Catalogue[A)]
- Questionnaire
- Making regression models

Introducing costs

- Catalogue[B)]
- Making regression models



A

B

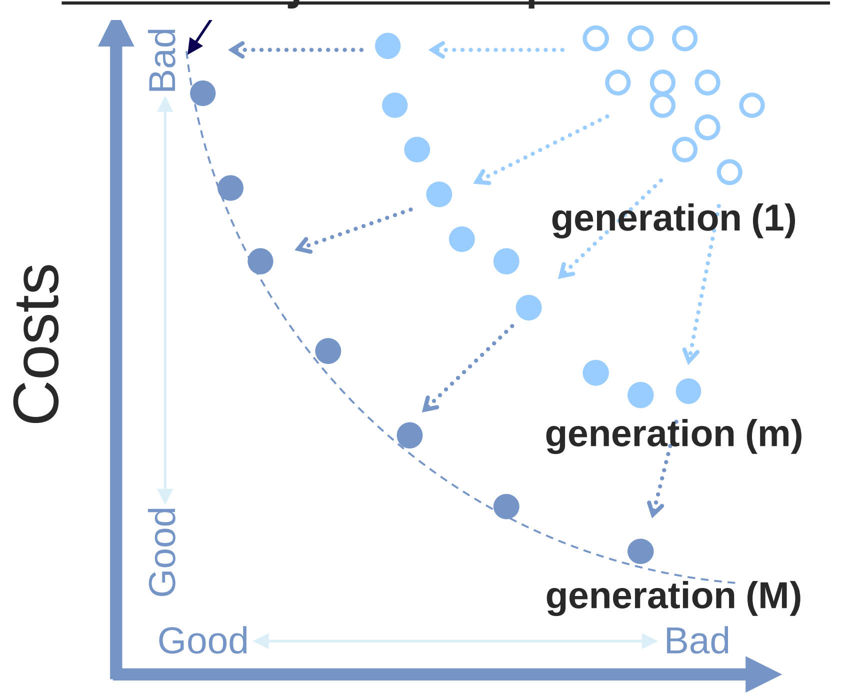
参考資料）
A) (財)建設物価調査会;月刊建設物価(平成19年7月)
B) 全日出版社;機械設備工事積算実務マニュアル(平成19年度版)

Running and maintenance costs

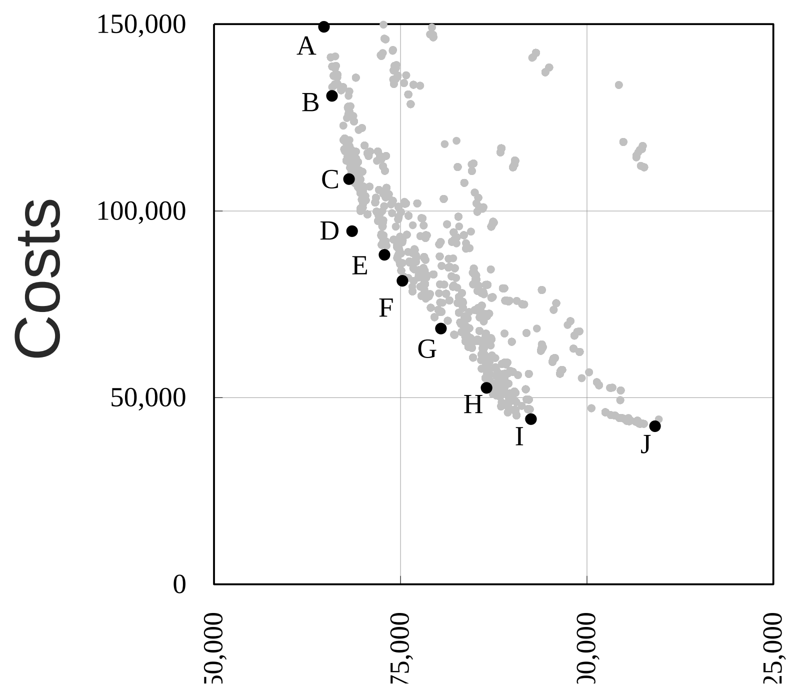
$$Cost_{run} = Cost_{gas} + Cost_{electrisity} \times 30_{[days/\,month]} \times 4_{[months/\,year]} \times 15_{[years]}$$

Case study: Hospital with 6,000m^2 of total floor space
Objective function:
1) primary energy consumption
2) Initial and running costs

Multi-objective optimization



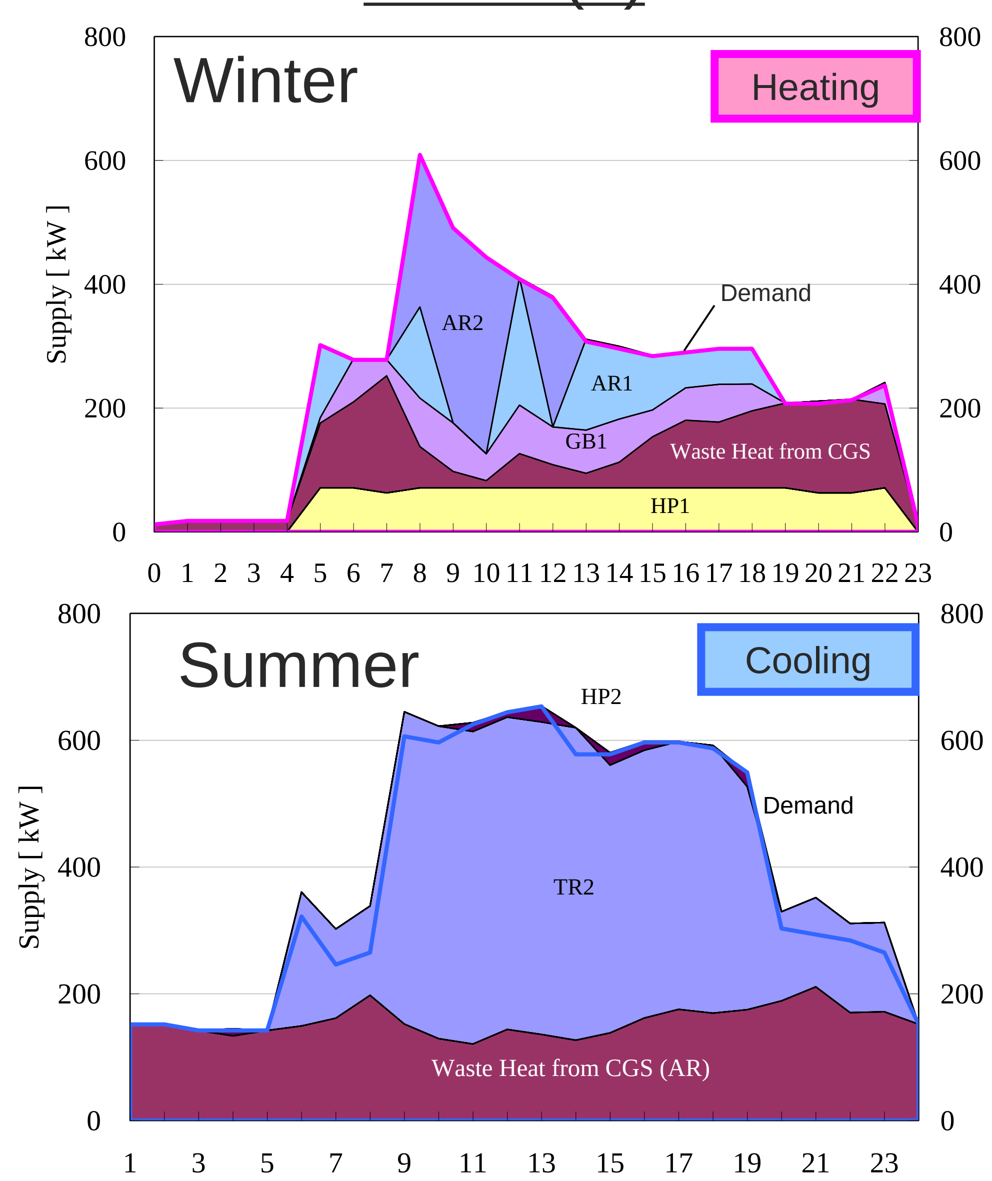
Energy usage vs. costs



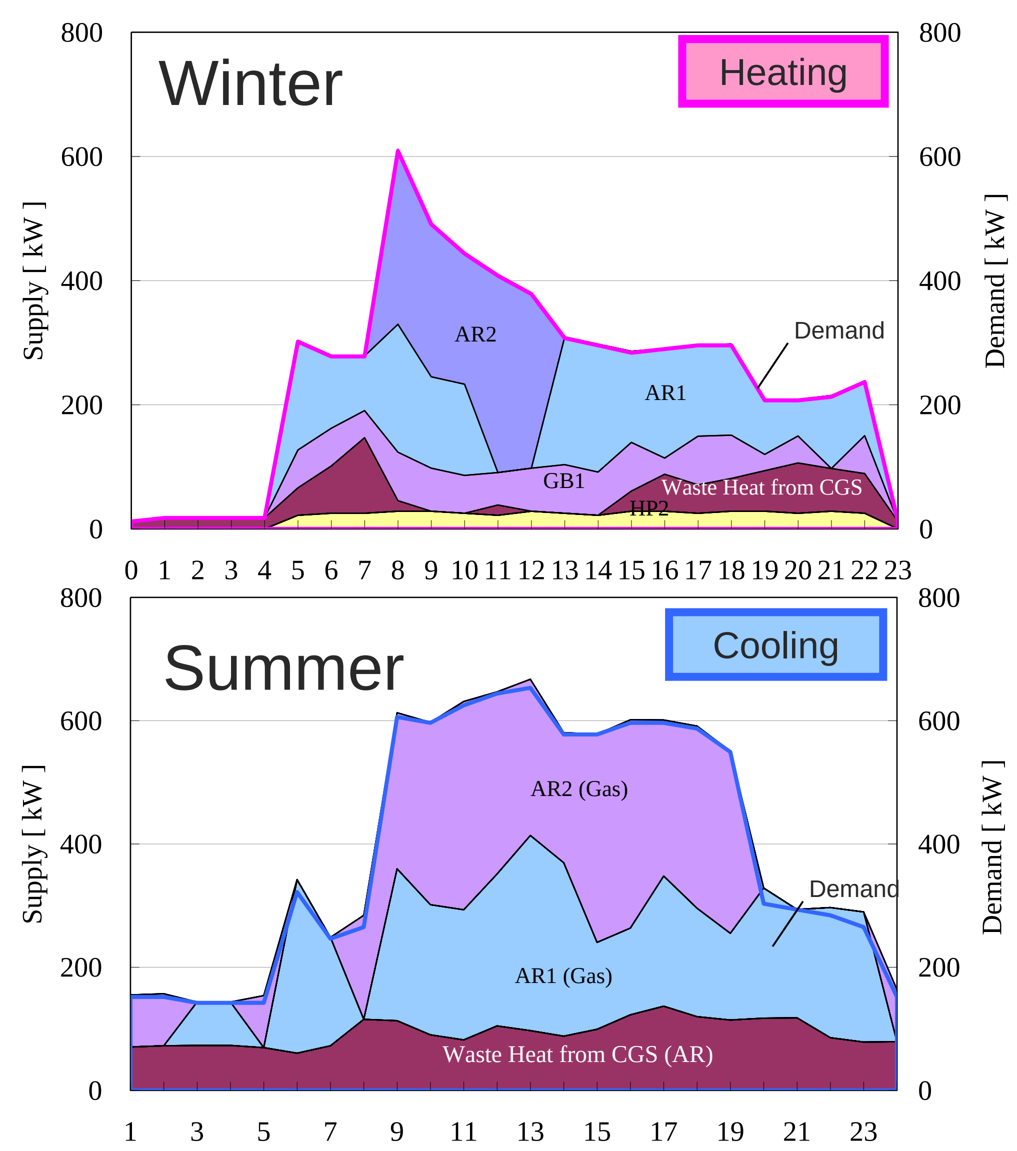
Results: capacity combination (pareto solutions)

System Candidate	Cooling TR1 [RT]	Cooling TR2 [RT]	Cooling HP1 [HP]	Cooling HP2 [HP]	Cooling/ Heating AR1 [RT]	Cooling/ Heating AR2 [RT]	Heating GB1 [kW]	Heating HP1 [HP]	Heating HP2 [HP]	Hot Water GB1 [kW]	Hot Water HP1 [HP]	Hot Water HP2 [HP]	Electricity CGS1 [kW]	Electricity CGS2 [kW]	Electricity PV1 [m^2]	Objectives Energy [MJ]	Objectives Cost [10^3Yen]	Remarks
A	0	200	10	10	120	120	87	25	25	186	10	10	300	300	500	64,754	149,254	Eenrgy minimum
B	0	150	20	0	50	120	87	32	25	186	10	10	300	300	50	65,843	130,736	
C	0	150	0	10	100	120	87	0	25	186	10	10	300	300	0	68,117	108,434	
D	125	150	20	0	50	120	87	32	25	186	10	10	300	230	500	68,548	94,516	
E	0	215	0	0	100	100	186	25	25	186	10	10	300	350	0	72,891	88,216	
F	0	200	0	10	100	120	87	25	0	232	10	10	300	350	0	75,279	81,231	
G	0	0	10	0	100	120	58	10	0	186	10	10	300	300	0	80,447	68,465	
H	0	0	16	0	100	120	87	20	10	186	10	10	300	350	0	86,552	52,554	
I	0	0	0	0	100	120	58	0	10	186	10	10	300	350	0	92,526	44,164	
J	0	0	0	0	100	120	87	0	10	186	10	10	350	350	0	109,168	42,270	Cost minimum

Result (F)



Result (J)



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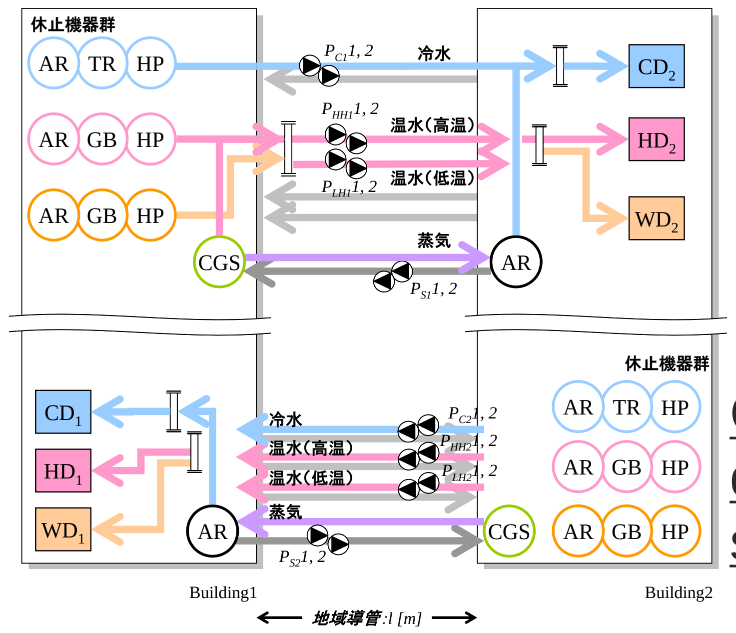
Development of planning optimization method for distributed energy system using GA

Optimal planning of heat sharing between two buildings

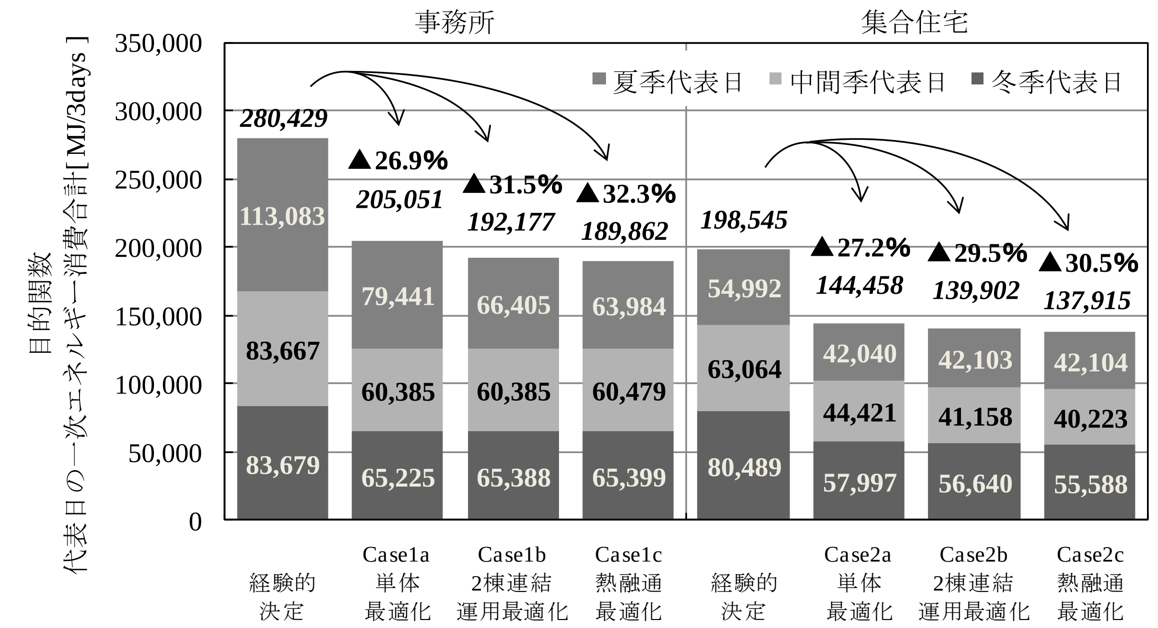
The building and machine models were improved to deal with a heat-sharing network between two buildings.

The new model considered detail functions of pipes and heat losses.



Conceptual diagram of heat-sharing

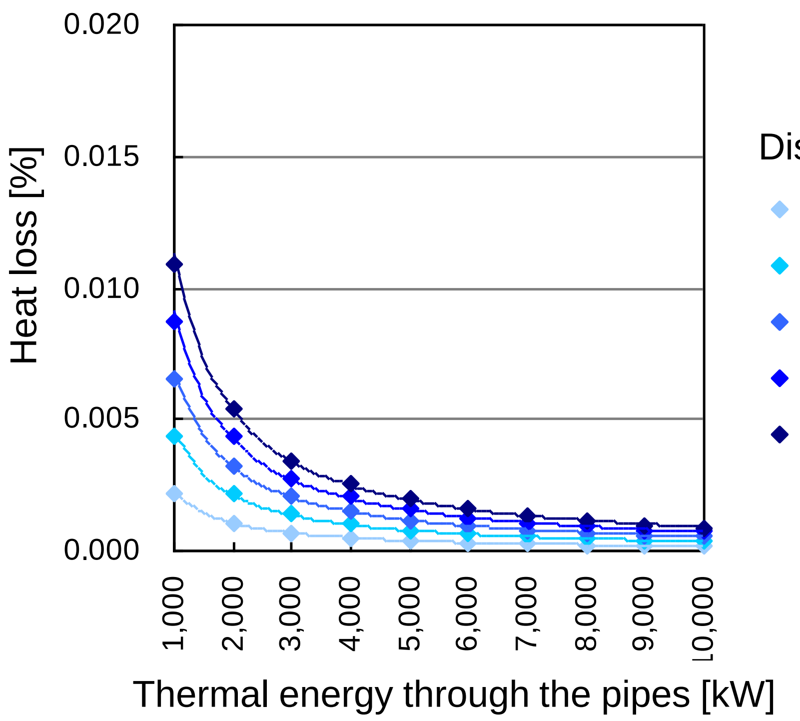
Results: primary energy consumption



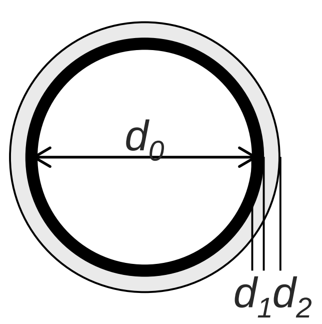
Heat losses through the pipes

- Regression model was developed
- Amount of heat loss depended on thermal output of machine.
- Heat loss: Q_{loss} [W/m]

$$Q_{loss} = \frac{2\pi\Delta T}{\frac{1}{d_o\alpha_i} + \frac{1}{\lambda_1}\cdot\ln\left(\frac{d_1}{d_0}\right) + \frac{1}{\lambda_2}\cdot\ln\left(\frac{d_2}{d_1}\right) + \frac{1}{d_2\alpha_o}}$$



Connected pipe with two buildings



Diameter: d_0 200〜400A
Thickness: d_1 25mm
Thickness of an insulation material: d_2 32mm
Temperature difference: ΔT
Δ7℃ (cooling)
Δ20℃(heating)
Δ120℃(Steam)

Regression model
20m: $y = 0.0023x^{-1.0947}$
40m: $y = 0.0045x^{-1.0947}$
60m: $y = 0.0068x^{-1.0947}$
80m: $y = 0.0091x^{-1.0947}$
100m: $y = 0.0113x^{-1.0947}$

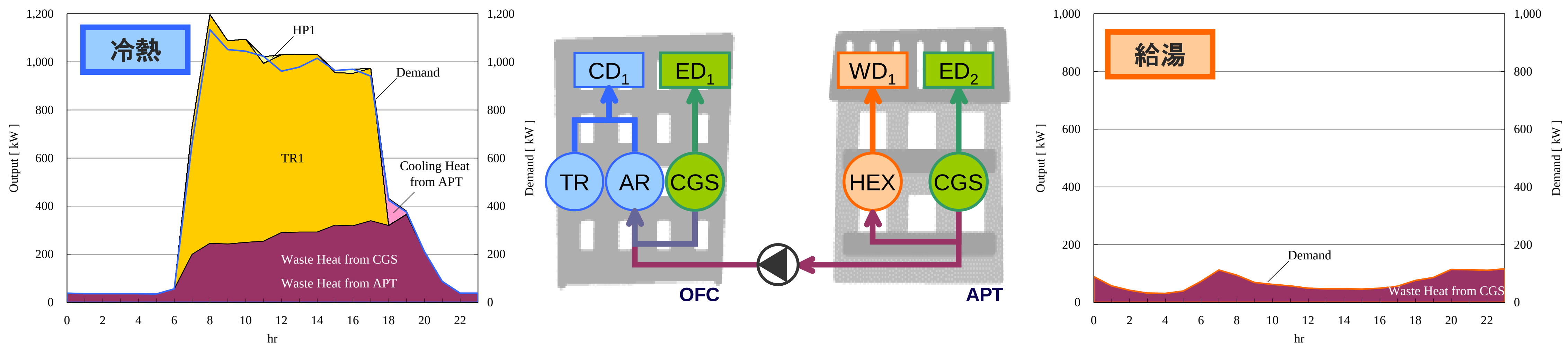
Result: optimal capacity of office building

Cooling				Cooling/ Heating		Heating				Hot Water				Electricity		
TR1	TR2	HP1	HP2	AR1	AR2	GB1	GB2	HP1	HP2	GB1	GB2	HP1	HP2	CGS1	CGS2	PV1
[RT]	[RT]	[HP]	[HP]	[RT]	[RT]	[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	***10***	10	40	40	***58***	58	10	10	58	58	10	10	115	115	50
150	150	13	13	50	***50***	87	87	13	13	87	87	13	13	200	200	100
200	200	16	16	100	***100***	116	116	16	16	116	116	16	16	230	230	250
215	215	20	20	120	120	151	151	20	20	151	151	20	20	300	300	500
250	250	25	25	***180***	180	186	186	25	25	186	186	25	25	***350***	350	750
300	300	***32***	32	250	250	232	232	***32***	32	232	232	32	32	480	480	***1,000***

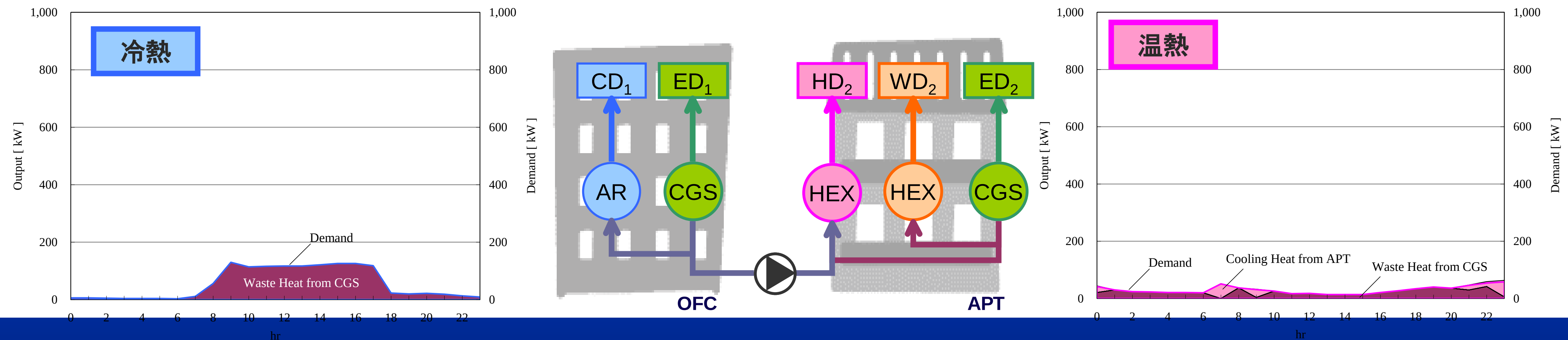
Result: optimal capacity of residential building

Cooling				Cooling/ Heating		Heating				Hot Water				Electricity		
TR1	TR2	HP1	HP2	AR1	AR2	GB1	GB2	HP1	HP2	GB1	GB2	HP1	HP2	CGS1	CGS2	PV1
[RT]	[RT]	[HP]	[HP]	[RT]	[RT]	[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	10	10	40	40	***58***	58	10	10	***58***	58	10	10	115	115	50
150	150	13	13	50	50	***87***	87	13	13	87	87	13	***13***	200	200	100
200	200	16	16	100	100	116	116	16	16	116	***116***	16	16	230	230	250
215	215	20	20	120	120	151	151	20	20	151	151	20	20	300	300	500
250	250	25	25	180	180	186	186	***25***	25	***186***	186	25	25	***350***	350	750
300	300	32	32	250	250	232	232	***32***	32	232	232	***32***	***32***	480	480	***1,000***

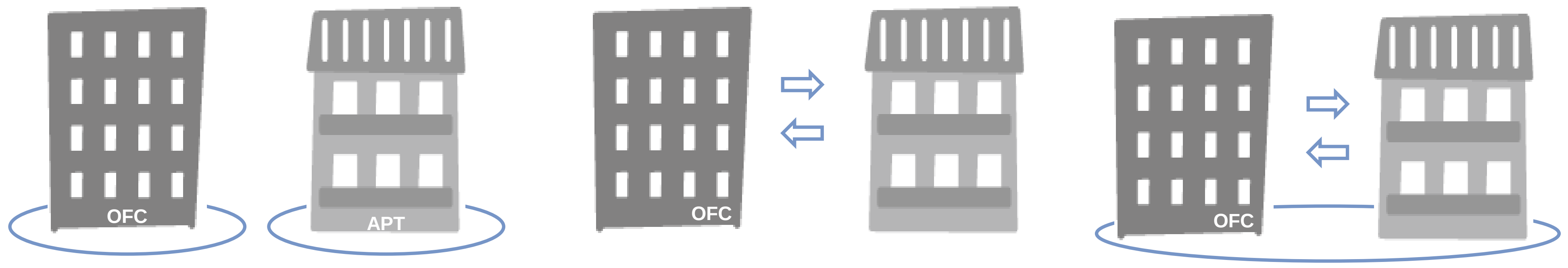
Optimal operation in Summer



Optimal operation in intermediate season



Case studies: office and residential building



Without heat-sharing

Connected buildings

Heat-sharing

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