An optimum design method utilizing a strategic system design concept

— Reduction of CO_2 emissions at a datacenter by reusing emitted heat for agriculture —

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Datacenters are important infrastructures of information and communication technology (ICT). Reducing electric-power consumption and the CO_2 emissions at the centers are urgent issues from the viewpoint of global environmental concerns. Improvement of efficiency within a single datacenter, however, cannot assure significant reduction of CO_2 emissions. Hence we propose the concept of "strategic system design", which optimizes system design by combining different stake-holders not only from the viewpoint of the "physical system" but also from that of the "value system". As an example, a system in which greenhouse cultivation farms reuse emitted heat at datacenters was considered from both the physical side and the value side. The complex system designed by such a strategic system design idea was found to be effective in reducing CO_2 emissions compared with a single isolated system, and was clarified to be an excellent value system.

Keywords **:** Datacenter, global environment, system design, emitted heat, greenhouse business

1 Introduction

Information and communication technology (ICT) has greatly contributed to the reduction of CO_2 emissions through efficient energy use and conservation by avoiding redundancy in economic activities and by enabling efficient transportation and its alternatives. However, power consumption in offices and homes is increasing due to the wide uptake of ICT, and as a result, it has become one of the main factors that push up CO_2 emissions in Japan. If this increase continues, ICT power consumption in 2025 will be 5.2 times more than 2006, dominating 25 % of the total power generated in Japan[Note 1]. The reduction of power consumption in the ICT field is a major issue.

Particularly, datacenters equipped with multiple servers consume a large amount of electric power, and power consumption increases every year. From the perspective of preventing global warming, energy consumption and reduction of CO_2 emissions are becoming major issues. Therefore, the Japanese datacenter industry is working to introduce efficient servers, air conditioners, and power supply facilities. However, the potential of efforts to increase energy efficiency for a single datacenter alone is limited, and a design approach that looks at the essence of the issue is in demand.

Therefore, as a new design approach, we propose the "strategic system design" in which the systems of multiple companies are combined. As an example of the strategic system design, we shall explain that a composite system, in which low-temperature waste heat from a datacenter is reused in greenhouse farming, is an effective use of energy that is also economically feasible.

2 Limit in achieving efficiency by a single datacenter

The energy flow and energy consumption configuration in a typical datacenter is shown in Fig. 1 and Table 1. The model considered here is a datacenter with maximum capacity of 1,000 racks (actual operation rate 85 %) and maximum power supply at 6 kW/rack (average 4.2 kW/rack). When the power consumption of the entire datacenter is simulated, and the simulated figure is multiplied with an emission coefficient published by electricity companies[Note 2], the CO_2 emissions are as shown in Table 2.

One of the effective methods for improving energy efficiency, when considering power consumption of air conditionings at the datacenter, is to raise the air conditioning efficiency by constructing the datacenter in a cold climate area. For example, comparing Sapporo and Tokyo where there are

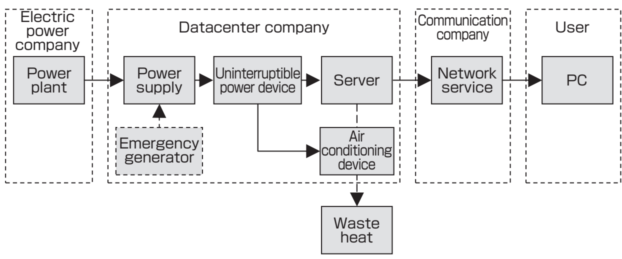

Fig. 1 Energy flow of the datacenter

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many datacenters, there is a temperature difference of about 5~10 °C per year[Note 3]. It is projected that the power consumption of air conditioning can be reduced about 8 % by constructing the datacenter in cold climate areas such as Sapporo (Table 2). Conversely, the power consumption of air conditioning increases about 8 % in warm areas such as Naha. However, since the power consumption of air conditioning is about 30 % of the total power consumption of a datacenter, only about 2 % total reduction can be expected between Tokyo and Sapporo (Table 2).

Another method for improving air conditioning efficiency is a method called "capping" where the racks are surrounded by panels to prevent the mixing of waste heat from servers and cold air from air conditioners (Fig. 2)[Note 4]. While this allows reduction of about 20 % of the power consumption of air conditioning, it is projected that the reduction will be about 5 % of the total power consumption of the datacenter (Table 2).

As it can be seen, there are limitations in achieving energy consumption efficiency for a single stand-alone datacenter, and a radical technological innovation or some new design approach is necessary to achieve significant CO_2 reduction.

3 Proposal of the strategic system design

3.1 Physical system and value system

We propose a new design approach through "strategic system design", a concept that transcends the conventional approach to optimizing stand-alone datacenters (a single system).

Figure 3 shows the concept of the strategic system design. In conventional system design, evaluation and optimization were conducted from the perspective mainly of physical performance of a single system. However, a system has a stakeholder who has a vested interest in that system, and therefore, evaluation of a system is based on what is valuable for the stakeholder. The value is dependent on the psychological values of the stakeholder, and while monetary matter is not the only concern, using the monetary scale allows generalization and quantification.

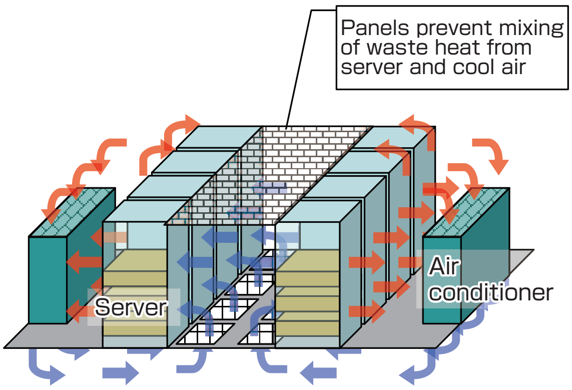

Fig. 2 Example in achieving efficiency of air conditioner by capping

Table 1 Details of energy consumption at the datacenter

Power consumption of server	58 %
Power consumption of air conditioner	27 %
Power supply facility, uninterruptible power supply	13 %
Lighting etc.	2 %

Table 2 Location of the datacenter and CO_2 emission

	Tokyo	Sapporo	Naha	Tokyo Aisle capping	Sapporo Aisle capping
Power consumption of air conditioner (MWh/year)	15,599	14,393	16,810	12,479	11,514
	100.0 %	92.3 %	107.8 %	80.0 %	73.8 %
Power consumption of entire datacenter (MWh/year)	57,817	56,611	59,029	54,697	53,733
	100.0 %	97.9 %	102.1 %	94.6 %	92.9 %
PUE*1	1.72	1.69	1.76	1.63	1.60
Power cost (million yen/year)	694	679	708	656	644
	100.0 %	97.8 %	102.0 %	94.5 %	92.8 %
CO_2 emission coefficient*2 kg-CO_2/kWh	0.339	0.479	0.934	0.339	0.479
CO_2 emission (t/year)	19,600	27,117	55,133	18,542	25,738
	100.0 %	138.4 %	281.3 %	94.6 %	131.3 %

*1 PUE (power use effectiveness) = power consumption of entire datacenter / power consumption of server.
*2 Figures for FY 2006 are according to the source from the Ministry of Environment (figures for Naha are for FY 2007).
Numbers below the dashed line are comparisons when Tokyo is set as 100 %.

The system exists in two spaces: the physical system that exists in the physical space, and the value system that exists in the psychological space of the stakeholder.

The datacenter is composed of the "physical system" including the building, power supply, air conditioner, racks, and others, and the "value system" for the company in the form of sales generated by the physical system.

In this case, the optimization of the physical system and the optimization of the value system do not necessarily coincide. In case of the datacenter, the optimization of the physical system means minimizing the power consumption, while the optimization of the value system means maximizing the profit by minimizing the cost. While the minimization of power consumption and minimization of cost run in the same direction, the two may not match. For example, the introduction of a highly efficient facility will reduce power consumption, but the cost may increase due to the high facility cost. If the value decreases, the company will not introduce the new facility even if it is highly efficient.

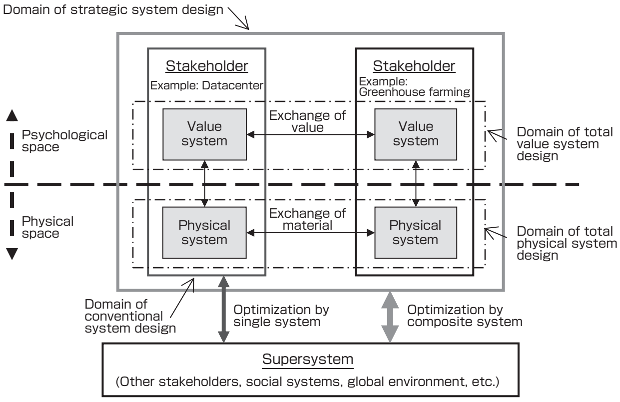

Fig. 3 Concept of strategic system design

No matter how the system is physically excellent, it cannot be realized unless it is also excellent in the value space. To realize a system, one must design the value system, which is a system that generates actual value.

3.2 System of other stakeholders and the supersystem

The actual system has mutual interaction with the systems of other stakeholders in both the physical and value systems (Fig. 4).

The system is also incorporated into the "supersystem" composed of multiple physical entities and stakeholders. The supersystem is a large physical and value system that influences the existence, performance, and value of the system including, for example, the global environment or the social system. The supersystem influences the individual systems in various ways and sets requirements. A system changes according to the other systems and the supersystem, and must optimize itself accordingly.

In the case of datacenters, the requirement is to minimize CO_2 emissions through the regulations by the social system such as public opinion or environment tax imposed for the purpose of preventing global warming.

In the conventional system design, optimization to meet this requirement was met in accordance with the perspective of a single stakeholder who possessed the system. The system was designed to maximize value for the single stakeholder, and in many cases, value for other stakeholders and the resource allotment were not taken into consideration.

For example, in the case of datacenters, attempts were made to reduce the CO_2 emissions by achieving efficiency of the devices in the datacenter only, such as optimizing air conditioning infrastructure that cools servers.

However, drastic reduction of CO_2 emissions is physically difficult with the improvement of datacenter facilities alone.

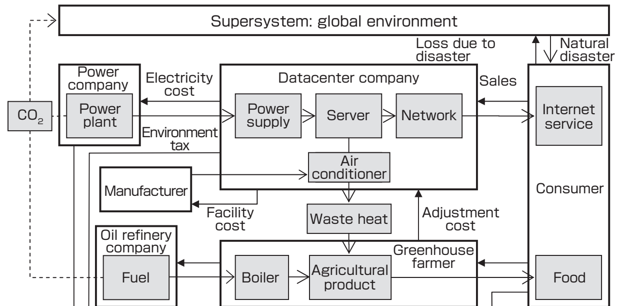

Fig. 4 Systems of other stakeholders surrounding the datacenter and the supersystem

Moreover, in the value space, it is difficult for a single company to increase its value (profit) because expensive facility investment may suppress profit margins and furthermore, environmental taxes may be imposed.

For major issues such as environmental improvement required by the supersystem, there is a limit in the optimization effort that can be handled within the system by a single stakeholder.

3.3 Design optimization using the strategic system design

On the other hand, issues required to be addressed by the supersystem are also placed on other stakeholders. Therefore, design optimization using the "strategic system design" is an attempt to optimize the requirements from the supersystem by combining the systems of multiple stakeholders, and to raise the values of all stakeholders involved.

The physical systems of the individual stakeholders exist in a common physical space. Therefore, they can be optimized as a single system as they are influenced equally by a common physical law and can be combined through physical exchange. This is the "total physical system design" (Fig. 3). Using datacenters as an example, waste heat can be reused for heating greenhouses.

The result of the optimization of a physical system may not necessarily mean optimal value for the stakeholders of different systems. For example, reusing waste heat from the datacenter may be a cost reduction to the farmer, but it will be a cost increase for the datacenter company due to the need for additional facilities. To realize the waste heat reuse system, it is necessary to design a value system that increases the values for the two stakeholders, or both the datacenter company and the farmer. This need is coined as "total value system design" (Fig. 3).

It is necessary to implement some mechanism for adjusting the value, such as a contract whereby the farmer pays the cost (adjustment cost) of using the waste heat to the datacenter company.

The "strategic system design" can be defined as the optimization by designing the "total physical system" and the "total value system" between the systems of different stakeholders.

4 Proposal for a composite datacenter through strategic system design

4.1 Total physical system design for a composite datacenter through strategic system design

To achieve optimization in response to the social requirement for the reduction of CO_2 emissions based on the concept of a strategic system design, a composite datacenter that combines the datacenter and agriculture is designed to review the effectiveness quantitatively.

First, a datacenter seen from the physical aspect is considered. Looking at the energy flow of the datacenter in Fig. 1, most of the energy is emitted from the datacenter as heat. The electricity consumed by the CPU for computation is less than 1 % of the overall energy.

A more efficient system can be proposed by combining the business and system for reusing the waste heat from the datacenter (Fig. 5). The businesses that may reuse waste heat include: cooling/heating and hot water supply in offices, residences, and hospitals; warm water supply for bath, pool, and plants; and heating for greenhouse farming. In heating for greenhouse farming, the required temperature is relatively low, the time change for heat demand is relatively stable, and the waste heat from the datacenter that serves as a low-temperature heat source can be used directly in the form of warm air. Therefore, this system is a likely candidate for adoption by a business that employs waste heat from the datacenter. Also, the farmer can see a direct benefit because the majority of the cost of greenhouse farming during winter is dominated by heating fuel cost (Fig. 6).

An estimate is carried out for the effects of reductions in fuel cost and CO_2 emissions, assuming the greenhouse heating using waste heat from the datacenter in the Utsunomiya area, which is a relatively cold area and is within the supply region of the Tokyo Electric Power Company that is a power company with least CO_2 emission coefficient in Japan.

The assumed model datacenter has a maximum capacity of 1,000 racks (actual operation rate 85 %) with a maximum power supply of 6 kW/rack (average 4.2 kW/rack). It is assumed that the waste heat from the air conditioners of the datacenter will be used for heating a greenhouse, and the necessary amount of heat needed to heat the greenhouse to 15 °C or higher during the winter period from October 1 to May 31 is calculated. As a result of the estimation, the amount of heat generation from the datacenter reaches 566,300 MJ/day, and this corresponds to combustion of 12.6 kL/day of kerosene. Even considering the reduction of heating efficiency, this amount is capable of heating a greenhouse of 88,100 m^2 size during the midwinter period (Table 3)[Note 5].

Table 3 Reduction in CO_2 emission by a composite datacenter

Waste heat from entire datacenter (Utsunomiya)	MJ/day	566,308
Surface area of greenhouse	m^2	88,100
Reduction in heating fuel (kerosene)	kL/year	1,709
Cost reduction of heating fuel	1,000 yen	189,734
Reduction in CO_2 emission by reduction of heating fuel	t-CO_2	4,256
CO_2 emission from datacenter	t-CO_2	19,464
Rate of reduction of CO_2 emission seen from datacenter	%	-21.9 %
Rate of reduction of CO_2 emission of datacenter + greenhouse	%	-17.9 %

This will allow a reduction of cost needed for greenhouse heating by about 190 million yen per year, and CO_2 will be reduced by 4,256 t per year. This corresponds to 21.9 % of CO_2 emitted by the datacenter, and the combination of the datacenter and the greenhouse will have a CO_2 reduction effect of 17.9 % (Table 3). Dramatic reduction in CO_2 emissions can be expected by compositing the datacenter and the greenhouse.

4.2 Total value system design for a composite datacenter through strategic system design

Unless the two stakeholders, the datacenter company and the greenhouse farmer, accept the values (stakes), it is not possible to realize optimization by achieving the physical system. Therefore, we shall investigate the value design of the composite system of the datacenter and the greenhouse.

4.2.1 Condition when the datacenter alone invests in environmental measures

The profit of datacenter company is set as P_0, the sales of service is S, and the energy cost is EC. It is assumed that an environment tax (TC) is introduced by the social system that attempts to control the CO_2 emissions of the energy consumption. The company makes an environment measure investment (IC) such as introducing efficient air conditioning to minimize profit reduction, and attempts to reduce the energy cost and environment cost. Here, the condition under which the environment measure investment IC is conducted is when the sum of reduced energy cost ΔEC_2 and the reduced environment tax ΔTC_2 is higher than the investment IC, as

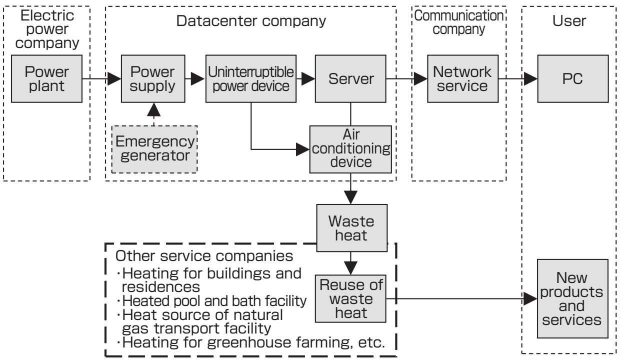

Fig. 5 Energy flow of the composite datacenter

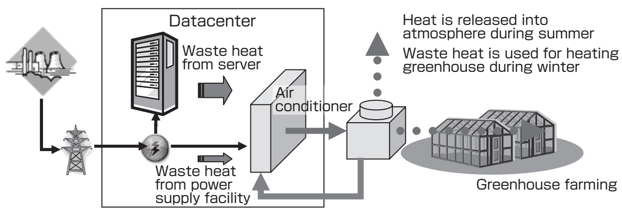

Fig. 6 Use of waste heat from datacenter in farming

shown below (Fig. 7).

$$P_2 \geqq P_1 \quad \Delta EC_2 + \Delta TC_2 \geqq IC \qquad (1)$$

Moreover, when the amount of reduced cost $\Delta EC_2 + \Delta TC_2$ is higher than the sum of environment measure investment IC and environment tax TC, the profit after measure P_2 will be higher than the profit before environment tax P_0, and the company will engage more actively in environment measure investment (Fig. 7).

$$P_2 \geqq P_0 \quad \Delta EC_2 + \Delta TC_2 \geqq TC + IC \qquad (2)$$

However, in practice, it is extremely difficult to fulfill the conditions of (1) and (2) by the effort of the datacenter company alone due to technological limitations.

4.2.2 Two conditions for multiple companies

Next, value design is done for the case where the datacenter company X recovers waste heat energy and the greenhouse farmer Y reuses it.

In this case, the environment measure investment will be conducted to improve the facility, if the total of the cost reduction by both parties $\Delta EC_2x + \Delta TC_2x + \Delta EC_2y + \Delta TC_2y$ surpasses the total environment measure investment ICx + Icy.

$$\Delta EC_2x + \Delta TC_2x + \Delta EC_2y + \Delta TC_2y \geqq ICx + ICy \qquad (3)$$

X and Y are different businesses, and they attain the advantage of significant cost reduction by Y reusing the waste heat from X. To reallocate the advantage between X and Y, it is necessary to conduct some monetary adjustment (AD). Here, the model considered is that in which the greenhouse farmer pays the adjustment cost AD to the datacenter company as the cost of used waste heat.

$$\Delta EC_2x + \Delta TC_2x + AD \geqq ICx$$
$$\Delta EC_2y + \Delta TC_2y - AD \geqq ICy \qquad (4)$$

When condition (4) is fulfilled, X and Y can reduce the profit decrease due to the addition of external measures through investments ICx and ICy, and the two businesses can join hands to take measures (Fig. 8).

Moreover, in the case of condition (5) shown below, the sum of the reduced costs of the two businesses $\Delta EC_2x + \Delta TC_2x + \Delta EC_2y + \Delta TC_2y$ will be greater than the total of the environment tax and environment measure investment TCx + TCy + ICx + ICy, and both businesses can increase profit ability compared to before the imposition of the environment tax (Fig. 8).

$$\Delta EC_2x + \Delta TC_2x + AD \geqq TCx + ICx$$
$$\Delta EC_2y + \Delta TC_2y - AD \geqq TCy + ICy \qquad (5)$$

To realize the composite system in which greenhouse farming uses the waste heat energy from the datacenter, it is necessary to introduce the facility cost ICy that fulfills the conditions of (4) or (5), the facility of ICx, as well as the adjustment cost AD.

4.2.3 Value evaluation of the composite datacenter in case environment tax is imposed

Assuming the case when environmental taxes are introduced by the social system that attempts to control emissions, calculations are done for the single datacenter and the composite datacenter in which the waste heat is used for greenhouse farming, using the model of environment tax rate 2,400 yen/t-CO_2 (electricity 0.25 yen/kWh, kerosene 0.82 yen/L) assumed by the Ministry of Environment in October 2005[Note 6]. Assuming a single datacenter with 1,000 racks and 6 kW/rack located in Tokyo, the annual power consumption is 57,817 MWh. Other than the annual electricity cost EC = 693,807 thousand yen, the annual environment tax TC = 14,454 thousand yen will be required.

When capping, the most effective measure, is done, the annual power consumption will be 54,697 MWh, and this will be a power cost reduction (ΔEC_2) of 37,437 thousand yen per year and an environment tax reduction (ΔTC_2) of 780 thousand yen per year. However, the acceptable upper limit of the facility investment IC for CO_2 reduction must be less than 38,217 thousand yen per year. The investment per rack

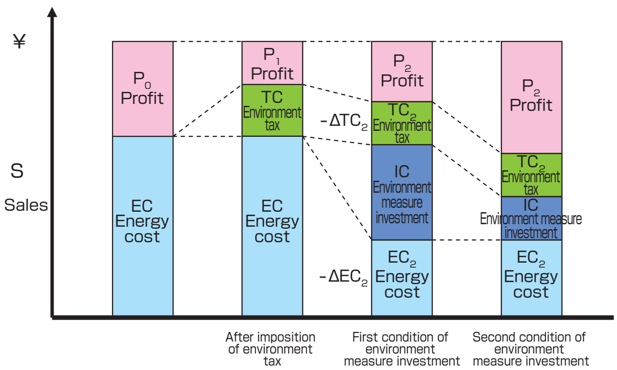

Fig. 7 Earnings from a single datacenter

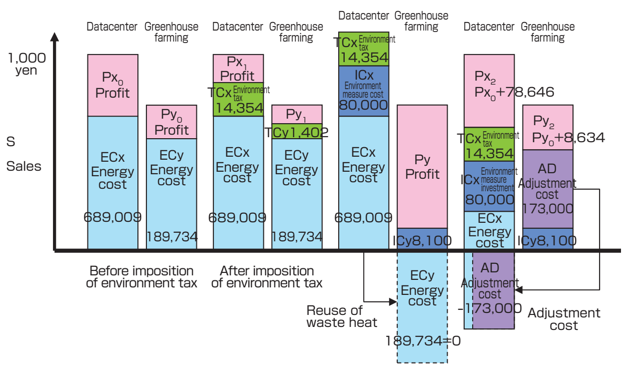

Fig. 8 Earnings from a composite datacenter

is 224 thousand yen (at an amortization period of 5 years) or less. Comparing this to the general cost needed for capping, the figures are unrealistic. If capping could be done at 200 thousand yen per rack, the amount of cost reduction for the datacenter as a whole will be merely 4,217 thousand per year. It is quite impossible to achieve the condition (2) where the profit can be increased more than before tax imposition.

Next, we assume a composite datacenter with the same 1,000 racks and 6 kW/rack located in Utsunomiya, and the greenhouse of 88,100 m^2 size that uses the waste heat.

The annual power consumption of the datacenter is 57,417 MWh, and the annual power cost ECx = 689,006 thousand yen and annual environment tax TCx = 14,354 thousand yen must be paid by the datacenter company. On the other hand, by reusing waste heat, the annual fuel consumption 1,709 kL and the annual fuel cost ECy = 241,390 thousand yen for the greenhouse heating become 0, and the annual CO_2 emissions of 4,256 t and environment tax TCy = 1,402 thousand yen can be reduced. The upper limit of the annual facility investment ICx + ICy appropriate for this reduction effect is less than 191,135 thousand yen (1,124 thousand yen per rack). There is about five times cost difference compared to a single datacenter. Assuming the annual facility investment at 88,100 thousand yen (1,032 thousand yen per rack), compared to before environment tax imposition, the datacenter company will experience a profit increase of 78,646 thousand yen a year, and the greenhouse farmer will see 8,634 thousand yen more profit. With the composite datacenter, it is possible to design a system with high CO_2 reduction in terms of the environment, and the company and the farmer can both enjoy high earnings.

Table 4 Environment measure investment and improvement of earnings

		iDC capping	iDC+ greenhouse farming
Datacenter location		Tokyo	Utsunomiya
Energy cost of datacenter	1,000 yen/year	656,370	689,009
Environment tax of datacenter	1,000 yen/year	13,674	14,354
Energy cost of greenhouse farming (before use of waste heat)	1,000 yen/year	—	189,734
Environment tax of greenhouse farming (before use of waste heat)	1,000 yen/year	—	1,402
Energy cost reduction by facility investment	1,000 yen/year	37,437	189,734
Environment tax reduction by facility investment	1,000 yen/year	780	1,402
Reduction of CO_2 emission	t-CO_2	1,058	4,256
Effect of reduction of CO_2 emission	%	-5.4 %	-17.9 %
Upper limit of allowable facility investment	1,000 yen/year	38,217	191,135
Per rack	1,000 yen/rack	224	1,124
Upper limit of facility investment for increasing profit	1,000 yen/year	23,763	175,379
Per rack	1,000 yen/rack	140	1,032
Calculation for the model case			
Amount of facility investment by datacenter	1,000 yen/year	34,000	80,000
Amount of facility investment by greenhouse farmer	1,000 yen/year	—	8,100
Cost reduction for datacenter after imposition of environment tax	1,000 yen/year	4,217	93,000
Cost reduction for greenhouse farming after imposition of environment tax	1,000 yen/year	—	10,036
Increase/decrease of profit compared to before tax imposition (datacenter)	1,000 yen/year	-10,237	78,646
Increase/decrease of profit compared to before tax imposition (greenhouse farmer)	1,000 yen/year	—	8,634
Amount of adjustment between datacenter and greenhouse farmer	1,000 yen	—	173,000

5 Summary

Strategic system design is a comprehensive design of the physical space and the psychological (value) space of the different stakeholders.

As a result of investigating the design of a datacenter for the purpose of CO_2 reduction, the following points became apparent.

(1) In the design optimization of a single datacenter using the conventional design approach, the effect of physical CO_2 emission reduction is limited, the maximum amount that can be invested for environmental improvement in terms of value is small, and facility investment is difficult. Also, it is almost impossible to maintain the same profit as before the imposition of environmental taxes.

(2) In the case of the composite system where the waste heat of a datacenter is used for greenhouse farming by employing the concept of total physical system design, the overall CO_2 emission reduction is 17.9 %, and there is potential for achieving greater environmental improvement.

(3) As a value system based on total value system design, by introducing the contract system where the greenhouse farmer pays an adjustment cost for the use of waste heat to the datacenter company, it is possible to maintain sufficient facility investment even after the imposition of the environment tax. This shows the potential of increasing the value by expanding the profit more compared to before the imposition of environmental taxes.

(4) The possibility is shown for designing an efficient system in terms of physical performance and cost-effectiveness through strategic system design for multiple stakeholders, in comparison to the conventional strategic system design that targets single stakeholders.

The basic thinking of the strategic system design of attaining overall optimization by satisfying all stakeholders involved, while maintaining the overall balance of the physical system and values, can be applied to regional cooling and heating reusing the waste heat from plants and power plants, and is not limited to the relationship of datacenters and farming. It can be applied to the realization of new composite systems between the stakeholders with different goals in society, such as the smart grid where the batteries of the electric vehicles parked at home are used as the batteries of the electrical network of the entire society.

In the future, we shall investigate using strategic system design for the optimization of more complex systems such as the composite system with three or more stakeholders, by adding solar power generation to the two-stakeholder system of the datacenter and farming.

Acknowledgments

This research was conducted as a part of the Center for Education and Research of Symbiotic, Safe and Secure System Design, Global COE Program, Keio University. We are thankful to Professor Haruki Sato, Graduate School, Keio University, who provided us with discussions on the use of waste heat.

Notes

Note 1) 25 % of total national power generation: Projection of energy consumption by IT devices, *IT Policy Roadmap*, 31P, 2008.6.11 (Strategic Headquarters for the Promotion of an Advanced Information and Telecommunications Network Society)

Note 2) Emission coefficient of the power companies: On the publication of the emission coefficients by power companies for FY 2006, 2008.9.27 (Ministry of Environment)

Note 3) Temperature difference between Tokyo and Sapporo: Climate statistics information 2008 (Japan Meteorological Agency)

Note 4) Capping: Rack air conditioning system, Patent Publication 2009-257730, 2009.11.5 (NTT Facilities, Inc.)

Note 5) Heating for greenhouse: Fuel consumption estimate tool for greenhouse heating (prototype Ver.0.90), 2008.2.25 (Advanced Greenhouse Production Research Team, National Institute of Vegetable and Tea Science, National Agriculture and Food Research Organization)

Note 6) Environment tax rate: Specific plan for environment tax, 2005.10.25 (Ministry of Environment)

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Senior researcher, Strategic Consulting Room, Mitsubishi Research Institute, Inc. Completed the masters program for mechanical engineering at the Faculty of Science and Engineering, Waseda University. Currently enrolled in the doctorate program at the Graduate School of System Design and Management, Keio University. After joining the Mitsubishi Research Institute in 1989, worked as a consultant for Government and agencies on social systems such as tax system, technological development plan, traffic system, and medical information system. Recently, engaged in consulting for Internet business and Internet datacenter, and supports the activities of the Japan Datacenter Council. In this paper, proposed the strategic system design and conducted simulation estimates.

Taketoshi Hibiya

After working as a senior researcher of Fundamental Research Labs, NEC Corporation, visiting professor of Tokyo Institute of Technology, and professor of Tokyo Metropolitan University, currently working as the professor of the Graduate School of System Design Management, Keio University. Doctor of Engineering. Worked on the development of electronics material, heat property measurements of high-temperature melt, and material process research in zero gravity using rockets and aircrafts. In this paper, considered the composition of datacenter and greenhouse farming from the perspective of system design management.

Discussions with Reviewers

1 Hierarchy of the system

Question (Koh Naito, Center for Service Research, AIST)

The terminologies such as "single system", "supersystem", "social system", and "stakeholders" are used. Please explain how each system is related to one another.

Answer (Jiro Fukuda)

The systems have various levels such as personal, organizational, social, and global levels. They have a hierarchical, stratified structure and influence each other. This paper intends to point out the existence of various stakeholders outside the single system. The effect on the system and the optimal solution under a certain environment on the scale, attribute, and structure of the stakeholders shall be the subjects for future research. In this paper, we explain the optimization in the simplest combination involving two stakeholders and the external environment of environment tax imposition.

2 Case of the datacenter

Question (Akira Yabe, AIST)

I think the proposal of the concept of strategic system design and the discussion of the combination of multiple systems from the perspective of physical and value systems is a unique way of thinking. For example, I can think of many applications of this concept such as the combination for using biomass and waste disposal, as in the use of the waste material from the manufacture of distilled spirits as fertilizer. However, it is said to be unrealistic to apply this concept to the reuse of waste heat from datacenters. This is because the efficient use of low-temperature waste heat has been discussed for a long time as an issue of efficient use of waste heat from power plants, and there have been many discussions assuming various physical and value systems, and we have not yet been able to propose any economically feasible applications. Yet, I think you are proposing a very unique and useful concept. I think it will be convincing if you present this thinking as an analysis of the case that has been realized. What do you think about this point?

Answer (Jiro Fukuda)

In the latest datacenters, there are places that use outdoor air-cooling, where the outside air is directly taken in to cool the server and the heat is released outside of the building, alongside cooling using the heat pump. I think it is possible to maintain the temperature necessary for greenhouse farming using waste heat from the datacenter. There are cases of successful greenhouse farming using waste heat in the Japanese datacenters as a physical system (IDC Frontier: Press release – The effect of outdoor air conditioning was confirmed in the demonstration experiment of Asian Frontier of the IDC Frontier; the reduction in power consumption of air conditioning was maximum 40 %; efficacy of use of waste heat in agriculture was also confirmed, 2010.3.29). Also, the calculations are done assuming that the waste heat during summer is unused, but the result shows that the reuse of energy in winter alone is sufficiently economically feasible. Even considering the environment tax that is expected to be imposed in the near future, I think it is one of the factors that lead to the increased value of waste heat use.

In this paper, our goal is to establish both the physical and value (economic) feasibility that cannot be optimized by a single stakeholder, by taking the strategic viewpoints including those of different stakeholders such as the datacenter company and farmer, other than looking at the dual system of physical and value systems. From this perspective, we used the datacenter as a subject rather than the case of energy reuse within a plant by a company.

Comment (Koh Naito)

You propose a model for optimization from the mutual relationship of the system using the datacenter as a case study. I think it is better to clarify that the use of waste heat from a datacenter is a case study, and to emphasize the universal applicability of the idea proposed in this paper.

Answer (Jiro Fukuda)

The basic view of “strategic system design” can be expanded to other models of energy management by stakeholders with different objectives such as the smart grid, not just reuse of waste heat. We made the revisions to reflect this thought.