Does Telework Really Save Energy?

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[Abstract] Although telework is expected as an effective tool for energy saving, the effect of telework on the energy consumption depends on the usage of the equipment. There are two opposite possibilities of the effect of telework because energy consumption increases at home while energy consumption decreases in the office by telework. In order to evaluate the effect of telework, the energy consumption model of telework was proposed. In the model, the energy saving effect is estimated according to the type of equipment. Type A equipment is used by each teleworker in the workplace independently. Personal computers and the desk lamps are the Type A equipment. Type B equipment is shared and used by several persons including teleworkers and their family members at home. Air-conditioners, ceiling lights and computer servers are the Type B equipment. As for Type A equipment, the effect of telework is decided by the energy efficiency of appliances. As for Type B equipment, the effect of telework on energy is affected by the number of people who share the equipment. There are 4 cases of using Type B equipment. These cases are determined by the office space reduction and the number of people at home. In order to evaluate the effect of telework, it is necessary to know the usage of equipment at home such as the number of people who share the equipment in the workplace. A survey was conducted to know the sharing situation of the equipment. According to the survey, 64% of teleworkers work alone in the workplace at home and use the energy. The energy consumption at home may increase by 73-85% of the energy decrease attained by the office closure. It was clarified that following conditions are the keys to the energy-saving by home-based telework: 1) the equipment with high energy efficiency should be used at home, 2) the large scale telework with office closure or office space reduction should be introduced, and 3) high energy consuming equipment such as air-conditioner should be shared with family members at home.

[Keywords] Telework, energy consumption, equipment, energy efficiency, energy saving effect

Introduction

Telework is expected to save the energy for commuting and the energy for equipment used in the office. After the Fukushima nuclear plant accident due to the Great East Japan Earthquake in 2011, the energy-saving effect of telework was paid attention and telework is thought to be one of the effective tools for energy saving in Japan (Nakanishi, 2015). Although there may be rebound effects by using car for shopping or leisure during empty time, the energy used for commuting is thought to be saved by telework and there are many studies on the effects of saving energy for commuting by telework such as Henderson & Mokhatarian (1996) and Walls & Nelson (2004). However, only a few studies focused on the change of energy consumption of office equipment at home and in the office during telework.

Purpose of this study is to verify the energy saving effect of home based telework and discuss the condition to realize the energy saving by telework.

At first, previous studies on the effect of telework on energy consumption in the office and at home are reviewed. Then the model of energy consumption of equipment for home based telework is proposed. The model is divided into two parts by the use type of equipment during telework. The first part of the model is for the equipment used by teleworkers independently (Type A). The second part of the model is for the equipment shared with other teleworkers or their family members (Type B). For the Type B equipment, energy increase at home and energy decrease in the office is compared and discussed by 4 cases. The outline of the survey which is conducted to know the usage of Type B equipment is explained and its results are analyzed with the model. The conditions of telework to save energy are discussed in the last chapter.

Previous Studies

At the office, the energy is mainly used for air-conditioning, lighting and office appliances and is expected to decrease if telework is introduced. Does the energy really decrease by telework? Even though some of employees telework and do not come to the office, the office may remain open and the space will not be reduced if rest of the employees come to the office. We cannot expect energy saving effect of telework in this case. It is important to know whether office space will decrease or not. Some studies conclude that the energy consumption in office remains the same in spite of telework because the air-conditioning and lighting keep working even if a few employee telework (Mokhatarian, Handy & Salomon, 1995; Matthews & Williams, 2005). TIAX (2007) reports that the space reductions are assumed only for the frequent teleworkers who telework more than 3 days per week. But some studies estimate the decrease of energy consumption assuming the reduction of office space. For example, Romm (1999), Avaya (2009), Masaki (2011) and Röder & Nagel (2014) estimated the decrease of energy consumption using statistical data concerning office space and energy consumption and the estimation of reduction area. Sun Microsystems (2009) and Ministry of Internal Affairs and Communications (2011) calculated the decrease amount of energy by actual measurement of companies which introduced telework (Table 1).

On the other hand, the energy consumption at home may increase by telework but it is difficult to estimate the amount of the change because the situation of working at home is not studied well. The estimation varies according to the studies not only because the surveyed equipment is different by the studies and the efficiency of the equipment may be different by the year of the research but also because the methods of estimation are different (Table 1). Nilles et al. (1976) is one of the earliest papers which mentioned telework and calculated the energy increase by telework. Mokhatarian, Handy & Salomon (1995), Romm (1999) and Masaki (2011) estimated the energy increase by summing up the electric power of equipment at home. Matthews & Williams (2005) and Röder & Nagel (2014) estimated the increase of energy consumption using national statistical data. Sun Microsystems (2009) and Ministry of Internal Affairs and Communications (2011) calculated the amount of energy increase at home by distributing measuring device to teleworkers. However, these papers do not consider how many people share the appliances at home. Röder & Nagel (2014) pointed out the possibilities of overestimation of energy consumption at home because not every teleworkers is living alone.

Table 1
*Equipment and the Change of Energy Consumption by Telework in Previous Studies**

Previous studies	Equipment used at home	Energy increase**	Enegy decrease***
Nillles et al.(1976)	Computer terminal, Network, Phone line	1.1kWh	n.a.
Mokhatarian et.al (1995)	Air conditioning, computers, stoves, lights	5.5-20.5kWh	n.a.
Romm (1999)	Air-conditioning, Lighting, Office Appliance	6.0kWh	▲21.6kWh
Matthews & Williams (2005)	Heating/Cooling (in the United States) Climate control, Lighting (in Japan)	10.4kWh 4.0kWh	n.a. n.a.
Sun Microsystems (2009)	Home Office Equipment, Heating and Cooling	0.8-1.4kWh	▲1.0kWh
Avaya (2009)	n.a.	n.a.	▲5.4kWh
Ministry of Internal Affairs and Communications (2011)	Air-conditioning, Lighting, Office Appliance	1.1kWh	▲1.65kWh
Masaki (2011)	Air-conditioning, PC	0.1kWh	▲8.6kWh
Röder & Nagel (2014)	All home apliances	7.5kWh	▲2.8kWh

Notes: *As the amount of energy change was expressed in different unit according to the studies such as W, kW, MJ (megajoule) and M Btu (Million British thermal units), the author united the units to kWh from the data in each study assuming 8-hour telework in one day.
** Energy increase: The increase of consumption of electric power by one day telework at home.
*** Energy decrease: The decrease of consumption of electric power by one day telework in the offices.

Energy Consumption Model of Telework

Structure of the Model

In order to calculate the change in energy consumption by the telework considering the usages of office equipment, the energy consumption model of telework was proposed (Figure 1).

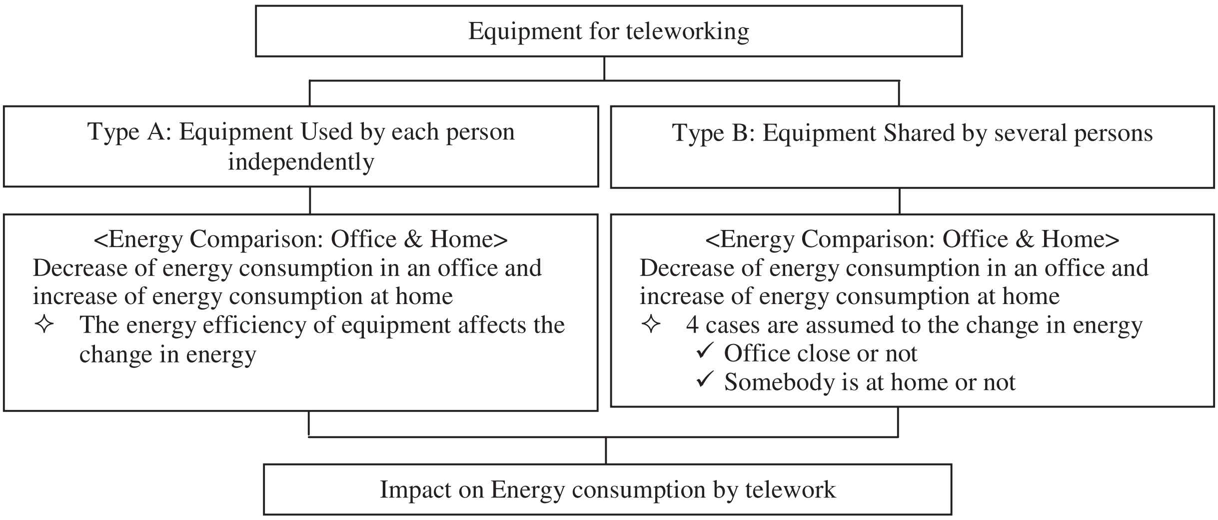

Figure 1. Framework of the energy consumption model of telework

The increase of energy consumption at home and the decrease of energy consumption in the office are compared to determine the energy saving effect of telework. The change in energy consumption by the introduction of telework depends on the usages of the equipment. There are two types of equipment, Type A and Type B. Type A equipment is used by each teleworker in the workplace independently. Personal computers and the desk lamps are categorized as Type A (Table 2).

Table 2
Example of Energy Consumption of Type A Equipment

Equipment	Power Consumption	Manufacturer & Specification
Desk-top Computer	187W	NEC Valuestar G series (with TV)
Laptop	45W	NEC LaVie G Type Z
Desk lamp	27W	TWINBIRD

Type B equipment is shared and used by several persons including teleworkers and their family members at home. Air-conditioners, ceiling lights and computer servers are the example of Type B (Table 3). The method of estimating the change in energy consumption for telework is different by the type of equipment. For Type A equipment, the energy efficiency of appliances used in the office and that of used at home are compared. For Type B equipment, the number of the people who share the equipment affects the change in energy consumption by one teleworker. We have to consider if somebody is in the workplace at home and if the office is closed during telework. Therefore, the energy change is divided into 4 cases by the office closure and the usages of the equipment at home. The energy consumption of Type A equipment and that of Type B equipment are estimated in each method and then they are totaled. The framework of the energy impact estimation model of telework is shown in Fig 1.

Table 3
Example of Energy Consumption of Type B Equipment

Equipment	Power Consumption	Manufacturer & Specification
Air-conditioner	590W (Cooling) 470W (Heating)	Panasonic CS-223CF（for 10 m2）
Ceiling light	50W 72W	LED Fluorescent lamp

Type A equipment

Total energy consumption of Type A equipment will increase or decrease in proportion to the number of workers who use the equipment (Fig.2). When a worker is teleworking, Type A equipment is not used in the office and the energy consumption of Type A equipment in the office decreases. On the other hand, the same kind of Type A equipment is used at home and consumes the energy instead. If the working hours (duration of using the equipment) are the same between working in the office and telework at home, the difference of the energy consumption depends on the energy efficiency of the equipment in the office and at home.

Sun Microsystems reported that home office equipment used less power (65W) than Sun office equipment (124W) (Sun Microsystems, 2009). Considering laptops which use less power than desk top computer (Table 2) are often used at home (Sun Microsystems, 2009), the home office equipment is thought to be energy effective than the equipment used in the office. Sun Microsystems also reported that teleworkers tend to be conscious of saving energy at home (Sun Microsystems, 2009).

If the energy efficiency is higher at home than in the office, the energy-saving effect of telework can be realized. However, the introduction of telework is neutral for the energy consumption if the energy efficiency of equipment for the office and for personal use is the same. As for Type A equipment, energy efficiency is the key to the energy saving.

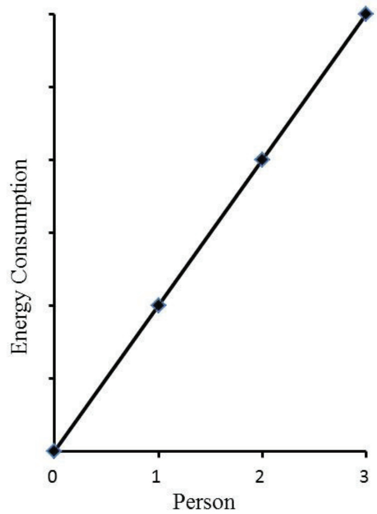

Figure 2. Change in energy consumption of Type A

Type B equipment

As Type B equipment includes an air conditioner whose energy consumption is the largest among the equipment used for telework (Table 3), it is important to consider the situation of usage of Type B equipment to estimate the energy saving effect. The energy consumption of Type B equipment for the first person, who turns on the switch, is large, but for the second or third person, the increment of energy use is not so large as for the first person (Fig.3) because the equipment is shared by the people there. In Japan, an air-conditioner is installed in each room. Increment of energy is quite different whether the teleworker is the first person or the second person in the room. It is therefore important to know the teleworker is alone or with somebody (family members) in the workplace.

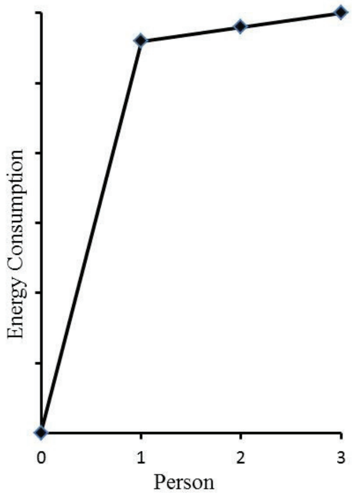

Figure 3. Change in energy consumption of Type B

APF (Annual Performance Factor) of Japanese air-conditioner for home use (Cooling capacity is 2.2kW) is 6.3 in average and 7.2 in highest (Agency for Natural Resources and Energy, 2014) while APF of brand-new air conditioner for business use (DAIKIN's FIVE STAR ZEAS P112, Horse Power: 4.0) is 6.6 and the number is the highest in this class (Daikin, 2015). The energy performance is almost the same between the equipment for office use and the equipment for home use. Consequently, the energy consumption of Type B equipment depends on the situation of workplace.

At the office, energy consumption of Type B will not decrease if the telework program of the company is small scale and the office space is not reduced. A small number of people telework and office space is not change, then air conditioners and lights will keep operating in the office. The consumption of energy remains almost the same as before the telework except the energy for the teleworkers' PCs and desk lamps which are small. We therefore cannot expect the energy saving effect for the small scale telework. But if telework is introduced on a large scale, some of the office floor can be closed and the equipment will be shut down. Office energy can be saved on large scale telework.

At home, if a teleworker is alone in the house and the only person who use the equipment, the increase of energy consumption is large. On the other hand, if someone is already in the house, the teleworker is the second or third person who uses the equipment, the increase of energy consumption by the teleworker is small. The switch of air conditioner has already been turned on by another member of the family before the teleworker starts working!

Cases of Equipment Use Situation and Energy Consumption

There are 4 cases of using Type B equipment. These cases are determined by the office space reduction and the number of people at home (Table 4).

Case 1: Office space is reduced and the teleworker is alone at home**.** Energy consumption in the office is reduced while energy consumption at home increases. The effect of telework is determined by the comparison of the efficiency of the equipment in the office use and that of at home.

Case 2: Office space is reduced and the teleworker is with his/her family**.** Energy consumption in the office is reduced and the increase of energy consumption at home is small. The energy saving effect of telework is large.

Case 3: Office space is not change and the teleworker is alone at home. Energy consumption in the office is not reduced and energy consumption at home increases. Total energy consumption will increase by the introduction of telework. This case of telework should be avoided for the energy saving.

Case 4: Office space is not change and the teleworker is with his/her family. Energy consumption in the office is not reduced and the increase of energy consumption at home is small. Telework does not affect the energy use in this case.

Table 4
Office/Home Situation and Energy Consumption

<Case 1> Office Space: Reduced At Home: The worker is alone Energy consumption is determined by the efficiency of equipment	<Case 2> Office Space: Reduced At Home: The worker is with his/her family Energy consumption will decrease
<Case 3> Office Space: not change At Home: The worker is alone Energy consumption will increase	<Case 4> Office Space: not change At Home: The worker is with his/her family Energy consumption is not affected by telework

It is necessary to obtain data whether the teleworker is alone or with somebody at home to evaluate the energy effect of telework at home. As there is no previous study on the situation at home when telework and there is no data of the number of people at the teleworking place, a following survey is conducted to obtain these data.

The Survey of Telework Situation at Home

In order to understand the sharing situation of the equipment, a survey was conducted from December, 2013 to January, 2014 with the questionnaire for 142 teleworkers in Japan. The teleworkers are asked to answer the questionnaire for the situation of their workplace such as the number of the room, the number of the person in the room and in the house, and the equipment which they use for teleworking.

Seventy-eight percent (78%) of the teleworkers are female and 23% are male. Seventy-Six percent (76%) of the teleworkers are self-employed and 24% are employees. Majority (60%) of the teleworkers works more than 5 days a week.

During the telework, Thirty-three (33%) of the teleworkers stay alone at home and 67% of them stay with somebody (Table 5). Forty-two (42%) of them are with their children and 36% of them are with their spouse. However, Sixty-four percent (64%) of the teleworkers work alone in the workroom (Table 6) and only 36% of them share the equipment like air-conditioner and ceiling light. Some companies ask their teleworking employees to work in a secured space for the security reasons. Some of the 64% teleworkers may be requested by the employer to work in an independent room. As a result, nearly two thirds of the teleworkers consume additional energy for air-conditioning or ceiling light for their own workspace.

Table 5
Situation at Home When Telework

Situation	%
Alone	33.1
With Child/Children	42.3
With Spouse	35.9
With Parents	15.5
With Other People	2.1

Table 6
Situation of the Room for Teleworking

Situation	%
Alone	64.1
With Child/Children	27.5
With Spouse	19.7
With Parents	2.1
With Other People	1.4

Estimation of Energy Increase by Telework

If a teleworker is the only person at home when telework, the energy consumption of telework can be estimated as the sum of Type A equipment and Type B equipment by the examples shown in Table 2 and Table 3 (Table 7). Energy consumption is different according to the season. Summing up of power consumption of desk-top PC, desk lamp, ceiling light, and air conditioner for cooling in the summer season is the maximum use of equipment and their total electric power is 854W and summing up of power consumption of laptop, desk lamp and ceiling light without air-conditioning is the minimum use of equipment and their total electric power is 122W. The consumption of electric power for telework in one day is estimated as 6.8kWh maximum and 1.0kWh minimum assuming one teleworker use the equipment for 8 hours. The number of the estimation is conformable to previous studies shown in Table 1. However, if Type B equipment is shared with teleworker's family members, the increase of energy use by telework is less than the estimation (6.8kWh and 1.0kWh). If 36% of the people shared the Type B equipment as this survey shows, the consumption of electric power at home becomes 5.0kWh maximum and 0.8kWh minimum. The decrease rates by the sharing are 27% and 15%.

If the office is closed and energy consumption in the office decrease to zero and the condition of equipment such as energy efficiency is the same between office use and home use, total energy saving (the sum of decrease in the office and increase at home) by telework will be 15% to 27% of the total energy for the equipment. However, if the office space is not reduced, the situation becomes as shown in Case 3 and energy consumption increases by the introduction of telework.

Table 7
Electric Power of the Increase Use of Equipment by Telework

	Maximum		Minimum	
	equipment	electric power	equipment	electric power
Type A	Desktop PC	187W	Laptop	45W
	Desk lamp	27W	Desk lamp	27W
Type B	Air-conditioning	590W	(no AC)	---
	Ceiling light	50W	Ceiling light	50W
Total		854W		122W

Table 8
Increment of Electric Energy for One Day Telework at Home

	Maximum	Minimum
Work alone (without sharing)	6.8kWh (100%)	1.0kWh (100%)
Work in a room with somebody (sharing 36% of Type B)	5.0kWh (73%)	0.8kWh (85%)

Conclusion

There are two opposite possibilities in the effect of telework on energy consumption, the energy increase case and the energy decrease case. It depends on the scale of telework and the number of persons at home. As for the office, the energy saving effect of telework is determined by the teleworking policy of the company. If telework is implemented on a large scale lead by the company and large part of the office is closed, air conditioning and lighting will be reduced and the energy consumption of the office will decrease significantly. But if the telework is implemented on a small scale, the energy saving effect will not be realized.

For the energy use at home where the teleworker is working, energy consumption will increase by telework but the amount of the increase depends on the number of person in the workspace. As 64% of teleworkers work alone in the workspace and use air-conditioners and lights only for themselves according to the survey, the energy consumption at home may increase 73% to 85% of the decrease in the office, that is, 15 % to 27% of energy saving can be expected if the office is closed completely with telework. But if the office is not closed, the energy consumption will increase by the introduction of telework. Telework cannot be a tool for energy saving.

As a result of the analysis of the usage of equipment for telework with the energy consumption model of telework and the survey on the usage of equipment for telework at home, it was clarified that following conditions are the keys to the energy-saving by telework: 1) the equipment with high energy efficiency should be used, 2) the large scale telework with office closure or office space reduction should be introduced, and 3) high energy consuming equipment such as air-conditioner should be shared with family members at home.

Brand-new air conditioners have new technologies for high energy efficiency. For example, Mitsubishi Electric's air conditioners have sensors that perceive persons in the room and heat or cool the room according to the condition of the room (Mitsubishi Electric, 2015). These air conditioners are very energy efficient, and the energy consumption will change according to the number of the people there. The category of air conditioner may shift from Type B (Table 3) to Type A (Table 2). With new technologies, the office space reduction and the high efficiency of the equipment at home become more important for the energy-saving by telework.

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