Energy Saving Behaviour (ESB) Level of Practice-Comparison case study between green and conventional office building

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Abstract

Findings from previous studies show that many cases of green buildings have not achieved their desired performance. Often the actual energy consumption is different from that predicted at design stage. In some cases, actual energy usage consumed more energy than a similar conventional building. The difference between actual and predicted energy usage can be explained by the differences between assumed and actual behaviour of occupants, the use of building energy controls, and building operation management. While implementation of green buildings is not entirely successful in achieving energy saving targets, adoption of energy saving behaviour should result in better energy efficiency performance. Currently energy saving behaviour has been given less focus in improving green building performance. This study uses a comparison case study between green buildings and conventional buildings to better understand Energy Saving Behaviour (ESB). The objective of this paper is to investigate the level of energy saving behaviour practiced in between green and conventional office buildings. Findings from case studies show respondents in green buildings practice more ESB than respondents in conventional building. This paper also identified ESB with high and low scores in both green and conventional building. Categorisation of these ESB may aid building managers to target which behaviours that requires increase in its adoption rate. In addition, the timing of some of the ESBs performed was identified to capture better understanding of occupant's preference to save energy. Findings from the survey show that most respondents answered with ESB "turned off at the end of the day" and "when away for an hour". The study concluded that although some ESBs are recognized in green building users, energy waste is still evident due to the high non-performance of other ESBs. .

Keywords: ***Energy Saving Behaviour (ESB), Energy Efficiency, Green Buildings, Energy Performance***

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1. Introduction

In many cases green buildings did not achieve optimum energy efficiency performance. Often the actual energy consumption is different from what was predicted at design stage and consumed more energy in comparison to conventional buildings of the same size and function(Bordass, Cohen et al. 2001, Office 2002, Cohen, Bordass et al. 2007, Sawyer, De Wilde et al. 2008, Wedding 2008, Scofield 2009, Ashuri 2010, Howe and Gerrad 2010). Howe and Gerrad (2010) and Wener and Carmalt (2006) pointed out that the reality is majority of green buildings are not energy efficient and these buildings will continue to be used for many years to come. Hes, D.(2005) , Armitage (2010)and Bond(2011) reported that many 4 star certified buildings do not perform even at a 2 star level. This "mismatch" primarily results from the differences between assumed and actual patterns of occupants, the use of controls, and building operation management (Cole and Steigner 1999, Bordass 2001, Reiss 2005, Kubba 2010). In an on-going research by Andrews et al.(2010) it was stated that buildings may fail to perform as planned, because operators do not- or cannot operate the buildings as intended, and because occupants sometimes behave differently than expected. Documented studies showing poor performance such as that indicated above could possibly impede the rate of implementation of green buildings in a country. Therefore, it is necessary that energy performance in green buildings should be improved to achieve optimum energy efficiency performance. A successful performance of green building can be achieved by further reducing energy consumption through changes in human behaviour. Study by Cole (1999) and Steinberg (2010) have shown that integration of Energy Saving Behaviours (ESB) has not been given sufficient focus in green buildings. ESB can be divided into two categories: efficiency and curtailment behaviours (Gardner and Stern 2002). Efficiency behaviours include actions like purchasing energy efficient equipment such as insulation, and energy efficient light bulbs. Curtailment behaviours involve repetitive efforts to reduce energy use, such as lowering thermostat settings. The focus in this paper is on curtailment behaviours since green buildings which already have energy efficient technologies have shown that efficiency behaviour alone did not achieve optimum performance in saving energy. In addition, Energy Efficiency Conservation Authority (EECA), New Zealand (EECA 2011) highly encourages curtailment behaviour as a way to reduce energy consumption in office buildings. This paper investigates the level of practice rate in Energy Saving Behaviour (ESB) between green and conventional office buildings. The aim of this paper is to acquire better understanding of the occupant's behaviour in the building in order to develop an effective intervention strategy to increase ESB adoption rate.

2. Literature Review

Energy Saving Behaviour (ESB) is defined as a specific action to reduce energy consumption (Gardner and Stern 2002). A total of 18 Energy Saving Behaviours (ESB) was compiled from previous studies in a residential, office, and university context as shown in Table 1. These ESB are common behaviours that are encouraged for occupants in buildings to help save energy. The aim of this study is to investigate the current level of practice in ESB between green and conventional office building

Table 1 Energy Saving Behaviour (ESB) List

CODE	Item Description	Reference
ESB1	Use dishwasher only when there is full load	(Barr and Gilg 2006, Wood and Newborough 2007)
ESB2	Boil less water instead of filling up the whole kettle	(Wood and Newborough 2007)
ESB3	Read documents on computer screen rather than printing	(Steinberg 2009)
ESB4	Use double sided printing	(Steinberg 2009)
ESB5	Reduce multiple computer monitors to one (if you are using multiple computer screen)	(Heerwagen 2010)
ESB6	Work on a laptop instead of a computer	(EECA 2011)
ESB7	Turn down computer screen brightness	(Steinberg 2009, Ryu 2010)
ESB8	Put screen to sleep instead of using screen saver	(Kolata 1986, Ulrich 2008).
ESB9	Print in booklet format or double sided rather than one sided	(Steinberg and Landis 2010)
ESB10	Shut down my computer	(Kolata 1986, Stern 1986)
ESB11	Shut down colleagues computer if seen left turned on	(Kolata 1986, Stern 1986)
ESB12	Turn off my computer monitor if seen left turned on	(Kolata 1986, Ulrich 2008, Steinberg 2009).
ESB13	Use task lighting whenever appropriate, and switch off main lights	(Kolata 1986, Ulrich 2008, Steinberg 2009).
ESB14	Switch off lights in unused space	(Energy 2011, Lab 2011) (Carriere and Rea 1988, Barr and Gilg 2006, 2011)
ESB15	Use natural daylight whenever appropriate, and switch off lights	(Heerwagen and Diamond 1992)
ESB16	Close windows and exterior doors when heating/ cooling systems are used	(Heerwagen and Diamond 1992, Heerwagen 2010)
ESB17	Close curtain/ window blind at night to prevent heat loss	(Heerwagen and Diamond 1992, Barr and Gilg 2006, Andrews, Yi et al. 2011)
ESB 18	Ensure electronic appliances are turned off	(EECA 2011)

3. Research Methodology

Four case studies were selected to compare energy efficiency practices among occupants in green and conventional buildings. Two of each category of buildings was chosen. Thomas Building (TB) and Owen G Glenn Building (OGGB) were identified as green building because the designintent was to be energy efficient. Faculty of Engineering (FoE) and Old Choral Hall (OCH) building was selected as suitable for conventional building as it does not incorporate energy efficient design.

***Case study 1- Thomas Building – Green Building (TB)**.* The extension Thomas Building, a 4 storey building was built in 2011 with the design intention for the building to be green building certified by GreenStar New Zealand. The area of the building is 4,958m2 with an estimated population of 160 occupants. The design intended a rating NZGreenStar between 4 star to 5 star. Energy efficient features in the building incorporated a double glazed tinted low E with double skin facade. The outer glazing with fritted dot pattern provides 30 % shading. Access for natural ventilation is provided through inoperable window louvers. Most areas in the building have occupancy sensors. The building also adopts the variable air volume (VAV) system which is energy efficient compared to a typical air-conditioning system.

Case study 2- Owen Glenn Building – Green Building(OGGB). The Owen G. Glenn Building, a 7 storey building was completed in 2007. The area of the building is 74,000m2 with an estimated population of 400 occupants.The main energy efficient features incorporated in the building were highly glazed window to optimise natural daylight, with layered facades to provide solar shading. Occupancy sensors and automatic building control systems were connected with the Energy Management System.

Case study 3- Old Choral Hall– Conventional Building (OCH). Old Choral Hall building, a 4 storey building completed in 1872. Total estimated population in the building is 100 occupants. This building was identified as one of the historical buildings in New Zealand. No energy efficient design was incorporated at the time it was built. Hence this building was selected suitable as a conventional building.

Case Study 4- Faculty of Engineering- Conventional Building (FoE).Faculty of engineering building, is a 12 storey building with an estimation of 300 occupants. The building was reported to have no energy efficient features in the building.

A survey was conducted to evaluate the extent of energy saving behaviour practice, and identify potential strategies to encourage energy saving behaviour. The questionnaire was structured into four parts. Part 1 consisted 17 items on ESB asking respondents to rate their actions using a likert type scale of 5 – Always to 1- Never. Part 2 in the questionnaire was on ESB performance in different time events for 3 items using a categorical scale of three. Part 3 required respondents to select which of the electronic appliances they have and consequently select their actions after usage on the electronic appliances they have using a categorical type scale of three which are “I leave it ON”, “I turn off appliance” and “I turn off main switch”.

4. Results and Discussion

The questionnaire was sent out to an estimated total of 1100 people in the building in from May 2012 to September 2012. A total of 270 replies were received for a response rate of 25%. Table 2 shows the breakdown percentage response rate in each building. A total of 113 respondents received in conventional building with a percentage of 28 percent. 157 respondents were received in green buildings constituting a percentage of 22 percent.

Table 2 Response Rate

Type	**Total Population**	**Total Respondents Received**	**Response rate**	**Name of Building**	**Population**	**Respondents received**	**Response rate**
Conventional Buildings	400	113	28%	**FoE**	300	80	27%
				OCH	100	33	33%
Green Buildings	700	157	22%	**TB**	300	68	23%
				OGGB	400	89	22%
TOTAL	**1100**	**270**	**25%**	TOTAL	1100	270	25%

4.1 Part 1: Energy Saving Behaviour (ESB) Actions

Respondents were asked to rate their actions for 17 items on Energy Saving Behaviour (ESB) using Likert scale of 5=Always to 1=Never. The total score of ESB actions for each respondent is aggregated to represent the overall performance in practicing ESB as shown in Figure 1.Total scores of the ESB actions are categorised into five levels with minimum score at 17 and maximum score at 85. A comparison in the ESB scores between green and conventional building is shown in Figure 1. Respondents who rated "I always do" for most ESBs, is seen highest in green building (26%) as compared to conventional building (11%). While respondents who never practice ESBs is seen highest in conventional building (27%) as compared to in green building (14%). Findings from these results are similar with study by Tajabadi (Tajabadi 2010) where green building practices more ESB than respondents in conventional building.

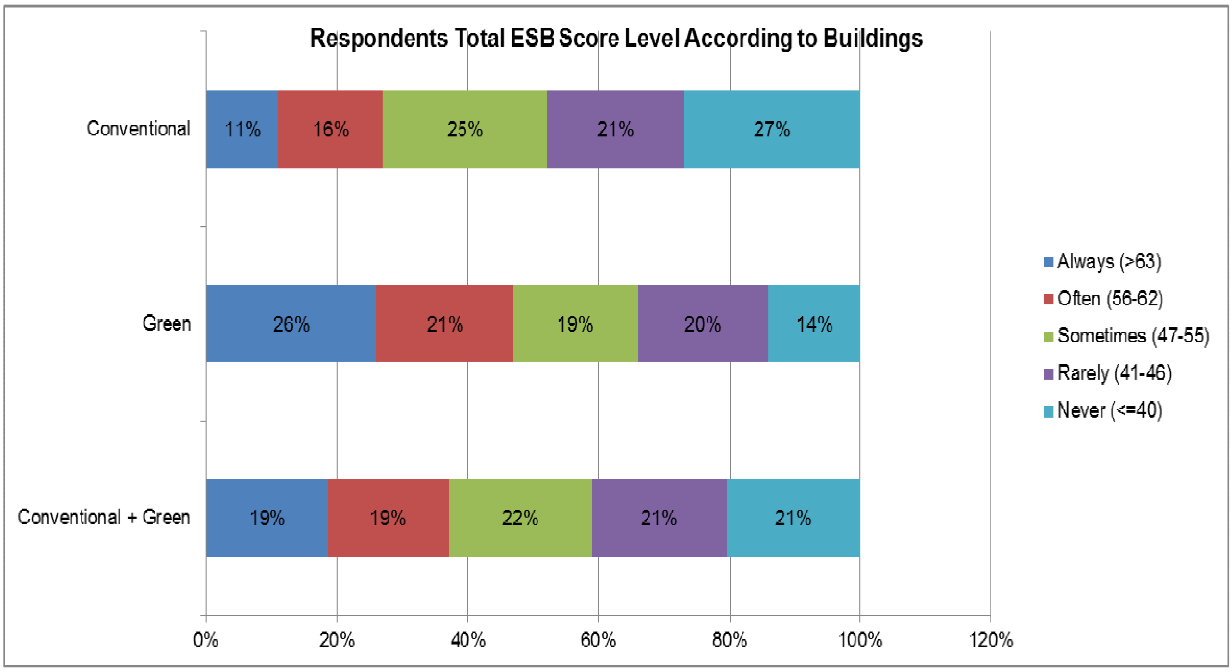

Figure 1 Respondents ESB Total Scores Level

Mann-Whitney U test was conducted to compare the energy saving behaviour scores on each of the ESB actions by respondents from green and conventional building. A significance value of p less than 0.05 indicates that there is a significant difference between the two groups. Table 6 shows that there is significant difference for five ESBs which are ESB 1Use dishwasher only when there is full load, ESB 2 Boil less water instead of filling up the whole kettle, ESB 5Reduce multiple computer monitors to one (if you are using multiple computer screen);ESB 6 Work on a laptop instead of a computer; and ESB 13Use task lighting whenever appropriate, and switch off main lights. The highest mean ranks in all five behaviours were respondents from green building. These results show that respondents in green building perform better for these behaviours as compared to respondents in conventional building.

Table 3 Mann-U Whitney U test on ESB between Green and Conventional Building

CODE	Item Description	Sig. Difference (p)	Existence of Difference	Mean Rank		Higher Mean Rank
				Conventional	Green	
ESB1	Use dishwasher only when there is full load	.000	Significant	79.23	**121.78**	Green
ESB2	Boil less water instead of filling up the whole kettle	.000	Significant	81.71	**119.30**	Green
ESB3	Read documents on computer screen rather than printing	.691	Not Significant	98.95	102.05	-
ESB4	Use double sided printing	.359	Not Significant	104.09	96.92	-
ESB5	Reduce multiple computer monitors to one (if you are using multiple computer screen)	.026	Significant	92.81	**108.19**	Green
ESB6	Work on a laptop instead of a computer	.009	Significant	90.29	**110.71**	Green
ESB7	Turn down computer screen brightness	.153	Not Significant	94.91	106.09	-
ESB8	Put screen to sleep instead of using screen saver	.185	Not Significant	95.22	105.78	-
ESB9	Print in booklet format or double sided rather than one sided	.212	Not Significant	105.45	95.56	-
ESB10	Shut down my computer	.222	Not Significant	95.69	105.31	-
ESB11	Shut down colleagues computer if seen left turned on	.159	Not Significant	95.84	105.17	-
ESB12	Turn off my computer if seen left turned on	.988	Not Significant	100.56	100.44	-
ESB13	Use task lighting whenever appropriate, and switch off main lights	.011	Significant	87.63	**113.38**	Green
ESB14	Switch off lights in unused space	.194	Not Significant	90.53	110.47	-
ESB15	Use natural daylight whenever appropriate, and switch off lights	.418	Not Significant	95.32	105.68	-
ESB16	Close windows and exterior doors when heating/ cooling systems are used	.460	Not Significant	97.27	103.74	-
ESB17	Close curtain/ window blind at night to prevent heat loss	.119	Not Significant	103.41	97.60	-

ESB that are significantly different are shown in the red circles in Figure 2. The largest gap between the trend line for green and conventional is on ESB 1 (use dishwasher only when there is full load). Respondents in green building claimed to often practice ESB 1 with mean value of 3.04, while respondents in conventional building rarely practices it with a mean value of 1.57. Respondents also claimed to often practice ESB 2 (Boil less water instead of filling up the whole kettle) with a mean value of 3.22 in green building, while respondents in conventional building claimed to rarely practice this behaviour with a mean value of 1.99. ESB 5 (Reduce multiple computer monitors to one) is sometimes practiced by respondents in green building with a mean value of 2.10, while in conventional building it is rarely practiced with a mean value of 1.70. ESB 6 (work on a laptop instead of a computer) is sometimes practiced by respondents in both green and conventional building with a mean value of 2.72 and 2.19 respectively. ESB 13 (use task lighting whenever appropriate, and switch off main lights) is sometimes practiced in both green and conventional building with a mean value of 2.77 and 2.23 respectively

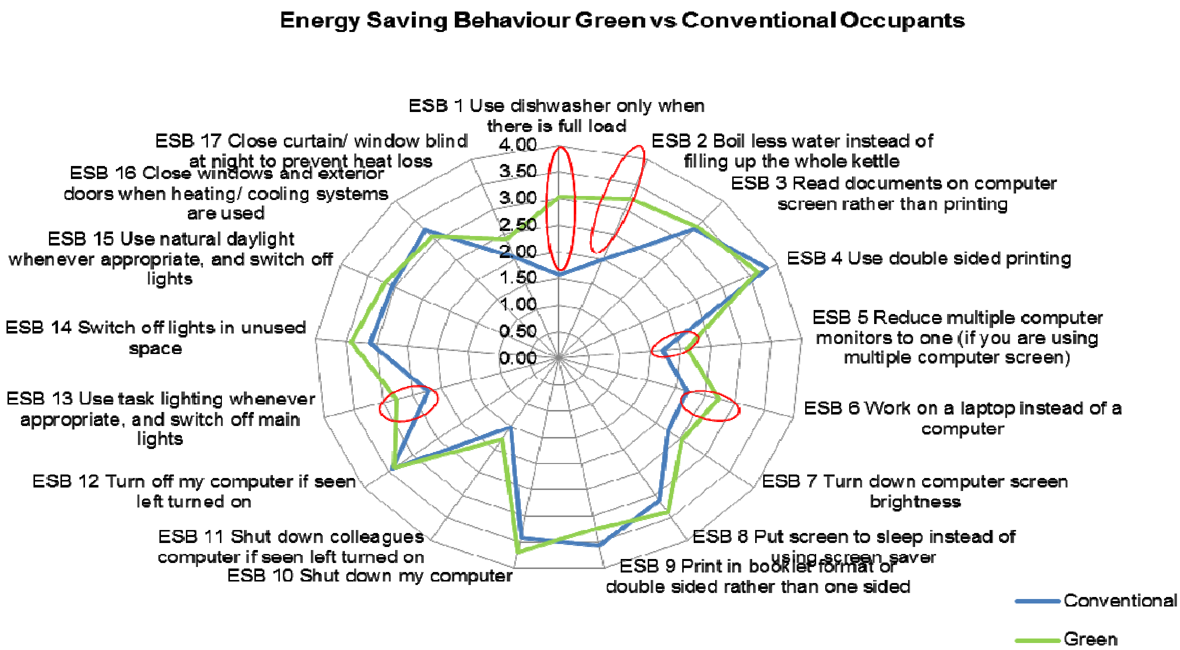

Figure 2 Energy Saving Behaviour Green vs Conventional Occupants

The remaining ESB list (3, 4, 7, 8, 9, 10, 11, 12, 14, 15, 16, and 17) are determined not statistically significant different between green and conventional building through Man-U Whitney test as shown in Table 5. This shows that the rest of the ESBs are practiced somewhat at a same level. An illustration of the overall performance in both green and conventional building can be seen in Figure 2 where a trend line of higher mean scores of the ESBs are from green building. There are a total of eleven ESBs with mean score value between 3.00 to 4.00 rated as often practiced in green building, and a total of nine ESBs often practiced in conventional building. Out from the eleven ESBs that are often practiced, a total of nine ESBs often practiced were identified common in conventional and green building as listed in Table 7. The remaining two ESBs (ESB 1 and ESB 2) found in green building is not seen in conventional building. In conventional building, the only ESBs with higher mean score are for ESB 4, 12, 9, and 16, while mean score for the rest of the ESBs are seen higher in green building

Table 4 Mean Score ESBs (HIGH and LOW SCORES)

CODE	***ESB***	***Mean Score***	
		Green	***Conventional***
ESB 10	Shut down my computer	3.69	3.42
ESB 4	Use double sided printing	3.65	3.81
ESB 14	Switch off lights in unused space	3.42	3.11
ESB 12	Turn off my computer if seen left turned on	3.39	3.42
ESB 8	Put screen to sleep instead of using screen saver	3.38	3.12
ESB 3	Read documents on computer screen rather than printing	3.34	3.29
ESB 9	Print in booklet format or double sided rather than one sided	3.24	3.57
ESB 15	Use natural daylight whenever appropriate, and switch off lights	3.19	3.05

ESB 16	Close windows and exterior doors when heating/ cooling systems are used	3.09	3.25
ESB 1	Use dishwasher only when there is full load	3.04	1.57
ESB 2	Boil less water instead of filling up the whole kettle	3.22	1.99
ESB 13	Use task lighting whenever appropriate, and switch off main lights	2.77	2.23
ESB 6	Work on a laptop instead of a computer	2.72	2.19
ESB 7	Turn down computer screen brightness	2.53	2.24
ESB 17	Close curtain/ window blind at night to prevent heat loss	2.40	2.05
ESB 5	Reduce multiple computer monitors to one (if you are using multiple computer screen)	2.10	1.70
ESB 11	Shut down colleagues computer if seen left turned on	1.77	1.50

*Note: Boxes highlighted indicates LOW scores

A total of six ESBs have mean score below 3.00 in both green and conventional building as shown in Table 7 highlighted in red. These results indicate that improvement in adoption rate of the ESBs is necessary in both buildings. Nevertheless, improvement of behaviour in conventional building is required more since there is an additional two ESBs (ESB 1 and ESB 2) that are identified as low score.

4.2 Part 3: ESB 18 Ensure electronic appliances are turned off

Table 9 shows that respondents in green building perform better than in conventional building due to the higher number of personal electronic appliances turned off at main switch (24% in green building, and 16% in conventional building). As for office electronic appliances; are very few turned off at main switch in both buildings. An improvement in this behaviour may potentially save more energy. Respondents in green building show less occurrence of personal electronic appliances turned on, while in conventional building showed less occurrence of office electronic appliances left turned on. Reasons for these behaviours are unknown and a further investigation is required to gain better understanding of the situation. Nevertheless, a comparison between personal and office electronic appliances shows that there is a larger percentage of office electronic appliances left turned on. It is suspected that the reason for the behaviour is because of the sense of ownership on personal belongings of the electronic appliances. This creates a higher sense of responsibility for their actions after using the electronic appliances(Lopes, Antunes et al. 2012). However, a higher percentage of items switched off at the appliance itself is seen in conventional building 56% personal electronic appliances in conventional building turn off appliance after usage while only 51% total items in green building turn off appliance after usage.

Table 5 Actions on Electronic Appliances

		Personal Electronic Appliances		***Office*** Electronic Appliances	
		Conventional	*Green*	Conventional	Green
Actions	I leave it ON	29%	26%	71%	78%
	I turn off appliance	56%	51%	24%	19%
	I turn off MAIN switch	16%	24%	5%	2%
TOTAL		100	100%	*100%*	100%

5. Conclusion

Findings from case studies show respondents from green building significantly practices more ESB than respondents in conventional building for five ESBs which are ESB 1 (Use dishwasher only when there is full load), ESB 2 (Boil less water instead of filling up the whole kettle), ESB 3 (Reduce multiple computer monitors to one (if you are using multiple computer screen), ESB6 (Work on a laptop instead of a computer), and ESB 13 (Use task lighting whenever appropriate, and switch off main lights). Respondents from green building performed ESB 18 better for personal electronic appliances. This is due to the higher number of appliances turned off at main switch and lesser appliances left turned on. However, respondents in conventional building have higher number of appliances turned off at the appliance itself for both personal and office electronic appliances. Respondents in conventional building also performed better for higher office appliances turned off main switch and leaving lesser office appliances turned on. This paper also identified high and low scores in ESB for both green and conventional building. Categorisation of these ESB may aid building managers to target which behaviours that requires increase in its adoption rate. ESB with high scores are ESB 10, 4, 14, 12, 8, 3, 9, 15, and 16. ESB with low scores are ESB 13, 6, 7, 17, 5, and 11. It is only ESB 1 and 2 that has high scores in green building but low scores in conventional building.In addition, the timing of some of the ESBs performed was identified to capture better understanding of occupant's preference to save energy. ESB 12 and ESB 14 were more likely to be turned off at the end of the day and when away for an hour. An improvement in ESB 12 and 14 is to have them implemented at every 10 minutes. Respondents perform ESB 10 at the end of the day the most in green and conventional building. It is suggested that energy can be further reduced if performed at every one hour. This information may contribute in developing a strategy to increase ESB adoption rate. Results also showed ESB 12(turn off computer) and ESB 14(switch off lights) are claimed to be practiced more.It is expected that occurrence of energy waste for these two events(EW 4 and 5)are seen lesser. However, observations on energy waste for these two events were reported to be seen more. Other observations on energy waste were seen for EW 1 and EW 6 which indicates necessary for improvement. The findings showed that behaviours to reduce energy consumption in these scenarios is necessary for improvement. EW 3 showed low score and its ESB showed high score which indicates good performance. As for EW2 scored too low demonstrating that occurrence of energy waste in this event is rarely seen. Thus, EW 3 and EW 2 is not necessary for improvement. Gaining better understanding of people at work, can ensure that interventions are successful. Future research is required to understand the underlying motivational and barrier factors of these ESB are necessary. The following are questions to be addressed How come respondents in GB practices more ESB than in CB? What makes the respondents scored high on ESB? Why do some respondents score low on ESB? How can we increase the rate for respondents with low score on ESB? A qualitative evaluation tool is suggested as the appropriate research methodology to gain in depth answers from the questions.

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