THE SCENARIOS OF GREENHOUSE GAS REDUCTION ON SEOUL NATIONAL UNIVERSITY

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ABSTRACT: To respond to global warming and climate change, Korean Government has implemented the GHG Target Management, which leads to a voluntary reduction in greenhouse gases from large businesses. Korean universities have put efforts on reducing GHG emissions and energy consumptions in the campuses, however, because of various activities and its characteristic of non-profit organization, establishing a long-term plan for reducing greenhouse gases is necessary. In this research, the Seoul National University's energy usage is analyzed and applicable technologies for reducing GHG emissions are extracted. Hence, three scenarios for performing the GHG Target Management are established. Proposed scenario is available for GHG Target Management and it would be expected to support decision-makings for reducing GHG emissions.
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Keywords: GHG Target Management, Scenario, Reducing Technology

1. INTRODUCTION

1.1 Background and Objective

Dramatic increase in greenhouse gases(GHG) since the Industrial Revolution has caused the problem of global warming and climate change. To achieve GHG reductions, Korean government have agreed to the Kyoto Protocol and formulated national policies such as the GHG Target Management. GHG Target Management is to set a target for GHG emissions, leads to a voluntary reduction in GHG from large businesses consuming energy highly.

Over the past decade, Korean universities' annual total energy usage is increased from 130,000TOE to 260,000TOE. However, total gross floor area is a growth only 20 percent in the same time. Consequently, the problem of Korean universities' low-energy efficiency is considered to be an important subject in Korea.

Ten universities, which use the energy more than 10,000 TOE, are registered on GHG Target Management until 2012. Almost Korean universities have put efforts on reducing GHG emissions and energy consumptions in their campuses. However, because of various activities and their characteristic of non-profit organization, they counteract GHG reduction passively. In order to come up with an effective plan for dealing with this problem, they need to establish a long-term plan for reducing greenhouse gases.

This research proposed the scenarios for performing the GHG Target Management by analyzing and establishing a GHG reduction plan for Seoul National University (SNU), which is the largest polluter in Korean universities.

1.2 Scope and Methodology

This research is focused on the SNU's GHG reduction scenarios from 2012 to 2016. It is carried out based on building and energy usage data of SNU. Gwan-ak and Yun-kun campus are focused in the entire campus because other campuses are too small to include the GHG Target Management.

In order to suggest the results, this research applied the following procedure.

(1) Previous researches of GHG reductions are analyzed.
(2) The status of GHG emissions is analyzed and expected allowed emissions of SNU are estimated.
(3) The database of the reduction technologies and the standard models are constructed based on actual data.
(4) The scenarios of GHG reductions are extracted and the proper scenario for performing GHG Target Management is suggested.

2. PRELIMINARY STUDY

2.1 GHG Target Management

GHG Target Management is the system which imposes incentives or penalties to large businesses depending on whether achieving energy goals which consulted with the government. In this system, the government will take care of 60% of the Korean GHG emissions. Total 584 businesses are registered until 2012, and they should submit the performance plan and reduce GHG emissions to target value. Ten universities which are registered on the system submitted GHG inventories of the past four years in 2011 and they should perform the system from 2012

2.2 Preliminary Research of GHG Reductions

Various researches have been published on this study because global warming and climate change are becoming a world-wide problem. There have been many researches, from engineering (Henryson 2000, Park 2006) to behavioral ones (Benders 2006, Lee 2010, Marcell 2004), however, few studies on the long-term plan for reducing GHG found in the literature.

Park(2006) proposed improvement methods by incorporating realities of the system to a linearly optimized energy system model. This method can evaluate uncertainty of technology. However, because it optimized industrial field, it is inappropriate to building GHG reduction technologies that GHG reductions tend to fluctuate with the conditions. Lee(2010) analyzed KNU's GHG emissions and estimated GHG reductions if the technologies will be applied. However, she do not consider cost and difficulty of installation. Moreover, results are not up to perform GHG Target Management.

3. Analyzing SNU GHG Emission

3.1 The Status of SNU GHG Emissions

The statuses of SNU GHG Emissions are drawn from Table 1. Annual GHG emissions has been increasing steadily and 111,679tCO_2-eq were recorded in 2010. In addition, the cause of the sudden increase in 2010 is investigated the advancement of the research equipment and the extension of dormitory

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Table 1. SNU GHG Emissions (2007-2010)

	GHG Emissions(tCO_2-eq)			
	2007	2008	2009	2010
Gwan-ak	85,620	87,888	87,761	97,560
Yun-gun	12,104	12,372	13,077	14,119
Sum	97,724	100,260	100,838	111,679
Rate	-	2.59%	0.57%	10.75%

3.2 BAU of SNU GHG Emissions

In order to estimate Business As Usual (BAU) of SNU GHG Emissions, the SNU total Gross Floor Area(GFA) status and extending plan was investigated first. Table 2 is the Annual GFA of SNU from 2007 until 2015. By construct and extend, total GFA is being increased steadily.

Table 2. Annual GFA Plan (2007-2015)

(unit : m^2)

year	Gwan-ak	Yun-gun	Sum
2007	908,851	115,041	1,023,892
2008	924,349	128,957	1,053,306
2009	938,148	128,957	1,067,105
2010	1,044,026	128,957	1,172,983
2011	1,050,410	128,957	1,179,367
2012	1,086,798	128,957	1,215,755
2013	1,095,820	128,957	1,224,777
2014	1,189,147	128,957	1,318,104
2015	1,280,732	145,957	1,426,689

Based on the annual GHG emissions and the GFA status, annual GHG emissions per unit area are calculated as Formula 1.

Annual GHG Emissions per unit area
= annual GHG Emissions / GFA
(**Formula 1**)

Table 3 is annual GHG Emissions per unit area from 2007 until 2010. Average GHG emissions per area of SNU were maintained at 0.095tCO2-eq.

Table 3. GHG Emissions per Area (2007-2010)

(unit : tCO_2-eq/m^2)

Year	2007	2008	2009	2010
GHG emissions per area	0.095	0.095	0.094	0.095

Based on annual GHG emissions per area and the GFA plan, BAU of SNU are calculated. By increasing GFA, emissions of SNU will be increased to 144,612tCO_2-eq. On the other hand, to carry out the GHG Target Management, SNU should reduce the expected GHG emissions by 15% over until 2016. Table 4 summarize BAU, estimated allowed emissions and require reductions.

Table 4. BAU, allowed emissions and require reductions (2012-2016)

year	GFA (m^2)	BAU (tCO_2-eq)	target	allowed emissions (tCO_2-eq)	Require reductions (tCO_2-eq)
2012	1,215,757	118,964	2.2%	116,347	2,617
2013	1,224,777	119,847	5.3%	113,495	6,352
2014	1,318,104	128,979	8.0%	118,661	10,318
2015	1,426,689	139,604	10.6%	124,806	14,798
2016	1,477,863	144,612	15.0%	122,920	21,692

4. Construction of Database

4.1 GHG Reduction Technology DB

In order to derive applicable GHG reduction technologies, we investigated and analyzed the following materials.

- Energy reduction projects of the SNU
- Reduction technologies based on the literature survey
- Reduction technologies presented by Korean Energy Management Corporation (KEMCO)
- Reduction technologies which applied other green buildings or green campuses
- Reduction technologies in energy consulting company, etc.

GHG reduction technologies are extracted by interviewing building energy experts and these are stored into database with their properties such as unit cost, energy efficiency, and payback time, etc. Table 5 is the sample of the database. Total 64 technologies are constructed into database and these are classified as shown in Figure 1.

Table 5. Database of Reduction Technologies (sample)

NO	Main-category	Sub-category	Content	Unit cost (won)	Energy Saving (tCO2/year)	Payback (year)	Difficulty
1	architecture	Lighting	LED bulb	30,900	0.028	5.1	easy
2	architecture	insulation	Outside insulation	28,000	0.022	5.8	normal
3	architecture	window	Double window	128,000	0.030	19.6	normal
4	architecture	lighting	Install lighting sensors	200,000	0.400	4.0	easy
5	equipment	transformer	load regulating resistor	6,060,000	18.7	1.5	easy

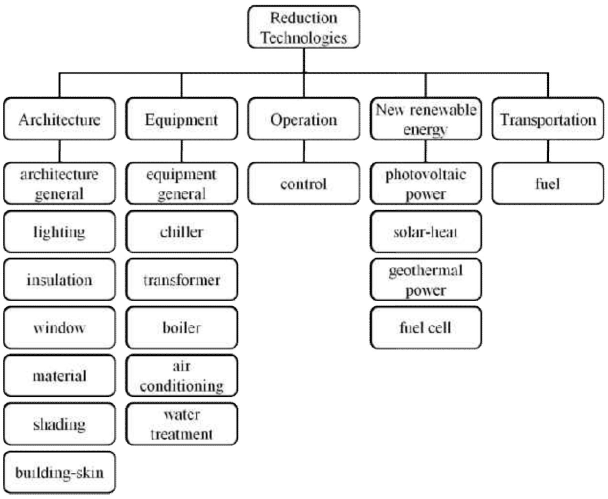

Figure 1. Classification of reduction technologies

4.2 Classify rooms by its purpose

Each room in campus has various characteristics of energy consumption according to its purpose, so distinguishing room type by its purpose is required. In order to calculate a potential GHG reduction, all rooms of two campuses are classified by its purpose. These are classified 8 main-categories and 24 sub-categories and represented Table 6. Table 7 represents the area of each main-category by room type.

Table 6. Classification of room type

Main-category	Sub-category
Education	▪ classroom ▪ meeting room ▪ multimedia classroom
Activity	▪ research room ▪ professors' office ▪ library ▪ gym
Office	▪ business office ▪ service office ▪ administration office
Residence and commerce	▪ residence ▪ commerce ▪ restaurant
Commom space	▪ corridor and hall ▪ stairs ▪ toilet
Facility	▪ pit ▪ parking ▪ equipment room ▪ warehouse
Laboratory	▪ laboratory (experiment) ▪ laboratory (non-experiment)
Etc.	▪ vacancy ▪ etc.

Table 7. Area of room type

(unit : m^2)

Class	Gwan-ak	Yun-gun	Sum
Education	106,760	8,946	115,706
Activity	200,266	15,518	215,784
Office	84,316	10,026	94,342
Residence and commerce	95,798	11,930	107,728
Commom space	270,702	31,872	302,574
Facility	169,763	15,494	185,257
Laboratory	83,974	26,874	110,848
Etc.	64,535	8,203	72,738

4.3 Standard Model by use

Based on 4.2, the eleven sub-categories (classroom, meeting room, multimedia classroom, research room, professors' office, library, gym, business office, administration office, toilet and laboratory) are derived that use much energy and are utilized frequently. For each category, the standard rooms are selected with the median value of the GFA and investigated in basic information and energy equipments information. Basic information includes GFA, number of user, operation hours per day, operation days per year, etc. Energy equipments information is divided into 4-categories, such as personal electronic devices, public electronic devices, lightings and experimental equipments. These are stored in the database and Table 8 is the sample of the database.

Table 8. Database of Standard model (classroom)

Basic Information				
room	area (m^2)	number of user (people)	operation hours (hour)	operation days (day)
1-102	58.41	18.0	5.0	140.0
Energy Equipments Information				
Category	Equipment			EA
electronic devices	fluorescent bulbs			12
public electronic devices	TV			1
	EHP			1
	ventilating fan			0
	speaker			4
	projector			0
	eraser cleaner			1

5. GHG Reduction Scenarios of SNU

5.1 Derive applicable reduction Technologies

In the GHG reduction Technologies database, the reduction technologies that can be applied for SNU immediately are deduced by considering the cost, the level of technologies, reductions and installation difficulty. Reduction technologies which are impossible to carry out validation and not clearly classified as a reduction method of GHG Target Management are excluded. Because of current technology level or cost problems, technologies such as smart grid and fuel cells are also excluded. The number of derived applicable technologies is 26 and they are summarized as Table 9.

Table 9. Derived Applicable Technologies

category		Technology
main	sub	
Architecture	lighting	LED bulb
		high-efficiency metal-halide lamp
		high-illuminance reflector
		Install lighting sensors
		3-way switch
	insulation	roof insulation
	window	double glazing
	building-skin	roof planting (grass)
	general	air leakage sealing
Equipment	chiller	Changing old chillers
		absorber chiller
	transformer	load regulating resistor
	air conditioning	turn off TR for EHP(spring/fall)
		night ventilation
	boiler	Changing old boilers
		replacement and repair old pipes
		adjustment fuel-efficiency and cleansing
	general	motor changing
Operation	control	reduce standby power
		e/v operate every other floor
		decreasing illuminance
		turn off lighting after lecture
		turn off lighting by window in the daytime
		smart system for heating and cooling
		dormitory energy usage based system
New renewable energy	solar-heat	solar water heating system

5.2 GHG reduction Scenarios

Based on the reduction technology database and standard models, we estimate the reductions that applied each scenario. Estimating GHG reductions per unit area by applying reduction technologies to standard model, and multiplying it by the total area of room type is the GHG reductions of room type. Sum of each reduction is the total GHG reductions. In order to avoid duplication between technologies, when the overlap between technologies occurs, large-reductive technology is prior to the others.

$$G = \sum_i \sum_j \left(\frac{g_j \times A_j}{a_j} \right)$$

(**Formula 2**)

where, G = total GHG reduction volume
g_{ij} = reduction volume of *j*th standard model when *i*th technology applied
A_j = total area of *j*th use
a_j = area of *j*th standard model

(1) Scenario 1 : SNU's Existing Plan for GHG Target Management

At December 2011, SNU made the plan for performing GHG Target Management and saving energy. For this, they applied 14 technologies such as replace with LED bulbs, install light sensors, etc. Estimated reductions when the technologies are applied at SNU are summarized as Table 10 and expected annual GHG reductions are Table 11. However, compared with required reductions (table 4), expected reductions of existing plan is insufficient for performing GHG Target Management. Therefore, SNU will make additional reduction plan and reduce more GHG than now.

Table 10. Reductions by Existing Plan

Technology	Reductions (tCO_2-eq)	Range
LED bulb	1,202	2473 ea.
install lighting sensors	135	toilet
	69	corridor
	262	2500 ea. for stairs
	343	20 underground parkings
	180	30 libraries
3-way switch	28	
changing old chillers	356	
absorber chiller	243	
load regulating resistor	634	
turn off TR for EHP	223	
changing old boilers	1,708	
adjustment fuel-efficiency and cleansing	87	
motor changing	24	43 ea.
reduce standby power	1,544	PC
	378	OA
turn off lighting after lecture	53	423 rooms
smart system for heating and cooling	6,508	60%
solar water heating system	334	22 buildings
sum	14,311	

Table 11. Annual Reductions of Scenario 1

(unit : tCO_2-eq)

Year	2012	2013	2014	2015	2016
Annual reductions	2,721	7,090	9,468	11,683	14,311

(2) Scenario 2 : Maximum Reductions

The Scenario 2 is the maximum reductions until 2016. It is calculated that entire applicable technologies are utilized at SNU, summarized as Table 12 and expected annual GHG reductions are Table 13. This scenario is over the annual required reductions.

Table 12. Maximum Reductions

Technology	Reductions (tCO2-eq)	Range
LED bulb	3,607	5000 ea.
high-efficiency metal-halide lamp	205	2400 ea.
high-illuminance reflector	645	6000 ea.
install lighting sensors	1,018	5000 ea.
3-way switch	28	
roof insulation	325	60%
double glazing	1,627	30%
roof planting (grass)	542	30%
air leakage sealing	904	50%
changing old chillers	356	
absorber chiller	445	central library + college of music and art
load regulating resistor	634	
turn off TR for EHP(spring/fall)	223	75hours/year
night ventilation	362	50%
Changing old boilers	1,708	
replacement and repair old pipes	13	
adjustment fuel-efficiency and cleansing	87	
motor changing	24	43 ea.
reduce standby power	1,922	14,000 ea.(PC)
e/v operate every other floor	25	50 ea.
decreasing illuminance	1,446	100%
turn off lighting after lecture	53	423 rooms
turn off lighting by window in the daytime	2,056	100%
smart system for heating and cooling	6,508	60%
dormitory energy usage based system	2,094	Entire dormitory
solar water heating system	667	44 bulidings
sum	27,524	

Table 13. Annual Reductions of Scenario 2

(unit : tCO_2-eq)

Year	2012	2013	2014	2015	2016
Annual reductions	3,260	8,524	11,830	18,789	27,524

(3) Scenario 3 : To response GHG Target Management

Based on scenario 1 and 2, the scenario for response to GHG Target Management is proposed. Reduction technologies of scenario 1 are applied first; and then additional technologies are added by considering cost, energy-saving and difficulty of installation. Annual reductions of this scenario are just above the required reductions and it is the optimum level for performing the GHG Target Management.

Table 14. Additional Reductions

Technology	Reductions (tCO2-eq)	Range
LED bulb	243	Yun-gun campus
high-efficiency metal-halide lamp	102	1200 ea.
high-illuminance reflector	322	3000 ea.
roof insulation	325	60%
double glazing	1,627	30%
roof planting (grass)	181	10%
air leakage sealing	904	50%
absorber chiller	202	college of music and art
night ventilation	72	50%
replacement and repair old pipes	13	
e/v operate every other floor	25	50 ea.
decreasing illuminance	1,446	100%
turn off lighting by window in the daytime	1,028	50%
dormitory energy usage based system	1,047	50%
sum	7,538	

Table 15. Annual Reductions of Scenario 3

(unit : tCO_2-eq)

Year	2012	2013	2014	2015	2016
Annual reductions	3,260	8,144	11,125	16,522	21,849

5.3 Comparison of the scenarios

Table 16 compares three scenarios with BAU and estimated allowed emissions. The Existing GHG reduction plan (scenario 1) has lower reductions than the estimated allowed emissions, whereas maximum reduction (scenario 2) can be reduced over required reductions. We suggest the response scenario that according additional technologies to scenario 1, and it is adaptable for performing GHG Target Management.

To establish a GHG reduction plan after 2016, reduction technologies such as Smart Grid, BEMS, and Passive-House technology are required. These technologies are now studying and applying worldwide. Nevertheless, they required more time for installation, SNU should make long-term plan for applying future technologies.

Table 16. Comparison of Scenarios

(unit : tCO_2-eq)

year	2012	2013	2014	2015	2016
BAU	118,964	119,847	128,979	139,604	144,612
allowed emissions	116,347	113,495	118,661	124,806	122,920
required reductions	2,617	6,352	10,318	14,798	21,692
Scenario 1	2,721	7,090	9,468	11,683	14,311
Scenario 2	3,260	8,524	11,830	18,789	27,524
Scenario 3	3,260	8,144	11,125	16,522	21,849

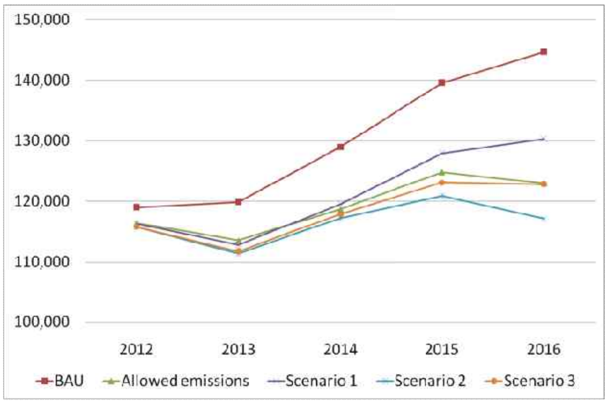

Figure 2. SNU GHG Reduction Scenarios

6. Conclusion

In this research, the Seoul National University's energy usage is analyzed and applicable technologies for reducing GHG emissions are extracted. Hence, three scenarios for performing the GHG Target Management is established.

Proposed scenario is available for GHG Target Management and it would be expected to support decision-makings for reducing GHG emissions. This scenario has applied to SNU's GHG reduction plan and utilized for basic information. In order to perform GHG Target Management continually, SNU needs to prospect and research for additional reduction technologies.

This research suggests the method of decision-making for GHG reduction. If the database is advanced, it will propose more various alternatives. As the research is limited to SNU GHG emission reductions, applying to other kinds of projects is required. Moreover, additional researches about cost fluctuations from economies of scale and external attributes which effect to GHG emissions are required. It will be developed establishing optimum GHG reduction path by applying optimization methodology such as Genetic Algorithms.

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