



# An integrated multi-objective optimization model for establishing the low-carbon scenario 2020 to achieve the national carbon emissions reduction target for residential buildings



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## ABSTRACT

This study aimed to develop an integrated multi-objective optimization (iMOO) model for establishing the low-carbon scenario 2020 to achieve the national carbon emissions reduction target (CERT) (27.0%) for South Korea's residential building sector. This study was conducted in six steps: (i) analysis on the energy consumption patterns of the multi-family housing complexes (MFHCs) by cluster; (ii) establishment of the energy retrofit models for the target MFHC through energy simulation; (iii) scale conversion from the target MFHC to the standard MFHCs by cluster; (iv) life-cycle economic and environmental assessment on the energy retrofit models of the standard MFHCs by cluster; (v) trend analysis of the energy saving effects for the energy retrofit models of the standard MFHCs by cluster; and (vi) establishment of the low-carbon scenario 2020 for achieving the national CERT by using an iMOO model. The results showed that if the optimal low-carbon scenario 2020 is to be implemented as of 2012, the energy-saving effect as of 2020 would be 27.20%. This was determined as follows: (i) the initial investment cost was \$1,410,252, 102.5% of the optimized value (optimization goal A); (ii) NPV<sub>40</sub> (net present value at year 40) was \$18,954,210, 71.9% of the optimized value (optimization goal B); and (iii) SIR<sub>40</sub> (saving to investment ratio at year 40) was 5.03, 74.2% of the optimized value (optimization goal C). The proposed model may be useful for policymakers in determining the optimal low-carbon scenario 2020 for achieving the national CERT under the budget limits, from the macro perspective.

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## Nomenclature

$BCC_{KCER}$	benefit from the sale of carbon credits by KCER	$f_{TS(i)}(x)$	function of calculating the total floor area of the standard MFHCs by cluster
ASHRAE	American society of heating, refrigerating and air-conditioning engineers	$f_{TT}(x)$	function of calculating the total floor area of the target MFHC
BAU	business-as-usual	$f_{CS(i,k)}(x)$	function of calculating the initial investment costs of the energy retrofit models for the standard MFHCs by cluster
BEP	break-even point	$f_{CT(i,k)}(x)$	function of calculating the initial investment cost of the energy retrofit models for the target MFHC
$BES_t$	benefit from the energy savings in year t	$f_{CSCF(i)}(x)$	function of calculating the CSCF
$BET_t$	benefit from the emissions trading in year t	$f_{RAEU(i)}(x)$	function of calculating the ratio of the annual electricity consumption per unit area between the target and standard MFHCs by cluster
CAGR	compound annual growth rate	$f_{RT(i)}(x)$	function of calculating the ratio of the total floor area between the target and standard MFHCs by cluster
CART	classification and regression tree	GA	genetic algorithm
CEF	carbon emission factor of energy	GHG	greenhouse gas
CERTs	carbon emissions reduction targets	iCAGR	improved compound annual growth rate
$CI_t$	cost of the initial investment in year t	iMOO	integrated multi-objective optimization
$CR_t$	cost of the repair work in year t	KLHC	Korea land & housing corporation
$CRT_t$	cost of the replacement work in year t	KEPCO	Korea electric power corporation
CSCF	cost scale conversion factor	LCC	life cycle cost
CV(RMSE)	coefficient of variation of the root mean square error	LCCO <sub>2</sub>	life cycle CO <sub>2</sub>
DT	decision tree	LED	light-emitting diode
ERMs	energy retrofit models	MFHCs	multi-family housing complexes
ESCF	energy scale conversion factor	MRA	multi-regression analysis
ESTs	energy saving techniques	NPV	net present value
$f_{ES(i,j,k)}(x)$	function of calculating the monthly electricity consumptions of the energy retrofit models for the standard MFHCs by cluster	NRE	new and renewable energy
$f_{ET(i,j,k)}(x)$	function of calculating the monthly electricity consumptions of the energy retrofit models for the target MFHC	PDF	probability density function
$f_{ESCF(i,j)}(x)$	function of calculating the ESCF	PV	solar photovoltaic
$f_{RMEU(i,j)}(x)$	function of calculating the ratio of the monthly electricity consumption per unit area between the target and standard MFHCs by cluster	REM	reference energy model
$f_{RAET(i)}(x)$	function of calculating the ratio of the annual electricity consumption per total floor area between the target and standard MFHCs by cluster	SIR	savings-to-investment ratio
		TFA	total floor area
		$UP_{KCER}$	unit price of CO <sub>2</sub> by KCER
		VBA	visual basic for applications

## 1. Introduction

Kyoto Protocol, which was adopted at the 3rd *Conference of the Parties* to the *United Nations Framework Convention on Climate Change* held in Kyoto, Japan, on 11 December 1997, defined the industrialized countries' obligation to reduce their respective greenhouse gas (GHG) emissions. According to the Kyoto Protocol, the industrialized countries established the carbon emissions reduction

targets (CERTs) by 2020 [1]. The United States (U.S.) established a 17% CERT from its total carbon emissions in 2005, and Japan established a 25% CERT from its total carbon emissions in 1990. In *Carbon Pollution Reduction Scheme* published in 2008, Australia also announced a 5%–15% CERT from its total carbon emissions in 2000. EU announced its *Climate and Energy Package*, which targets a 20% CERT from its total carbon emissions in 1990 [2,3].

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