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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_{40} (net present value at year 40) was $18,954,210, 71.9% of the optimized value (optimization goal B); and (iii) SIR_{40} (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.

Contents

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Nomenclature

BCC_{KCER}	benefit from the sale of carbon credits by KCER
ASHRAE	American society of heating, refrigerating and air-conditioning engineers
BAU	business-as-usual
BEP	break-even point
BES_t	benefit from the energy savings in year t
BET_t	benefit from the emissions trading in year t
CAGR	compound annual growth rate
CART	classification and regression tree
CEF	carbon emission factor of energy
CERTs	carbon emissions reduction targets
CI_t	cost of the initial investment in year *t*
CRr_t	cost of the repair work in year t
CRt_t	cost of the replacement work in year
CSCF	cost scale conversion factor
CV(RMSE)	coefficient of variation of the root mean square error
DT	decision tree
ERMs	energy retrofit models
ESCF	energy scale conversion factor
ESTs	energy saving techniques
$f_{ES(i,j,k)}(x)$	function of calculating the monthly electricity consumptions of the energy retrofit models for the standard MFHCs by cluster
$f_{ET(i,j,k)}(x)$	function of calculating the monthly electricity consumptions of the energy retrofit models for the target MFHC
$f_{ESCF(i,j)}(x)$	function of calculating the ESCF
$f_{RMEU(i,j)}(x)$	function of calculating the ratio of the monthly electricity consumption per unit area between the target and standard MFHCs by cluster
$f_{RAET(i)}(x)$	function of calculating the ratio of the annual electricity consumption per total floor area between the target and standard MFHCs by cluster
$f_{TS(i)}(x)$	function of calculating the total floor area of the standard MFHCs by cluster
$f_{TT}(x)$	function of calculating the total floor area of the target MFHC
$f_{CS(i,k)}(x)$	function of calculating the initial investment costs of the energy retrofit models for the standard MFHCs by cluster
$f_{CT(i,k)}(x)$	function of calculating the initial investment cost of the energy retrofit models for the target MFHC
$f_{CSCF(i)}(x)$	function of calculating the CSCF
$f_{RAEU(i)}(x)$	function of calculating the ratio of the annual electricity consumption per unit area between the target and standard MFHCs by cluster
$f_{RT(i)}(x)$	function of calculating the ratio of the total floor area between the target and standard MFHCs by cluster
GA	genetic algorithm
GHG	greenhouse gas
iCAGR	improved compound annual growth rate
iMOO	integrated multi-objective optimization
KLHC	Korea land & housing corporation
KEPCO	Korea electric power corporation
LCC	life cycle cost
$LCCO_2$	life cycle CO_2
LED	light-emitting diode
MFHCs	multi-family housing complexes
MRA	multi-regression analysis
NPV	net present value
NRE	new and renewable energy
PDF	probability density function
PV	solar photovoltaic
REM	reference energy model
SIR	savings-to-investment ratio
TFA	total floor area
UP_{KCER}	unit price of CO_2 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].