Is Energy Policy on the Right Track for the Climate Target in the Korean Building Sector?

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Abstract

The building sector in Korea is one of the key end-use sectors in terms of energy use and accompanying greenhouse gas (GHG) emissions. The sector currently accounts for about one-fifth of economy-wide final energy consumption and greenhouse gas emissions. In this study, we project a business as usual (BAU) scenario for energy and GHG emissions for the building sector based on the government energy forecast, and then develop a couple of policy scenarios which reflect the current state of energy policy. We compare each policy scenario and some combinations with already-pledged climate policy targets to determine whether energy and climate polices are inherently consistent and, if not, how much of an emission gap exists. The most aggressive energy policy combination can only curb the emissions level at 139 MtCO₂ by 2020, which falls 14% short of the climate target of 123 MtCO₂. Beyond 2020, the lowest emissions pathway of the current energy policy can only go as low as 115 MtCO₂ by 2035. These findings provide supporting evidence that there is a discrepancy between current energy policy and climate change policy and suggest that effective policy coordination is necessary among government ministries in setting a credible long-term climate policy target.

Keywords: greenhouse gas; energy policy; climate policy; building sector in Korea

1. Introduction

The Republic of Korea, which imports about 97% of its energy resources from overseas, has experienced growing energy consumption in past decades mainly correlated with economic growth, and this upward trend seems unlikely to change in the near future. Among other sectors, energy use in the building sector, which accounts for 20% of total final energy use in 2012, has increased from 22.0 million tons of oil equivalent (TOE) in 1990 to 37.9 million TOE in 2012 at the annual rate of 2.5% as shown in the upper panel of Fig.1. Energy use growth in the building sector has been mostly driven by commercial buildings while residential and public building energy use has been relatively stable over time.

The sector’s fuel mix, however, has experienced more of an extreme change over time. While the share of coal and oil has diminished from 80% in 1990 to less than 20% in 2012, the share of network-based...
energy sources—such as electricity, gas, and heat—is now responsible for a large portion of final energy consumption as presented in the lower panel of Fig.1.

When it comes to GHG emissions, the building sector emitted 140MtCO$_2$e in 2012 which accounts for about 21% of total GHG emissions in Korea (GIR, 2014) and has increased at the annual rate of 3.1% over the past 10 years. Indirect emissions which come from the use of electricity and heat account for about 65% of total emissions in the building sector.

The South Korean government has put forward an economy-wide domestic target to reduce its GHG emissions by 30% by 2020 (ROK, 2012) and 25.7% by 2030 (ROK, 2015) below BAU emissions levels as summarized in Table 1. This is equivalent to limiting GHG emissions at 543 MtCO$_2$e by 2020 and 632 MtCO$_2$e by 2030. For the 2020 target, also known as the Copenhagen pledge, the government materialized this abatement target for the building sector, which was set at 26.9% below the BAU level, equivalent to 122.6 MtCO$_2$e.

Another key policy, related to climate change policy, is the Energy Master Plan (EMP)—which is an overarching and comprehensive government plan that covers all energy sectors, and systematically links and coordinates energy-related plans from a macro perspective. It presents principles and directions for energy-related plans by source and by sector. The main purpose of the master plan is to suggest the direction of future-oriented energy policies and determine mid- and long-term strategies to systematically secure energy resources, expand stable infrastructure for supplying domestic energy, and rationalize the use of energy needed for the sound development of the national economy (MOTIE, 2014). In its latest version, the Second Energy Master Plan (2nd EMP), the forecast of final energy consumption and target for the building sector are specified as in Table 2.

There is emerging literature which evaluates the feasibility of individual countries' climate mitigation pledges and assesses the attainability of the long-term climate target on the global scale such as UNEP’s Emissions Gap Report series (UNEP, 2016). Most of these modelling and scenario studies estimated future emission pathways based on key energy and climate policies currently considered or implemented, and compared their estimates with the official government mitigation proposals.

In particular for Korea, there are several studies which address this question (Roelfsema et al., 2014; BENF, 2015; CAT, 2015; den Elzen et al., 2015). Most of these studies conclude that Korea’s climate mitigation proposal is too ambitious and unlikely to be met with current energy and climate policies. In line with this literature, this study aims to develop GHG emissions scenarios for the building sector in Korea until 2035—which are based on the government energy forecast and policy targets as outlined in the 2nd EMP; to compare them with climate mitigation targets to determine whether both energy and climate polices are inherently consistent; and, if not, to calculate how much of an emissions gap exists.

Table 1. Summary of Climate Change Policy of Korea

| MtCO$_2$e                | 2010 | 2015 | 2020 | 2025 | 2030 |
|-----------------------|-----|-----|-----|-----|-----|
| INDC (ROK, 2015)      |     |     |     |     |     |
| BAU Level             | 657 | 714 | 783 | 810 | 851 |
| 2020 Target           | -   | -   | -   | -   | 632 |
| Copenhagen Pledge     |     |     |     |     |     |
| (ROK, 2012)           |     |     |     |     |     |
| BAU Level             | 657 | 709 | 776 | -   | -   |
| 2020 Target           | 638 | 543 | -   | -   | -   |
| Bldg. Sector Target   | 140 | 142 | 123 | -   | -   |

Table 2. Energy Consumption Forecast and Policy Target for Building Sector in the 2nd EMP

| Million TOE | 2011 | 2025 | 2030 | 2035 | p.a. growth rate (%) |
|-------------|------|------|------|------|----------------------|
| Forecast    |      |      |      |      |                      |
| Residential | 21.6 | 24.2 | 24.6 | 24.9 | 0.59                 |
| Commercial  | 15.9 | 23.6 | 26.0 | 28.1 | 2.39                 |
| Target      |      |      |      |      |                      |
| Residential | 21.6 | 23.4 | 23.6 | 23.6 | 0.37                 |
| Commercial  | 15.9 | 22.1 | 23.8 | 25.0 | 1.9                  |

2. Method
2.1 Modeling Framework

We developed a Korean building sector model in the MESSAGE (Model for Energy Supply System Alternatives and their General Environmental impacts) framework (Messner and Strubegger, 1995). MESSAGE is widely used for medium- to long-term energy system planning, energy policy analysis, and energy-environment linked scenario development and analysis (Nakićenović et al., 1998; Nakicenovic and Swart, 2000; Metz, 2001; Schrattenholzer et al., 2004; Metz, 2007; Riahi et al., 2007; O’Neill et al., 2010; Riahi et al., 2011; GEA, 2012).

MESSAGE is a dynamic linear programming model of the overall energy system. It can model flows of energy and resultant environmental impact with all interdependencies within an energy system from resource extraction, imports and exports, through conversion, transport, and distribution, to the provision of useful energy services (e.g. thermal comfort, illumination, appliance use, industrial process heat, and mobility, etc.) to various end-use sectors (e.g. industry, residential, commercial, and transport sector).

The model uses two major types of decision variables: activity variables describing the fuel consumption of technologies and capacity variables for new installation of technologies. The model minimizes the objective function subject to the energy balance and demand constraints. The objective function is the sum of the discounted costs incurring in an energy...
system such as total fuel costs and investment and operating costs of technologies involved.\(^3\) In this study, MESSAGE, with the system boundary of the Korean building sector, finds the least cost solution for energy flows and reports associated GHG emissions under the assumptions of each scenario considered.

In the model, energy demand is broken into specific service categories such as heating & hot water, cooling, lighting, appliances, cooking, etc. Each service demand is linked to a set of technologies which provide the specific energy-related service. For example, heating and hot water service can be satisfied by an oil-burning boiler, gas-burning boiler, or solar thermal unit, etc. The reference energy system, as shown in Fig.2., schematically illustrates the structure of the model, delineating service categories, technologies, and fuel types considered in the model.

### 2.2 Service Demand Projection

Historical data for energy consumption of each service category comes from the Energy Consumption Survey (MKE, 2011). We, first, compiled the historical unit energy consumption (e.g. per capita for residential building and per floor space for commercial building) for each service, and forecasted them into the future based on the fitted historical trends. Then, we multiplied the unit energy consumption by total population or total floor space to estimate the total energy consumption for each service.

Fig.3. illustrates the historical development and resulting projection of energy consumption for each service. The resulting projections seem to be well in line with the historical trend.

### 2.3 Scenarios and Assumptions

We considered four scenarios as described in Table 1. The **BAU** scenario is a reference scenario where each energy service demand category is projected from a fitted historical trend using future socio-economic assumptions such as population, income, and floor space—as in Table 2. Each service demand was further adjusted in a way such that the total final energy consumption for the residential and commercial sector corresponded to that of the 2nd EMP’s baseline forecast until the year 2035.

The **LowDmd** scenario corresponds to the 2nd EMP’s policy target which aims to reduce the final energy consumption by 5% for residential and 11% for commercial buildings by 2035 compared to the baseline forecast.

The **Renew** scenario further expands renewable energy use. The share of renewable energy in the building sector was set to increase to 4.5% by 2020 and 15% by 2035 as targeted in the 2nd EMP.

The **ElecDeCO** scenario reflects the transformation of the power sector in Korea as manifested in the 6th Basic Plan for Long-term Electricity Supply and Demand (6th ESDP) (MKE, 2013) which is another key government energy plan on electricity supply and demand with a 15-year time horizon. Its objective is to provide electricity policy direction, information on electricity supply and demand outlook, and the electricity capacity plan to secure electricity supply.

Table 3. presents the projection of GHG emission factors of grid-connected electricity adopted from Cho and Jean (2014) who simulated the feasible range of GHG emissions given the electricity demand forecast and generation capacity plan of the 6th ESDP. It should be noted that the extent of decarbonization in ElecDeCO scenario is a very costly one, in which coal-fired electricity generation capacity would be substituted by gas-fired capacity in order to reduce the...
Table 3. Scenario Classification

| Scenario Name | Scenario description |
|---------------|----------------------|
| **BAU**       | *Business as usual.* Each energy service demand is projected from a fitted historical trend. Projection is a simple function of socio-economic assumptions such as population, income, floor space, value added, etc. |
| **LowDmd**    | *Low Demand.* The rates of demand reduction are adopted from the 2nd EMP’s target scenario: 5% for residential and 11% for commercial by 2035 compared to BAU. The plan prescribes the enhancement of insulation standards for new buildings, the scope expansion of the energy performance certification scheme for existing buildings, and improvement of energy efficiency standards for appliances as a building-customized energy conservation measure. |
| **Renew**     | *Renewable expansion.* The share of renewable energy in the building sector increases to 4.5% by 2020 and 15% by 2035 as targeted in the 2nd EMP. The share in BAU is 1.2% in 2020 and 4.8% in 2035. |
| **ElecDeCO2** | *Electricity decarbonization.* Two projections of electricity GHG emission factors are considered from Cho and Jean (2014) which simulates the feasible range of future GHG emission pathways based on the government electricity supply and demand plan, 6th ESDP. |

| GHG emission factors for electricity | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
|-----------------------------|------|------|------|------|------|------|
| **BAU**                     | 458  | 429  | 401  | 372  | 343  | 316  |
| **ElecDeCO2**               | 458  | 417  | 376  | 334  | 293  | 257  |

Table 4. Socio-economic Assumption

| Socio-economic variables | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | Source       |
|--------------------------|------|------|------|------|------|------|--------------|
| GDP (trillion KRW)       | 1,082| 1,263| 1,559| 1,837| 2,107| 2,407| KDI (2013)   |
| Population (thousand persons) | 49,410| 50,617| 51,435| 51,972| 52,160| 51,888| KOSTAT (2011) |
| Income per capita (thousand KRW) | 21,900| 24,950| 30,310| 35,350| 40,390| 46,390| -            |
| Floor space of commercial buildings* (km²) | 614  | 847  | 1,047| 1,206| 1,334| 1,432| -            |

*Floor space is regressed by value-added of commercial sector using the following equation:

\[ y_t = 1,051 \ln(x_t) - 13,249 \] (x: floor space, x: value-added)

![Fig.3. The Energy Service Demand (Left: Residential, Right: Commercial): Historical Trend and BAU Projection](image-url)
GHG emissions in the power sector. It is estimated that such fuel substitution incurs higher fuel costs and stranded coal-fired capacity.  

3. Result
MESSAGE finds flows of energy carriers and associated GHG emissions over time in a least cost way under the assumptions of each scenario such as efficiency improvement, enhanced renewable energy penetration, or the transformation of the power sector. Emission factors for GHGs, defined as tons of CO$_2$e per TOE, is parametrized in the model and the emissions level is accounted by energy carrier, technology, or sector depending on the reporting purpose. The scenario results are reported in terms of final energy consumption by energy carrier and the total GHG emissions of the entire building sector.

3.1 Final Energy Mix
Fig. 4. presents the development of final energy consumption for the building sector by energy source (i.e. upper panel for the BAU and lower panel for the LowDmd). In the BAU, the entire building sector would use 53 kTOE in 2035 which is a 43% increase from 37 kTOE in 2010. The energy consumption would reduce to 48.7 kTOE by 2035 in the LowDmd scenario, or 8% less than in the BAU.

In both scenarios the use of relatively disadvantageous fuels—such as oil and coal—continue to diminish while the share of network-energy—such as electricity, gas and heat—is expected to rise from 81% in 2010 to 93% in 2035. Among them, grid-supplied electricity would account for 56% of the final energy consumption by 2035. The share of renewable energy—such as solar photovoltaic and solar thermal—would rise from 0.3% in 2010 to 4.5% by 2035.

It should be noted that when it comes to building-related GHG emissions, indirect emissions become more significant as electricity and heat are expected to account for a large proportion of energy use. It implies that energy and climate policy should place greater attention to the energy supply side—such as the power and heat sector.

3.2 GHG Emissions
The resultant GHG emission pathways of all scenarios considered in this study are plotted in Fig. 5. Under the BAU scenario, emissions are estimated to rise to 160 MtCO$_2$e until the mid-2020s and then flatten thereafter. The main reason is that the building sector is expected to be further electrified and the power sector becomes moderately decarbonized even with growing energy consumption (see Table 3.)

If energy demand is reduced as much as the energy efficiency policy intends (LowDmd), the emission level reaches 146 MtCO$_2$e by 2035, 8% less than that of BAU. Enhanced renewable energy penetration (Renew) has slightly greater abatement potential than the energy efficiency policy curbing the emissions level at 143 MtCO$_2$e by 2035. The greatest mitigation can be achieved by decarbonization in the power sector (ElecDecCO$_2$) where we assume that the power sector successfully transforms into a less carbon-intensive one as planned in the 6th ESDP (see Table 3.). As the building sector is expected to be further electrified, the electricity sector may play a greater role in carbon reduction. It implies that while the building sector-customized energy policy should focus on energy efficiency improvements and renewable deployment, at the same time, policy attention should also be placed on cross-sector energy policies such as those included in the ESDP.
Given that any individual policy measure alone falls short of curbing the emissions below current levels we combined individual measures together (dotted green lines in Fig. 5.). The most aggressive policy combination \((\text{LowDmd} + \text{Renew} + \text{ElecDeCO}_2)\), which implements all three measures simultaneously, makes it possible to curb emissions at the current level by 2020 and at 115 MtCO\(_2\)e by 2035, 17\% lower than the current level.

The contribution of each policy measure to the cumulative emissions abatement in the 'LowDmd + Renew + ElecDeCO\(_2\)' scenario is illustrated in Fig. 6. On average, the emissions would be abated at an annual rate of 8.35 MtCO\(_2\)e until 2020 while a deeper cut would be possible at the rate of 31 MtCO\(_2\)e per year post-2020. Each measure's contribution to the total abatement is almost equal. Of the 553 MtCO\(_2\)e reduction cumulated from 2010 to 2035, energy savings and efficiency improvements would contribute 30\% while renewable energy expansion and power sector decarbonization would contribute 35\%, respectively. The result justifies that a portfolio of policy levers covering various aspects of carbon emitting activity should be pursued rather than a single silver bullet instrument.

4. Conclusion and Discussion

In this study we first developed the energy system model for the Korean building sector in the framework of MESSAGE. Four scenarios were considered. The \(\text{BAU}\) scenario is based on the latest government energy forecast and three policy scenarios reflect current energy policy manifested in the government energy planning. The main purpose of this study is to estimate the mitigation potential of each policy measure and their combinations against the \(\text{BAU}\); then, to evaluate whether current energy policy is on the right track to achieving the climate target; and, if not, determine how much of an emission gap exists by comparing the scenario results with the pledged GHG mitigation target.

The general conclusions we can draw from the results are as follows.

First, current energy policy falls short of achieving the climate policy target. The discrepancy implies that either the energy policy should be majorly revised into a less carbon-intensive one or the climate policy needs to be recalibrated toward an achievable goal rather than failing to meet an ambitious but impossible one.

Second, carbon abatement in the building sector is quite dependent on the energy supply side as network-based energy sources will further dominate in the future. Thus, the transformation of energy supply systems into a low carbon one is prerequisite to effective abatement in the end-use sector.

Third, related to the first and second conclusion, effective policy coordination among government ministries is necessary in designing a credible and inherently consistent energy and climate policy. Otherwise, the commitment of the Korean government to tackling the climate change problem would be impaired both domestically and internationally.

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Notes
1 In its submission of INDC (Intended Nationally Determined Contribution) to the UNFCCC the South Korean government stated that a 25.7% reduction below the BAU level will be achieved domestically and a further 11.3% reduction will be achieved by international market mechanisms.
2 Additional constraints can be defined depending on the needs of the application; for example, the need to limit the market penetration of new technologies or to curb the total GHG emissions in the energy system.
3 See Messner and Strubegger (1995) and Schrattenholzer et al., (2004) for a full description of the mathematical formulation of MESSAGE.
4 Cho and Jean (2014) estimated that there would be a 10 billion KRW increase in fuel cost and a 31 billion KRW equivalent-investment in coal-fired capacity would be stranded temporarily in 2020.
5 Emission factors of fossil fuels and heat are adopted from GIR (2014).

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