Machine Learning Decision Support Model for Greenhouse Gas Reduction Technology Application

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Abstract: Many countries have implemented policies to reduce greenhouse gas (GHG) emissions since the 21st Conference of the Parties (COP 21) of the United Nations Framework Convention on Climate Change (UNFCCC) in 2015. The parties to this convention have voluntarily agreed to a new climate regime that aims to reduce greenhouse gas emissions. Subsequently, reducing greenhouse gas emissions through specific reduction technologies (renewable energy) to reduce energy consumption has become a necessity rather than an option. With the launch of the Korea Emissions Trading Scheme (K-ETS) in 2015, Korea has certified and funded projects to reduce greenhouse gas emissions. To help the user make informed decisions about the economic and environmental benefits of using renewable energy, an evaluation model has been developed. This study establishes a simple assessment method (SAM), an assessment database (DB) of 1199 greenhouse gas reduction technologies implemented in Korea, and a machine learning-based greenhouse gas reduction technology assessment model (GRTM). In addition, proposals are made to assess the economic benefits that can be obtained in combination with the environmental benefits of technology to reduce greenhouse gas emissions.

1 INTRODUCTION

After the lead version of the Kyoto Protocol of the United Nations Framework Convention on Climate Change. In 1997, many countries around the world, including Korea, made significant efforts to reduce greenhouse gas (GHG) emissions. In particular, building energy efficiency has been highlighted both in Europe and abroad, and many countries are strengthening building energy efficiency policies by regulating building design standards, promoting environmentally friendly benefits, and introducing zero-energy buildings (Korea Energy Agency, 2018). In order to successfully reduce spending across the country, led by the public sector, Korea included an incentive system for a new climate regime under 100 policy objectives. This required the republican institution to maintain membership fees (Ministry of Environment, 2019). As a result, starting in 2020, any newly constructed building owned by public institutions is required to introduce energy efficiency and achieve a 30% reduction in baseline emissions (in accordance with the agreements of 2007, 2008 and 2009) by 2030 (Ministry of Environment, 2017). However, lack of experience and understanding presents a major challenge to the implementation of this system and is the main reason why the policy is not effective. Several studies have been carried out to develop policies to reduce energy consumption or to analyze the implications of reducing greenhouse gas emissions from renewable energy. In addition, using the Emissions Trading Scheme (ETS), a system designed to support emission reductions, government agencies voluntarily undertake external emission reduction projects, certify emission reductions, and receive economic benefits from emissions trading (Ministry of Environment, 2018). In previous studies on the efficiency and control of greenhouse gas emissions, a greenhouse gas emission prediction system was developed, which determines the factors that contribute to emissions fluctuations, with an emission control system that compares different buildings based on the developed prediction model. It is noteworthy that Che (2017) used data analysis technology to increase the renewable energy market and compare indicators to select the optimal building for simulation (Chan, 2017). Chan (2018) predicted energy production from real-time energy generation database based on machine learning (Jang, 2018).

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2 MATERIALS AND METHODS

A study by nakawa (2018) on reducing energy consumption and reducing greenhouse gas emissions analyzed the impact of replacing conventional lamps with LEDs. Singh (2015) proposed GHG emission reduction guidelines for GHG emissions forecast up to 2030 under the ezp program for Israel (Nakano, 2018; Singh, 2015). Further analysis of the efficiency of renewable energy sources is needed. In addition, national policy, along with economic and environmental decision-making regarding renewable energy sources, should be changed based on the results of a comprehensive assessment of the energy performance of buildings. Since the World Economic Forum in Davos, Switzerland in January 2016, the idea of a fourth industrial revolution has become a controversial issue around the world. The fourth industrial revolution refers to a consumer-oriented economy based on technological automation and represents an era when the world is understood through artificial intelligence (AI) (Bottou). AI refers to technology that analyzes data through visualization, machine learning, and data mining to find better solutions. In AI, machine learning is a technique that reads huge amounts of data, finds an algorithm, and predicts changes. In the field of environmental architecture, there is a growing number of cases where machine learning is applied to a system for predicting economic and environmental benefits. When comparing the predictive ability between models using traditional statistical technique and models using machine learning technique, various studies have shown that the model using machine learning has a higher level of predictive ability (Jordan). Therefore, this study proposes an optimal machine learning model for GHG projects with a high level of predictive power that uses real renewable energy sources and examples of external GHG projects. We believe that this model is superior to costly and inefficient methods such as energy modeling. Through this work, we aim to help select projects with the most significant economic and environmental benefits compared to the actual energy consumption of an existing building.

This can be achieved by looking at energy production in greenhouse gas emission reduction projects that cover renewable energy, installation cost, efficiency and energy consumption by use and source, all of which contribute to emission reductions. A database of certified GHG emission reductions from renewable energy sources was created and used as the basis for building a machine learning model to support decision-making on GHG emission reduction projects. To analyze the predictive power of the fitted model, we used principal component analysis (PCA), selected gradient boosted regression tree (GBRT), support vector machine (SVM), and deep neural network (DNN) machine learning algorithms optimized for the original data set. in this study. We also tested the predictive power of machine learning methods by comparing their predictive power with a multiple regression model. Unlike previous studies that only compared the predictive power of different models, this study examines the applicability of machine learning to greenhouse gas reduction technologies by analyzing calculated numerical values. The Korean government subsidizes a certain portion of the installation costs to promote the spread of renewable energy. In response, businesses are adopting government-subsidized renewable energy sources such as solar power, solar thermal power, and geothermal power, along with efficient technologies including high-efficiency lighting, LED lighting, and green vehicles (Korea Energy Agency, 2018).

To the extent that reduced energy consumption in green vehicles can be converted into economic benefits, this study includes green vehicles in greenhouse gas emission reduction technologies. We have defined the introduction of renewable energy and high-efficiency equipment as "technologies to reduce greenhouse gas emissions." These technologies are recognized as emission reduction certified by the ETS. A GHG technology government agency converts KoreanOfset Credit (KOC) into Korean Credit Unit (KCU) and trades at approximately $19/tCO2e. technology was proposed to reduce greenhouse gas emissions and a database was created to convert them into economic value. The raw data built by the method was used to develop a model for selecting technologies to reduce greenhouse gas emissions using machine learning.

3 RESULTS AND DISCUSSION

The methods used to calculate emission reductions from GHG technology include a direct calculation using variables and another one using statistical data (Ministry of Environment, 2017). Based on the established baseline greenhouse gas abatement technology unit data, we selected the modeling methods used for supervised learning in machine learning and performed the analysis. Although there are many simulation methods for this type of learning, GBRT, SVM, and DNN methods were chosen in our study, which were used to develop predictive models in previous studies in Korea and abroad. In order to identify the phenomena represented by the collected data and any problems, we performed exploratory data analysis (EDA) and data pre-processing. In order to calculate the certified emission reduction for a specific GHG emission reduction technology, it is first necessary to determine the amount of energy produced or reduced by this technology. In our study, we proposed a direct assessment of energy production and reduction in accordance with the application of greenhouse gas emission reduction technology. The results were used as input data for the evaluation database. Solar energy refers to a method of generating electricity that directly converts solar energy into electrical energy using the photovoltaic effect. The annual electricity production from solar energy can be calculated using the capacity, the number of installed systems, the electricity utilization rate and the operation time factors (Peng, 2013).

Solar thermal energy systems harvest solar energy to heat or preheat water and are often used as the energy source for water heating. The annual amount of energy produced by solar thermal collectors can be calculated by taking into account the installed area of collectors, the number of households with collectors, the total reduction from the energy source and the number of working days. Geothermal energy refers to the energy of the earth, including hot water and rocks located deep underground. It is used as an energy source for cooling and heating buildings. Calculation of energy production for solar energy, solar thermal energy and geothermal energy was made by applying the operating time and electricity utilization factor to the installed capacity of these sources. Equipment efficiency among daily storage application rate calculations was calculated using the statistical estimates provided in the Greenhouse Gas Emission Reduction Plan Implementation Guide of the Ministry of Environment and Renewable Energy of the National Administrative Urban Construction Agency. When energy production from GHG emission reduction technology is not monitored, the daily storage application factor was calculated taking into account the load factor, average daily operation time and geothermal efficiency factor (GFC). When electricity is used as an energy source for heating and cooling energy of a building, the geothermal efficiency factor (GFC) is calculated taking into account the load factor, the average daily operation time and the geothermal heating efficiency factor, and a unit conversion factor of 860 (Mcal/MWh) was applied (Porfiriev, 2010). The cooling energy GFC was calculated taking into account the geothermal heating efficiency factor and the geothermal cooling efficiency factor. For SFC, the daily amount of solar heat storage, it was calculated by applying daily solar radiation, heat collector efficiency and the same unit conversion factor as GFC.

In order to evaluate high-efficiency equipment in projects certified by ETS as emission reduction for government agencies, we separated external greenhouse gas emission reduction projects that used high-efficiency equipment, high-efficiency lighting, LED street lighting installation, and green roofs (Nikoláeva, 2018). For high-efficiency equipment such as green rooftops, high-efficiency lighting, LED street lighting, electric vehicles and natural gas vehicles, the amount of energy saved was calculated by comparing the energy consumption before and after the project. The energy consumption of high-efficiency lighting and LED street lamps was calculated using electricity consumption, the number of luminaires installed and the time the lights were turned off. Based on the report on the supply and use of lighting equipment prepared by the Ministry of Commerce, Industry and Energy and the Korea Energy Agency, high-efficiency lighting is 5.3 hours, and the installation of LED street lighting is 10 hours without light (Porfiriev, 2010). The GHG emission reductions were calculated by applying the GHG emission factors for each energy source to the energy production results and reductions. In order to establish a standard environmental assessment database for greenhouse gas emission reduction projects, in our study, the amount of energy produced and reduced by greenhouse gas emission reduction technology was converted to greenhouse gas emission reduction when developing the assessment database with greenhouse gas emissions as base unit.

4 CONCLUSIONS

After studying 1199 technology projects to reduce greenhouse gas emissions, a method was proposed for estimating the amount of energy reduced and produced, and a certified greenhouse gas emission reduction (KOC) method was proposed. Using 1199 GHG technology projects, SAM was created, which is a GHG technology assessment database. To consider energy consumption patterns and environmental conditions in a building, SAM was created to evaluate the effect of reducing greenhouse gas emissions across different uses and energy sources. These include heating, cooling, lighting, ventilation and water heating, as well as energy sources such as electricity, city gas and heat. Based on the original SAM data, machine learning methods (GBRT, SVM and DNN) were used to develop

GRTM, a model that supports decision making for greenhouse gas reduction technologies.

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