Demand Forecasting and Development of Diffusion Model for Carbon Dioxide Capture and Storage Technology

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Abstract

Due to the increase interest in climate change, many countries make an agreement for reducing greenhouse gas(GHG) emissions. Korean government also makes a goal to reduce GHG emissions by 37% from business-as-usual levels until 2030, and submits their target of reducing GHG emissions to the United Nations framework convention on climate change in June, 2015. However, current renewable energy policies and demand-side management in Korea are not enough to accomplish GHG reduction target. Moreover, if Korean government focuses on GHG reduction target, it is hard to achieve economic growth target. Under the current circumstances, the carbon dioxide capture and sequestration (CCS) technologies are considered as a possible alternative which could achieve both economic growth and GHG reduction target. Some previous researches forecast demand of CCS technologies with a simple assumption, but they do not consider competitive situation in renewable energy market. Because CCS technologies could compete existing renewable energies, this study considers competitive situation and forecasts future demand of CCS technologies in competitive market. In addition, this study proposes new diffusion model which includes competitive market situation and measures technological competitiveness of CCS technologies. Based on the results of this study, we can provide the policy directions for CCS technologies.

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1. Introduction

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Introduction

- Due to the climate change, economic and non-economic loss have increased continuously
  - Assuming that the climate change trends continue, the average temperature and the amount of total damage in Korea are expected to increase about 4℃ and 2800 trillion Korean won (KRW),respectively in 2100 (KEI, 2008)
- Korean government submits their target of reducing GHG emissions to the United Nations framework convention on climate change in June, 2015
  - Reduce GHG emissions by 37% from BAU until 2030
- However, current renewable energy policies and demand-side management in Korea are not enough to accomplish GHG reduction target

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Introduction

- There are many convergence technologies lowering GHG emissions, but the importance of carbon dioxide capture and storage (CCS) technology is increased
  - CCS technology is expected to reduce GHG emissions up to 19% of global GHG emissions
  - Under the current circumstances, CCS technology is considered as a possible alternative which could achieve both economic growth and GHG reduction target
- This study investigates the current status of domestic CCS technology development and provides the investment direction of CCS technology by forecasting future demand of CCS technology in Korea
  - To achieve the research goals, this study proposes new diffusion model which includes competitive market situation in renewable energy market

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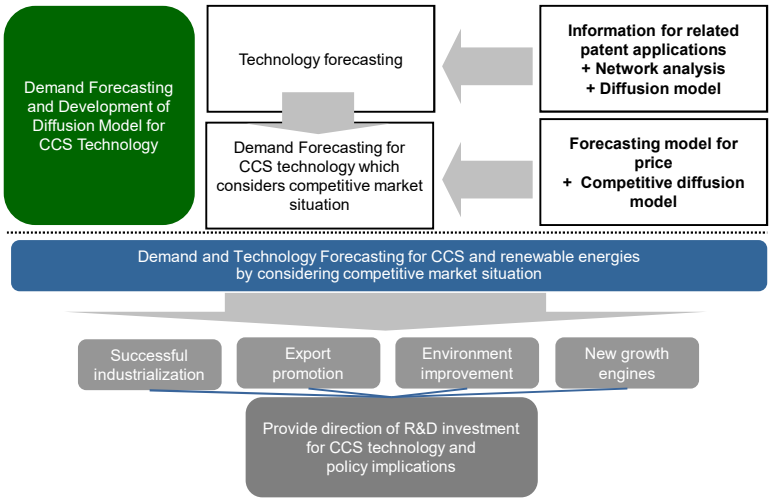
Introduction



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2. Literature

Literature

CCS technology policy trends

- **Global policy trends**
  - In 2008, International Energy Agency(IEA), Carbon Sequestration Leadership Forum and other organizations agreed to promote commercialization of CCS technologies
  - In 2010, the United States and China implemented CCS projects as a joint confrontation
- **Policy trends in Korea**
  - In 2010, the Committee on Green Growth and related department of Korea established 'synthesis promotion plan for CCS technology' to commercialize plants and secure technological competitiveness by 2020 (The Committee on Green Growth, 2010)
  - Ministry of Science, ICT and Future Planning set the goal which secures source technologies of CCS through 'KOREA CCS 2020' project
  - Ministry of Trade, Industry and Energy proceeded the large scale integrated project, which includes capture-transport-storage, in order to commercialize CCS technology by 2020
  - However, unlike global CCS policy, Korean government has not established mid/long-term road map for CCS technology after 2020

Literature

Existing research on GHG reduction technologies

- Previous research mostly focused on qualitative analysis and investigating the characteristics of related technologies, so quantitative analysis is relatively insufficient
- Research on renewable energy
  - Research for renewable energy could be divided into two parts: Acceptability of renewable energy technologies (Batley et al., 2001; Nomura and Akai, 2004; Yoo and Kwak, 2009; Kim et al., 2012) and consumer preference for renewable energy policies (Wiser, 2007; Mozumder et al., 2011; Longo et al., 2006; Shin et al., 2014)
  - Because renewable energy technologies and policies are in the initial phase, most previous research adopted contingent valuation methods and conjoint analysis by using survey data
  - However, previous research on renewable energy did not consider CCS technology which is one of the major growth engines in the future

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Literature

Existing research on GHG reduction technologies (Cont.)

- Research on CCS technology
  - Existing literature can be categorized into three different topics; Analysis of CCS technology characteristics(Liu and Gallagher, 2010), cost estimation of power generation after CCS adoption(Rubin and Zhai, 2012), and the reduced amounts of GHG emission and reduced cost(Azar et al., 2013)
  - According to existing studies, while technological characteristics, cost, GHG emission reduction effect and related costs regarding CCS technology were analyzed, those studies did not consider market environment and changing situation
  - Specifically, the fact that CCS adoption leads to increased competition with other renewable energies was not take into account

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3. Model

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Model

- The research models in this study are divided into two parts: Technology forecasting through patent analysis and demand forecasting through diffusion analysis
  - Patents are utilized to measure the level of technological development in industry or the level of technological convergence(Choi et al., 2015)
  - Diffusion model is widely used to forecast new products or technologies and find out how to diffuse these products/ technologies into the market (Lee, 2012; Frank, 2004; Ho et al., 2002)

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Model

Model for CCS technology forecasting

- **Network analysis for CCS technology**
  - Technological network analysis is the method to analyze the characteristics of technologies depending on level and category of technology groups by defining of relationships among technologies (Kim et al., 2015)
  - The number of patent applications and patent quality index(PQI) are used in patent analysis, and measure the technology competitiveness for each country

$$TC_i = \sum_{k \in IPC_i} ShareIPC_{i,k} \times (W_{k,D} + W_{k,B} + W_{k,C})$$

- **Technology forecasting model**
  - This study adopts research model of Choi et al. (2015) which analyze diffusion of technological convergence by using logistic model, and used the number of patent applications as input data

$$N(t) = \frac{N^*}{1 + e^{-(a+bt)}}$$

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Model

Proposal for the competitive diffusion model for CCS

- **Competitive diffusion model**
  - Due to the adoption of CCS technology in the power generation industry, CCS technology could be in competition with renewable energy technologies
  - This study adopted model framework of Huh and Lee (2014), so we divided competitive diffusion model into three parts
    - **1st stage:** Predict generation cost of each renewable energy source and a thermal power plant with CCS technology

$$P_{kt} = P_{k0} \times \exp(-\alpha_k t) + \epsilon_t,\ k = 1,2,3,\ldots$$ (Bayus, 1993)

    - 2nd stage: Analyze the competitive market situation among renewable energies and thermal power plants by using competitive diffusion model

$$n_{k,t} = \left[b_{k0} + b_{k1} \ln\left(\frac{x_{k,t}}{\sum_k x_{k,t}} \right) + b_{k2} \left(\frac{n_{k,t-1}}{m_k} \right) \right] \times [m_k - N_{k,t-1}]$$ (Hahn et al., 1994)

    - 3rd stage: Forecast diffusion of renewable energies and CCS technology based on the results of 1st and 2nd stage

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4. Data

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Data

Patent data for CCS technology

- **Patent data**
  - **This study collected patent data especially for patent applications because the purpose of this study is to analyze CCS technological competitiveness for each country, not intellectual property right**
  - **Patent data for CCS technology is collected from National Digital Science Library(NDSL)**

Country	Keywords	# of patents	Period
United States	- Carbon dioxide capture - Carbon dioxide capturing - Carbon dioxide emission capture - CO2 capture - Capturing of CO2	463	Aug.1995 - Jul. 2015
Japan		28	
EU		190	
WIPO		340	
Korea	- Collected form Korean government reports and Korea Carbon Capture & Sequestration R&D Center(KCRC)	270	

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Data

CCS and Renewable energy

- **Subject of analysis**

Source	Analysis method	Possible alternatives
Solar cell	Competitive relationships among energy sources (Forecasting demand by using competitive diffusion model)	O
Wind		O
Fuel cell		O
Water power	These energy sources are decided by government long-term plan	X
Ocean		X
IGCC		X
Bio	Forecast demand by reflecting intention of power generation companies	X
Waste		X
Geothermal	A slim chance of success in Korea	X
Solar heat		X
Thermal power + CCS	Forecast demand based on national roadmap and competitive diffusion model	O

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Data

CCS and Renewable energy

- **Generation cost of each energy source**

(Unit: KRW/kwh)

Year	Solar cell	Wind	Fuel cell	Bituminous coal	Anthracite coal
2009	498.38	105.15	314.98	60.23	109.1
2010	463.37	103.04	308.81	60.79	110.05
2011	396	100.98	302.75	67.13	98.55
2012	328	-	-	66.25	103.79
2013	300	-	-	58.84	91.65

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5. Results

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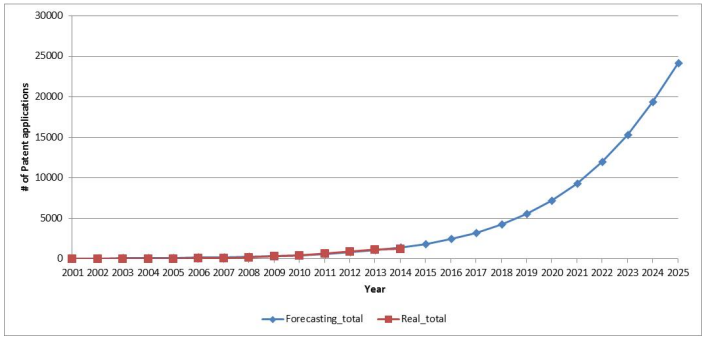
Results

Results for CCS technology

- **Technology forecasting for total CCS market**
  - Based on the estimation results, we predict demand of CCS technology until 2025



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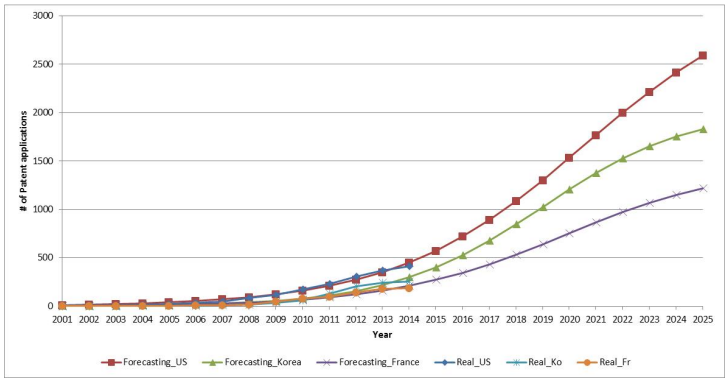
Results

Results for CCS technology

- **Technology forecasting for CCS market in each country**
  - Based on the estimation results, we also predict demand of CCS technology in each country (US, Korea, France)



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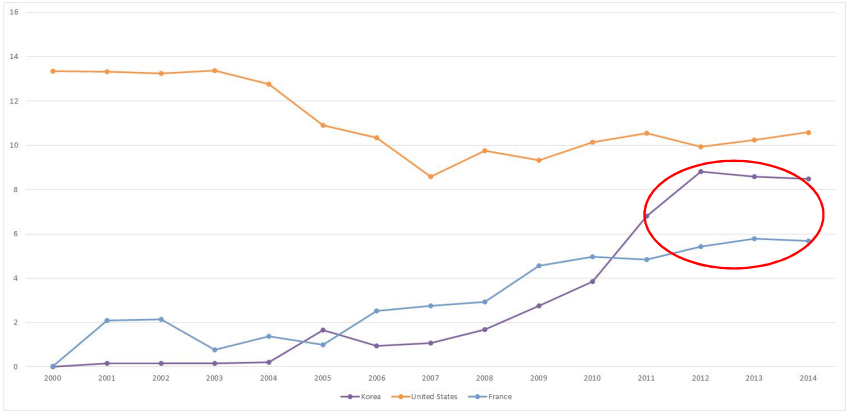
Results

Results for CCS technology

- **Technological competitiveness of CCS for each countries**



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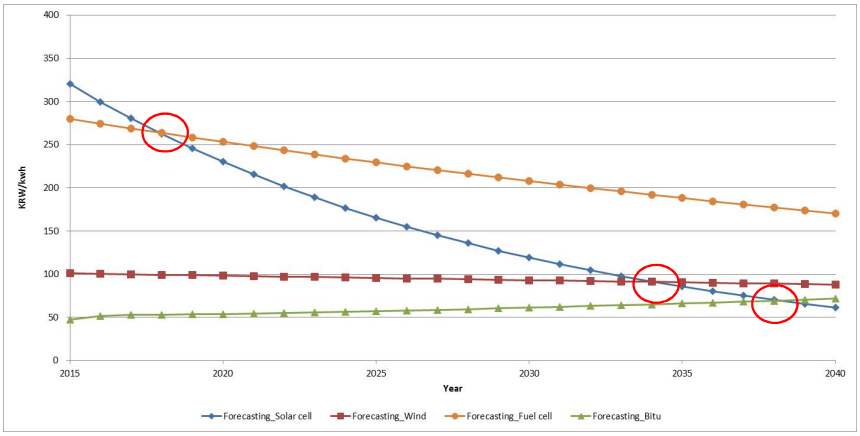
Results

Results for competitive diffusion model

- 1st stage: Forecast generation cost for each energy source



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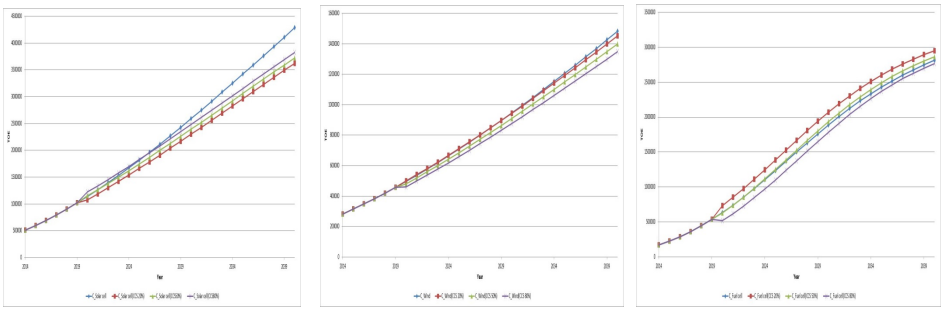
Results

Results for competitive diffusion model

- 2nd & 3rd stage: Estimate competitive diffusion model and forecast demand of each energy source
  - Assuming that CCS technology will be adopted after 2020, and generation cost of a thermal power generation with CCS will be increased from 20% to 80%



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6. Conclusion

Conclusion

Contributions

- **This study has three policy implications**
  1. This study forecasted uncertain future market situation based on quantitative analysis and thus can contribute to the guideline of further energy R&D investment.
  2. In terms of CCS technology competitiveness, despite the fact that increasing pattern in Korea is being continuously remained, it is possible to suggest useful implications for sustainable growth of CCS technological competitiveness by analyzing causes of CCS competitiveness decrease of US in early 2000 and of Australia in late 2000.
  3. Finally, the estimation results of CCS adoption effects can be useful to plan facility installation for each renewable energy source and to set GHG emission reduction target. Although the demand for each renewable energy source varies according to CCS technology competitiveness, such anticipatory plans which include comprehensive variations of each energy can contribute to remove political uncertainties.

Conclusion

Contributions

- As the model suggested in this study can be applied to transportation and heating as well as power generation in the same manner, it can contribute to plan specific policies for climate change, energy, and environment by quantitatively analyzing reduced GHG emissions incorporating technological development and market situation.

- In terms of estimation results, forecasting CCS technology and demand can provide criteria of GHG emission reduction target and energy R&D investment based on rational assumptions, contributing to appropriate policy plans and implementations.

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Thank you

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