An Analysis on Policy Options to Achieve Green Growth

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Contents

- Introduction
- Modeling
- Scenarios
- Results
- Conclusion

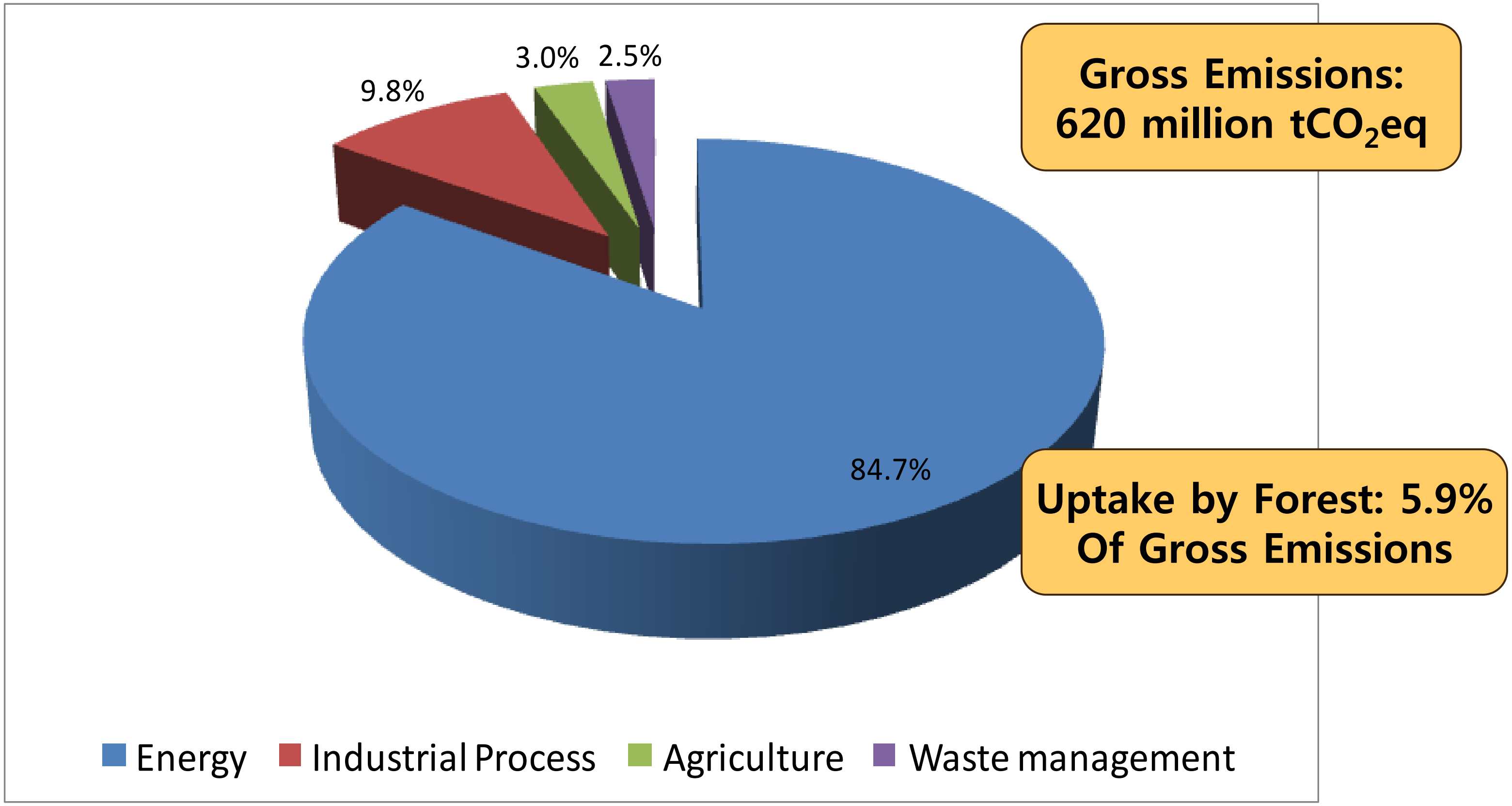
1. Introduction

❖ Korea at a glance

- Population (2010)
  - 48,875 million
- Economy (2010)
  - GDP : 1,014 billion USD, 20,759 USD per capita
  - Trade : 892 billion USD
- Energy Use (2010)
  - 261.1 million TOE - 96.2% imported
  - Energy import bill: 121.6 billion USD(09)
  - GHG: 610.5 MtCO2e(07)
- Korea ranks (2009)
  - No. 10 in energy consumption, No. 11 in oil consumption
  - No. 5 in oil imports, No. 2 in coal and LNG imports
  - No. 9 in CO2 emissions

1. Introduction

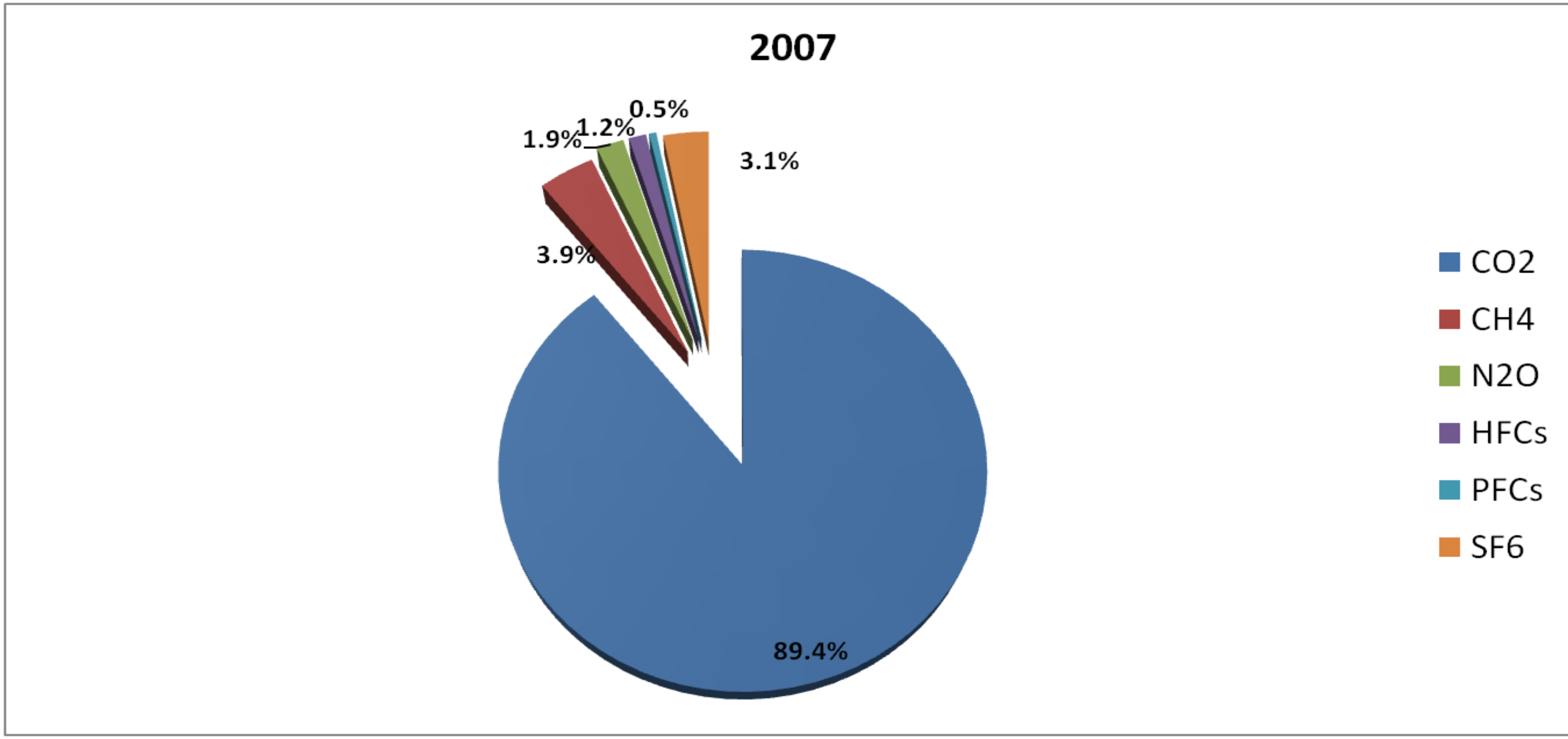
❖ Emission by sector



Source : Korea Energy Statistics Information System

1. Introduction

❖ Emission by gases



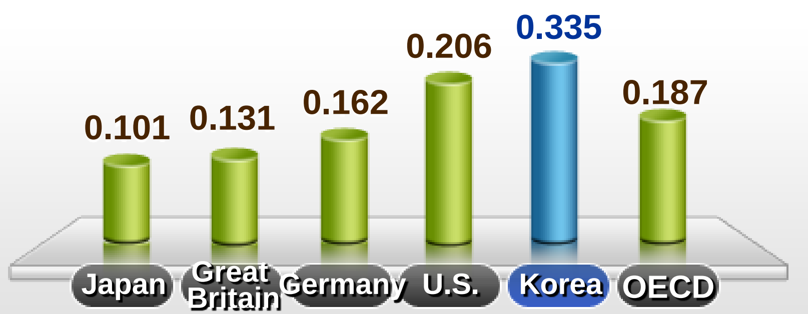
Source : Korea Energy Statistics Information System

- ❑ CO_2: Most important
- ❑ CH_4: ↓: 14.3 → 5.4 → 3.9%
- ❑ Other gases: 4.8%, increase in share

1. Introduction

High energy intensity

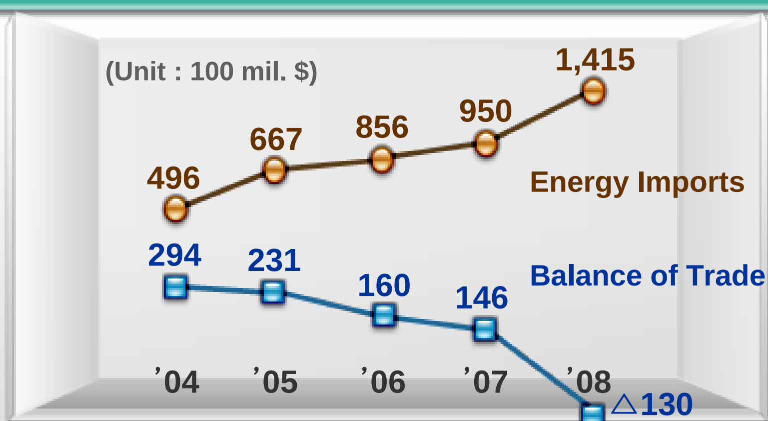
* Energy intensity (mil. toe/thou.$, '07 IEA)

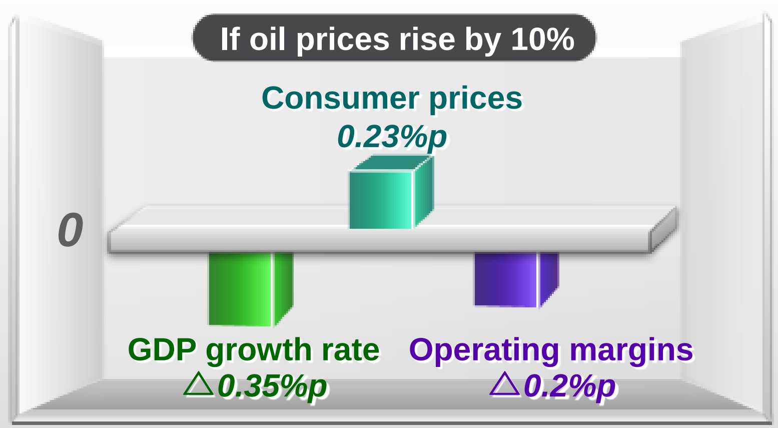


High percentage of major GHG emitting industries (SERI)

* 38% of total energy consumption in Korea,
80% of energy consumption in industrial sector

97% of energy is imported, 83% fossil fuels





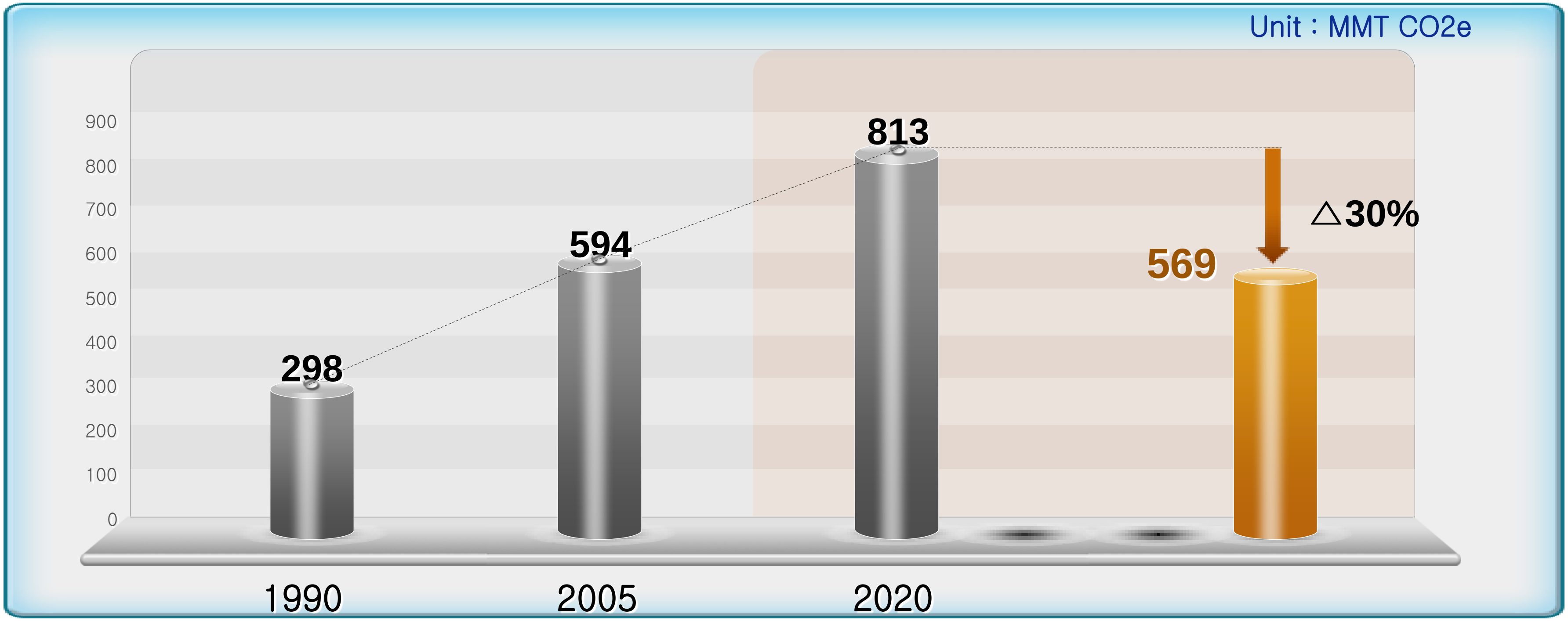
- Energy imports of 141.5 bil.$ in '08 is much higher than the export amount of semiconductors, autos, and ships combined(110.9 bil.$)

- SERI('07)

1. Introduction

❖ **Can we achieve Green Growth?**

- Energy intensive, trade oriented economy
- Not many low-cost mitigation options
- Increasing trend in energy use still persists
- Radical decoupling of emission and growth needed



1. Introduction

❖ Purpose of this study

- To see the economic impact of 2020 mitigation target of Korea
  - 30% reduction compared to BAU in 2020

- To search for policy options to achieve ‘Green Growth’
  - Achieving two goals - GHG reduction and GDP growth
  - R&D support from government
  - Apply backstop technologies and efficient transport
  - Increased penetration induced by carbon pricing and regulation

- Various scenarios on GDP growth and cost of new technology

2. Modeling: overview

- **Fully Dynamic CGE Model with Endogenous Technology Change**
  - Starts with the computational Ramsey model developed by Lau and Rutherford(2001)
  - Incorporates induced technology change(ITC) proposed by Goulder and Schneider(1999) so that technological changes result from profit maximizing investments in R&D
  - Incorporates spillover effect of technology that is non-excludable
  - New technology consists of renewable energy in power generation sector and automobiles with less carbon emission (green car) in transportation sector
  - All agents have perfect foresight

2. Modeling: overview

❖ Dimensions of the model

- Calibrated to the benchmark year 2007
- Solve one year intervals spanning the horizon from 2007 to 2050 with GAMS/MPSGE
- Consists of 7 industries such as refined oil, coal, natural gas, electricity, transportation, manufacturing, and service sectors
- Household, government, international trade sectors

2. Modeling: household sector

❖ Inter-temporal separable utility function

$$\max U(Z_t) = \sum_{t=0} \beta^t \frac{Z_t^{1-\theta}}{1-\theta}$$

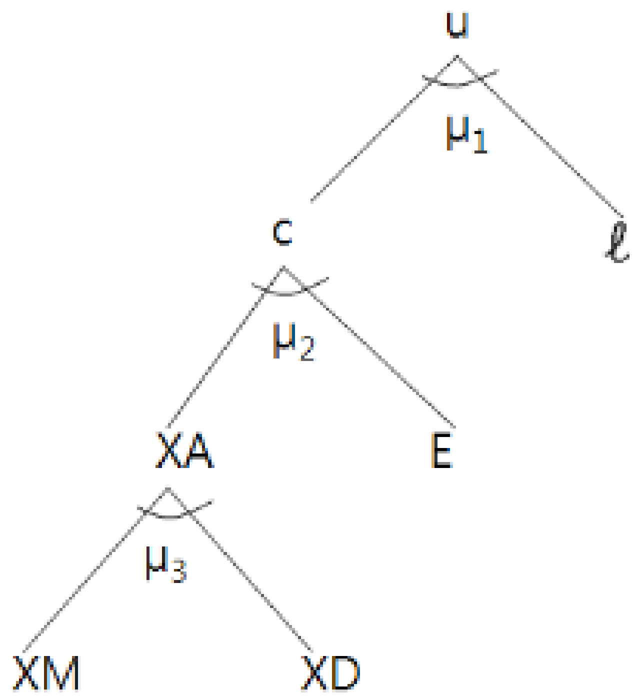
$$Z_t = \left[\alpha C_t^{\rho} + (1-\alpha)(1-H_t)^{\rho}\right]^{1/\rho}$$

s.t $\sum_t p_{c,t} C_t + \sum_t p_{k,t} I_{k,t} = \sum_t w_t L_{r,t} + \sum_t r_t K_{r,t} + \sum_t Tr_t$: **Inter-temporal Budget Constraint**

- Z_t : composite goods of consumption and leisure
- β : time discount
- $C_{r,t}$: composite of Armington goods and Energy composite goods
- $1/\theta$: inter-temporal elasticity of substitution
- H_t : working hours
- $\frac{1}{1-\rho}$: elasticity of substitution consumption and leisure

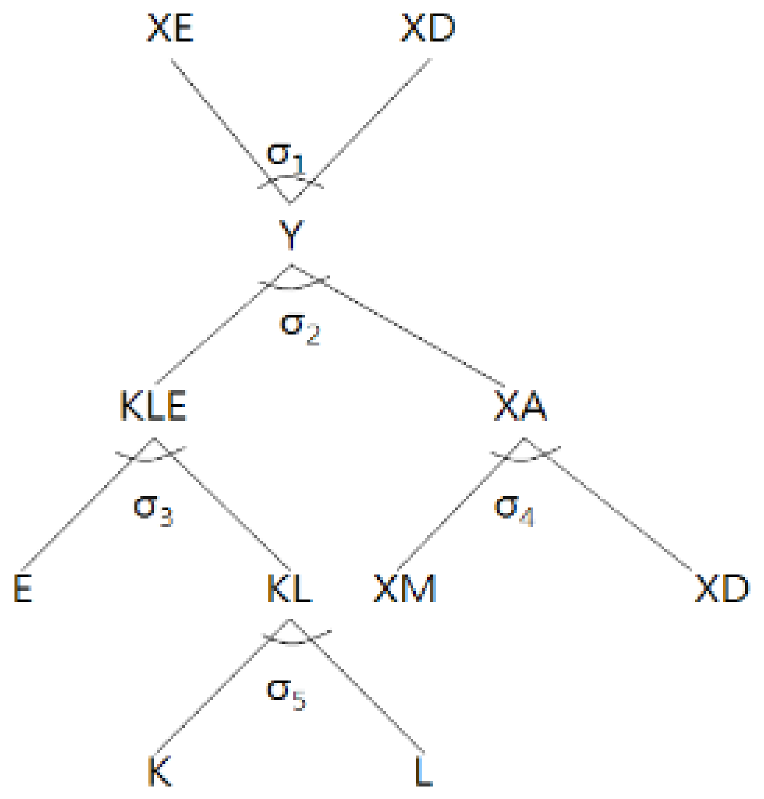
2. Modeling: household sector

Structure of Household Sector



2. Modeling: production sector

Structure of Production Sector



2. Modeling: new tech. in electric sector

❖ Accumulation of knowledge in new technology in electric sector enables production of renewable energy

- **Production function with new technology**

$$Y_{i,t} = \varphi(A_t)\left[\alpha KL\overline{E_{i,t}^{\rho}} + (1-\alpha)XA_{i,t}^{\rho}\right]^{\frac{1}{\rho}}$$

  - $\overline{E}$: composite goods of renewable and conventional energy
  - A : spillover technology which is non-excludable
  - $\varphi(A)_{i,t}$: increasing function of spillover technology

$$\varphi(A)_{i,t} = \frac{NE_{i,t}^{1/(1-\gamma_i)}}{NE_{i,t}}$$

$$0 < \gamma_i < 1, \quad \varphi(A)_{i,t} \geq 1$$

  - NE : knowledge of producing renewable energy

- **Accumulation of new technology**

$$NE_{t+1} = (1-\delta_a)NE_t + \upsilon_a RD_t$$

  - υ_a : magnitude of contribution of R&D to knowledge accumulation

2. Modeling: new tech. in electric sector

- **Competition between conventional & new tech. to minimize cost**

$$\min \quad P_{nel,t} NEL_t + P_{re,t} NE_t$$

$$s.t. \quad p_{nel,t} < P_{rs,t} \qquad \text{if } \nu_a < 1$$

$$NE_t = 0 \qquad \text{if } P_{nel,t} \leq P_{re,t}$$

$$NE_t = \overline{\alpha_t} NEL_t \qquad \text{if } P_{nel,t} \geq P_{re,t}$$

- $P_{nel,t}$: price of energy composition goods including the emission reduction cost(price of emission permit)
- $P_{re,t}$: rate of returns on new technology
- $\overline{\alpha_t}$: upper bound of the induced new technology level

- **Emission reduction policies by raising the prices of fossil fuel can create economic incentives to engage in more extensive R&D oriented toward discovery of new production technology**

2. Modeling: transportation sector

❖ Transportation with new technology

$$Y_{i,t} = \varphi(A_t)\left[\alpha \overline{KLE}^{\rho}_{i,t} + (1-\alpha) XA^{\rho}_{i,t}\right]^{\frac{1}{\rho}}$$

- $\overline{KLE}$: Green car nested with composite goods of capital, labor, and energy
- A : composite goods of renewable and conventional energy
- $\varphi(A)_{i,t}$: spillover technology which is non-excludable
- $\varphi(A)_{i,t} = \dfrac{GC_{i,t}^{1/(1-\gamma_i)}}{GC_{i,t}}$: increasing function of spillover technology
- $0 < \gamma_i < 1, \quad \varphi(A)_{i,t} \geq 1$
- GC : Stock of Green Car
- Accumulation of stock of Green Car

$$GC_{t+1} = (1-\delta_c) GC_t + \upsilon_c GC_t$$

- υ_c : magnitude of contribution of R&D to knowledge accumulation

2. Modeling: transportation sector

❖ **Competition between conventional & new tech. to minimize cost**

$$\min \quad P_{kle,t} KLE_t + P_{gc,t} \overline{KLE_t}$$

$$s.t. \quad p_{kle,t} < P_{gc,t} \qquad \text{if } \nu_c < 1$$

$$\overline{KLE}_t = 0 \qquad \text{if } P_{kle,t} \leq P_{gc,t}$$

$$GC_t = \overline{\alpha_{c,t}} KLE_t \quad \text{if } P_{kle,t} \geq P_{gc,t}$$

- $P_{kle,t}$: **price of conventional car using fossil fuel**
- $P_{gc,t}$: **price of green car with less emission than conventional car**
- $\overline{\alpha_{c,t}}$: **upper bound of green car**

3. Scenarios

❖ GDP growth scenarios(%)

	Low	High
2008	3.6	4.5
2010	3.6	4.4
2015	3.4	4.3
2020	3.1	4.0
2025	2.5	3.5
2030	2.1	3.1
2035	1.7	2.7
2040	1.5	2.5
2045	1.3	2.3
2050	1.2	2.2

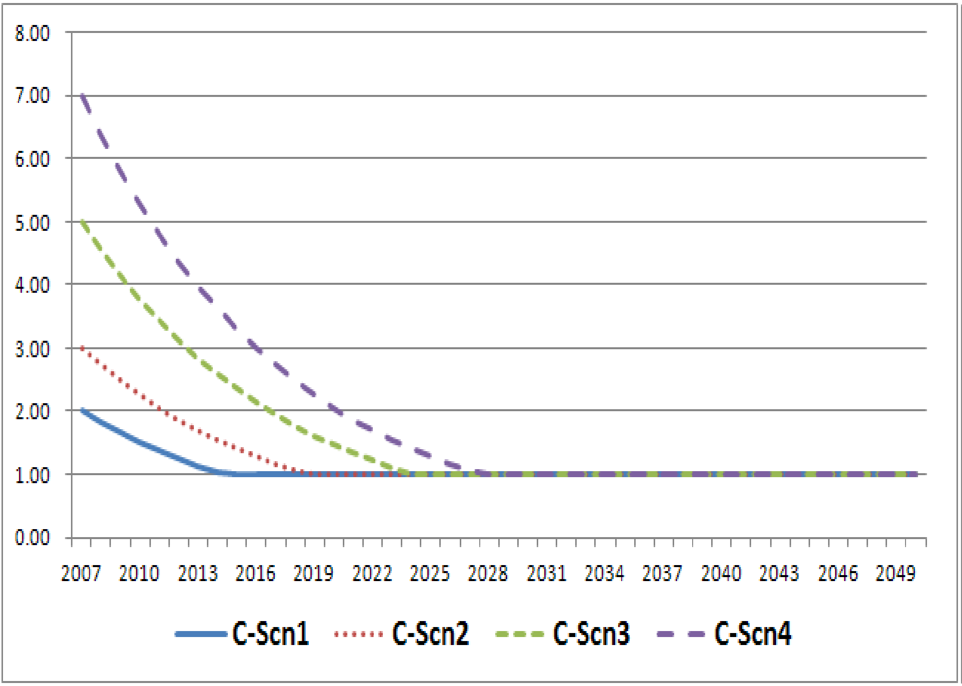
3. Scenarios

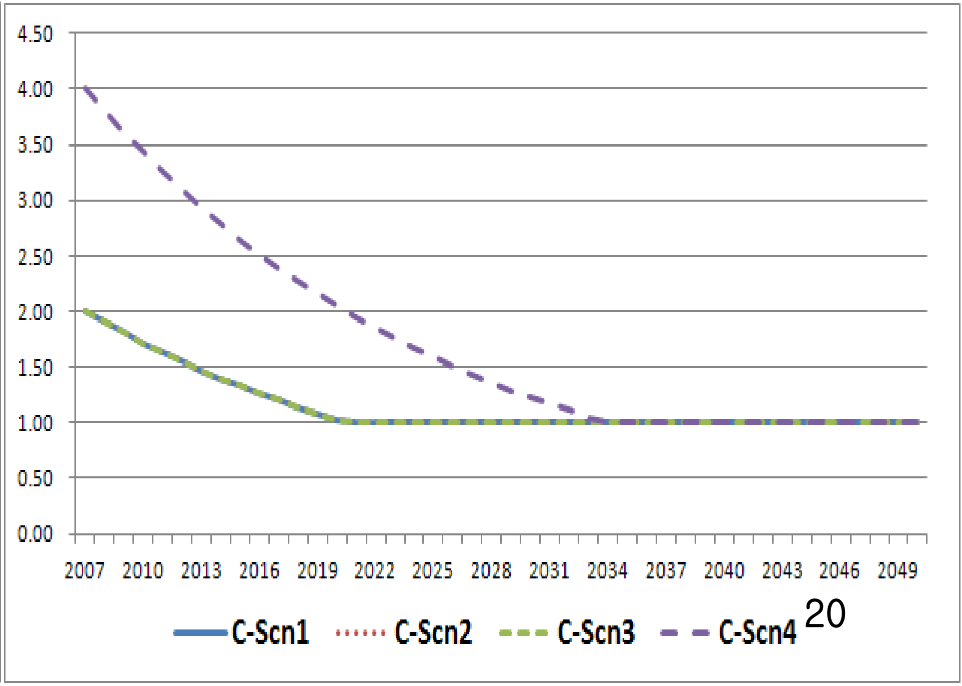
- **GHG emission scenarios**
  - 2020 : 30% reduction from BAU
  - 2050 : 50% reduction from BAU
- **GHG reduction amount**
  - Low growth – 2020: 222 million tCO2
  - Low growth – 2050: 561 million tCO2
  - High growth – 2020: 247 million tCO2
  - High growth – 2050: 827 million tCO2
- **R&D support from government**
  - No additional R&D support
  - 10% Scenario
    - 1.2 trillion KRW to renewable, 1,9 trillion KRW to green cars
  - 15% Scenario
    - 1.8 trillion KRW to renewable, 2.9 trillion KRW to green cars

3. Scenarios

❖ Cost of new technology compared to conventional ones

	Renewable Energy	Green Car
C-Scn 1	2	2
C-Scn 2	3	2
C-Scn 3	5	2
C-Scn 4	7	4



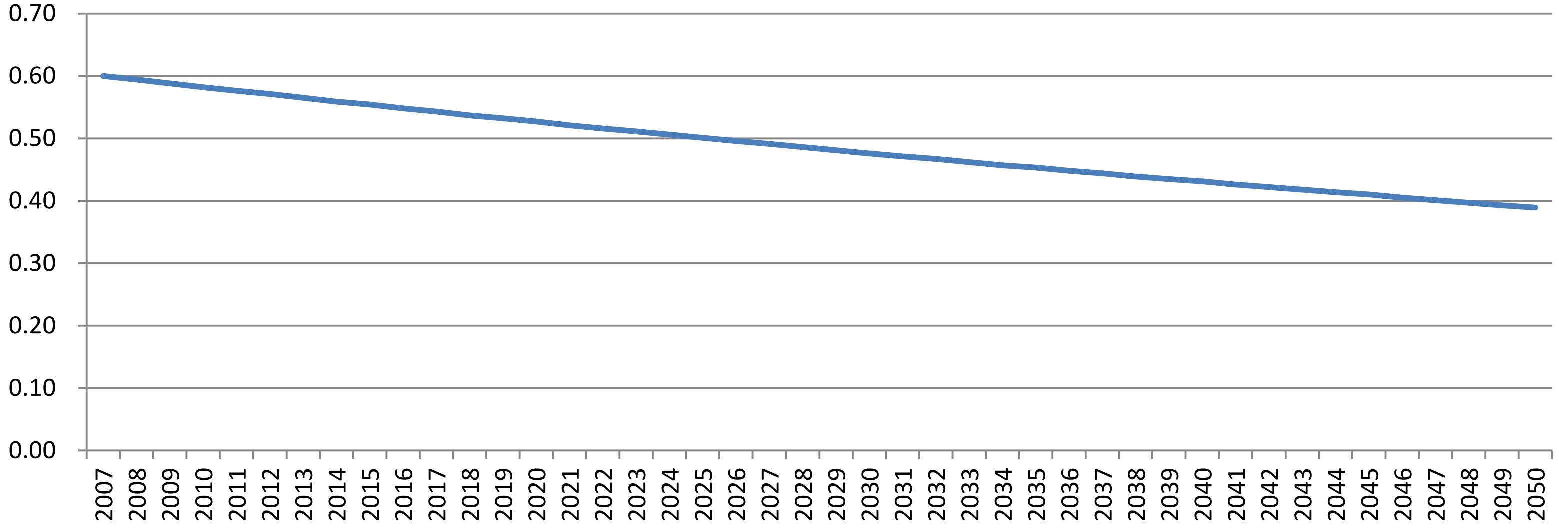


3. Scenarios

❖ Ratio of carbon content of new tech.

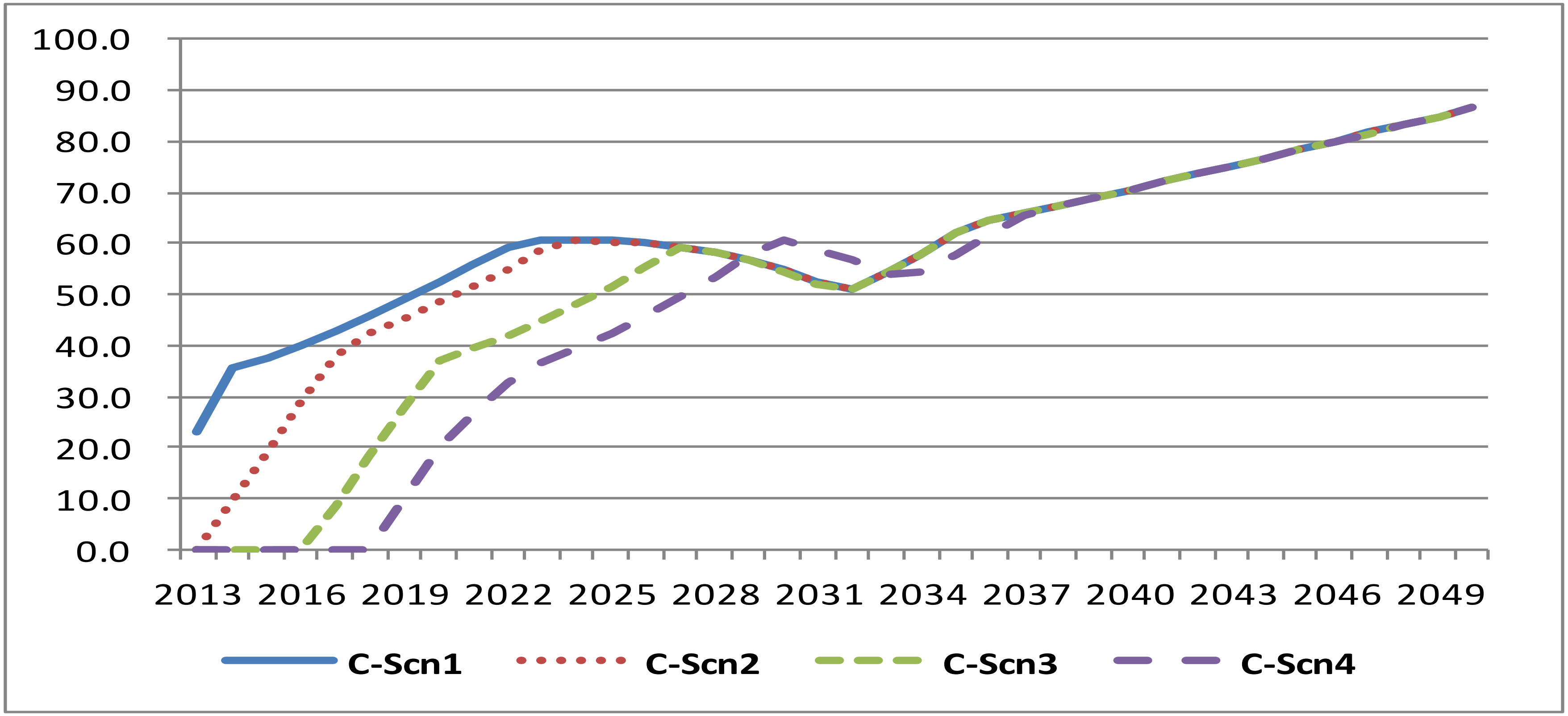
- Renewable energy: carbon free
- Green car: 60% in 2007 -> 40% in 2050 of conventional tech.

▪ **Ratio of carbon content of new technology compare to conventional technology**



4. Results – high GDP, 10% scn

❖ Portion of renewable energy in energy mix(%)

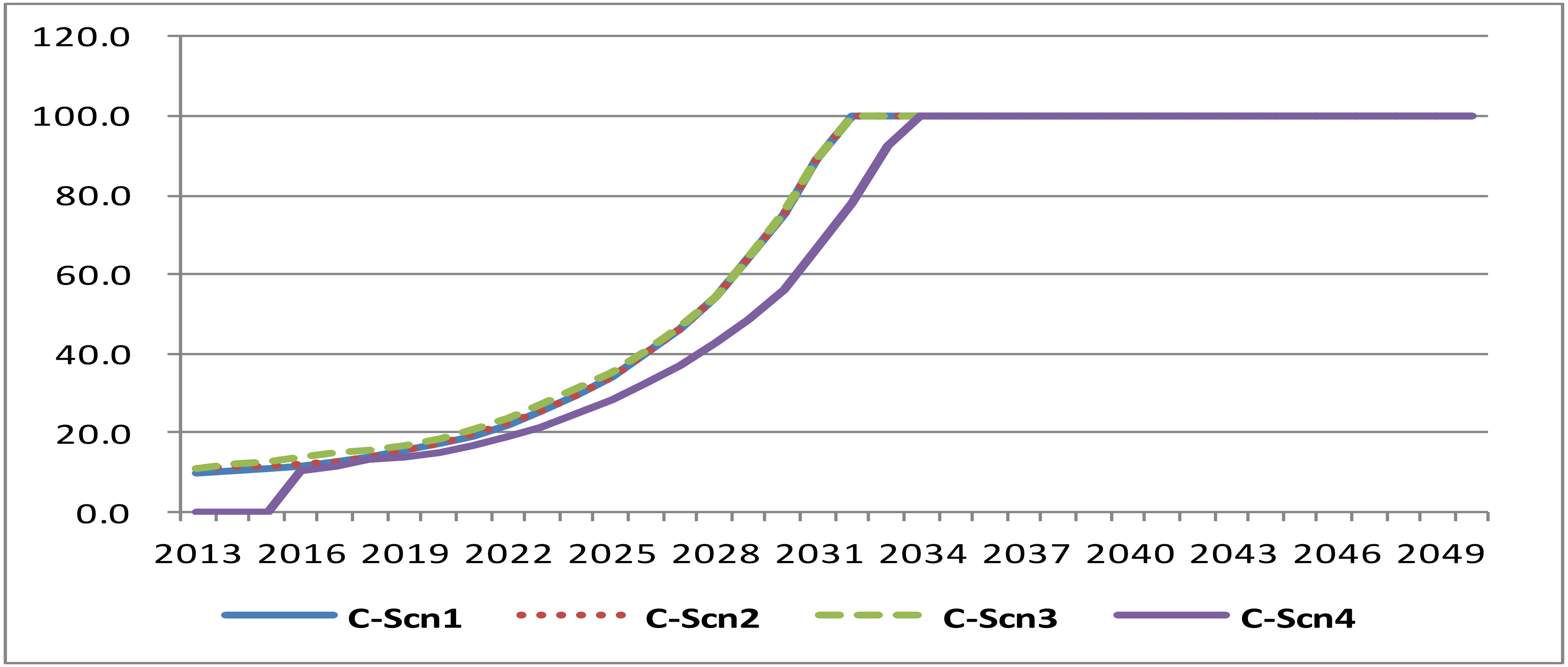


❖ Governing factors

- Cost of renewable, cost of GHG abatement
- GHG reduction amount, AEEI, elasticity btw. energy sources

4. Results

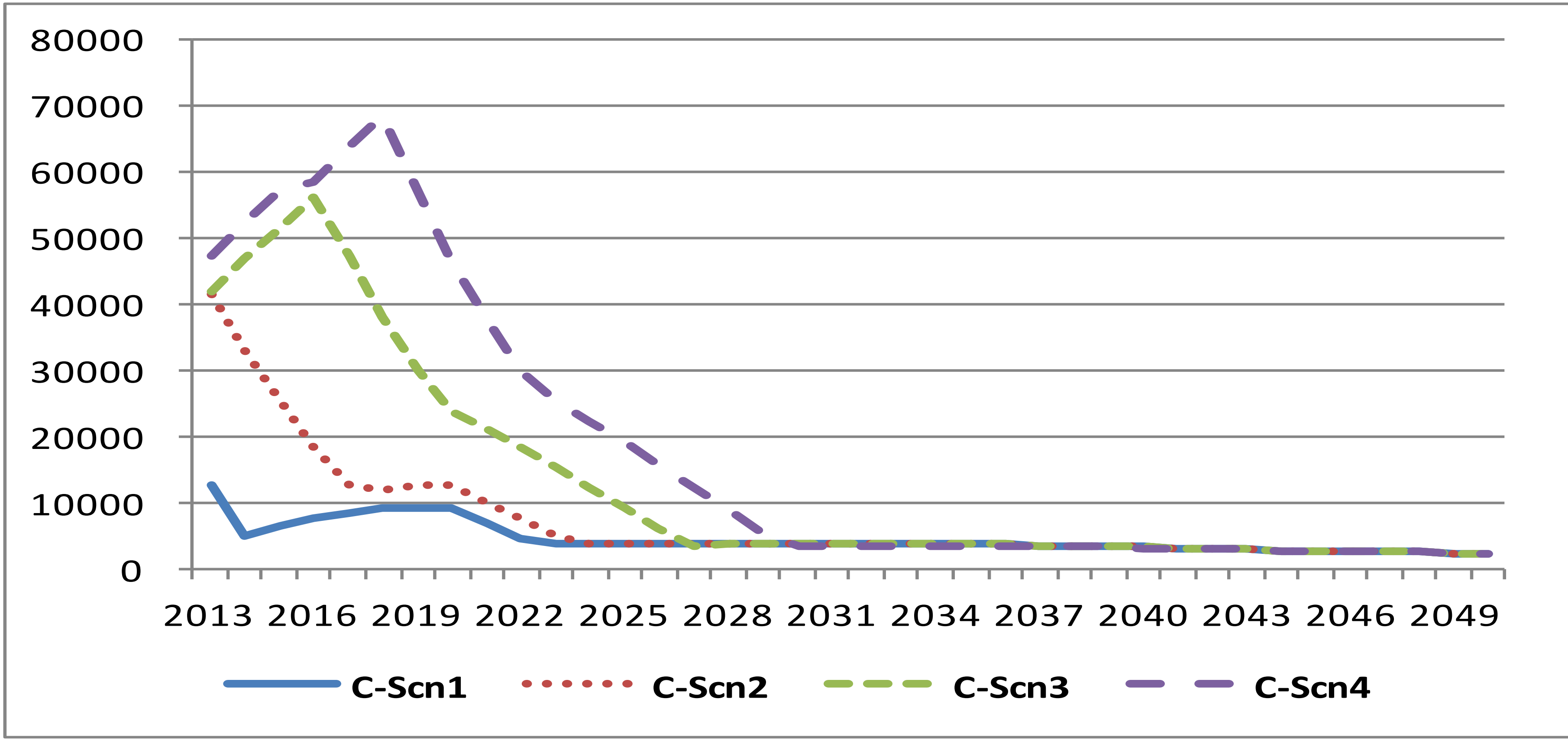
❖ **Portion of green cars in transport sector(%)**



❖ **Saturated in 2035**

4. Results

❖ **CO2 abatement cost (KRW/tCO2)**

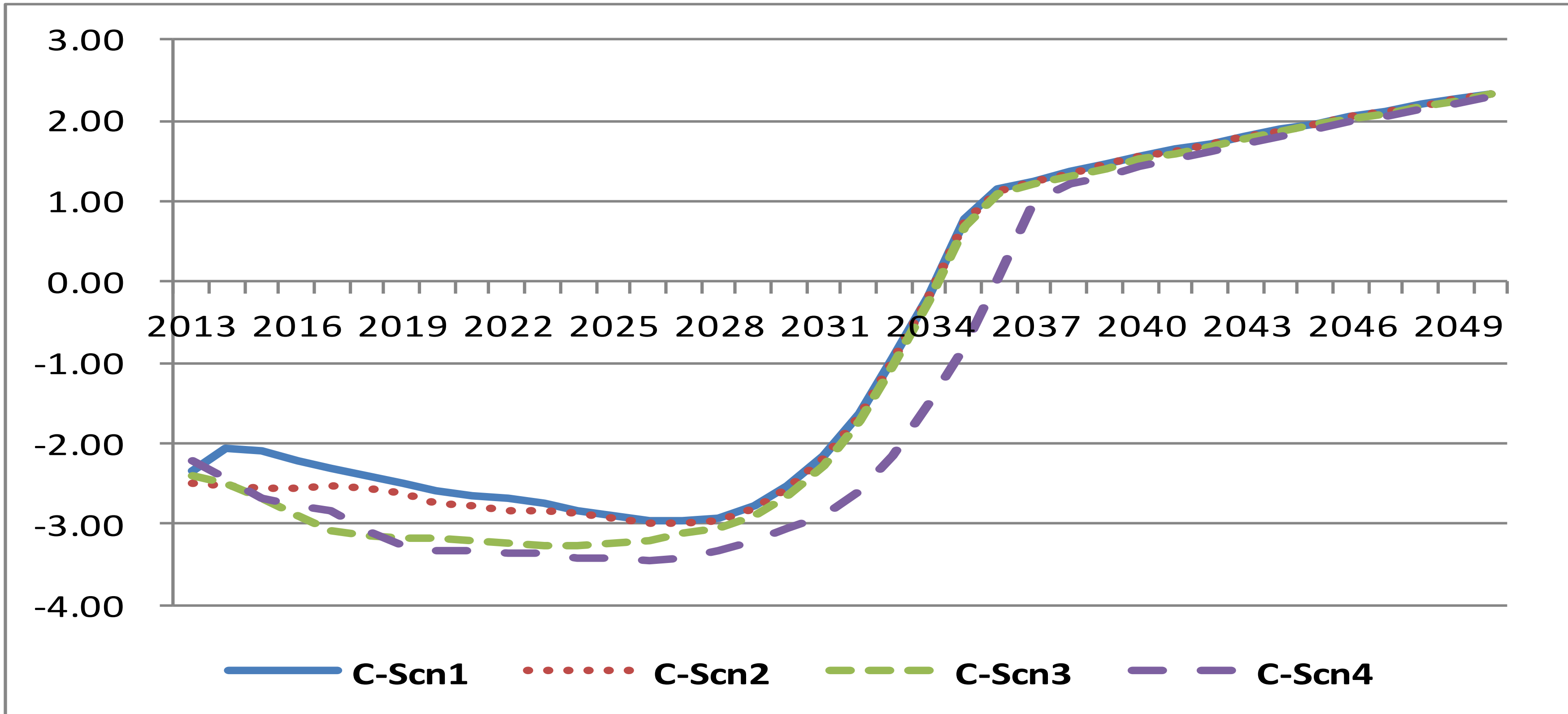


❖ **Pike shape**

➢ Not enough penetration of new tech.

4. Results

❖ GDP level(%)

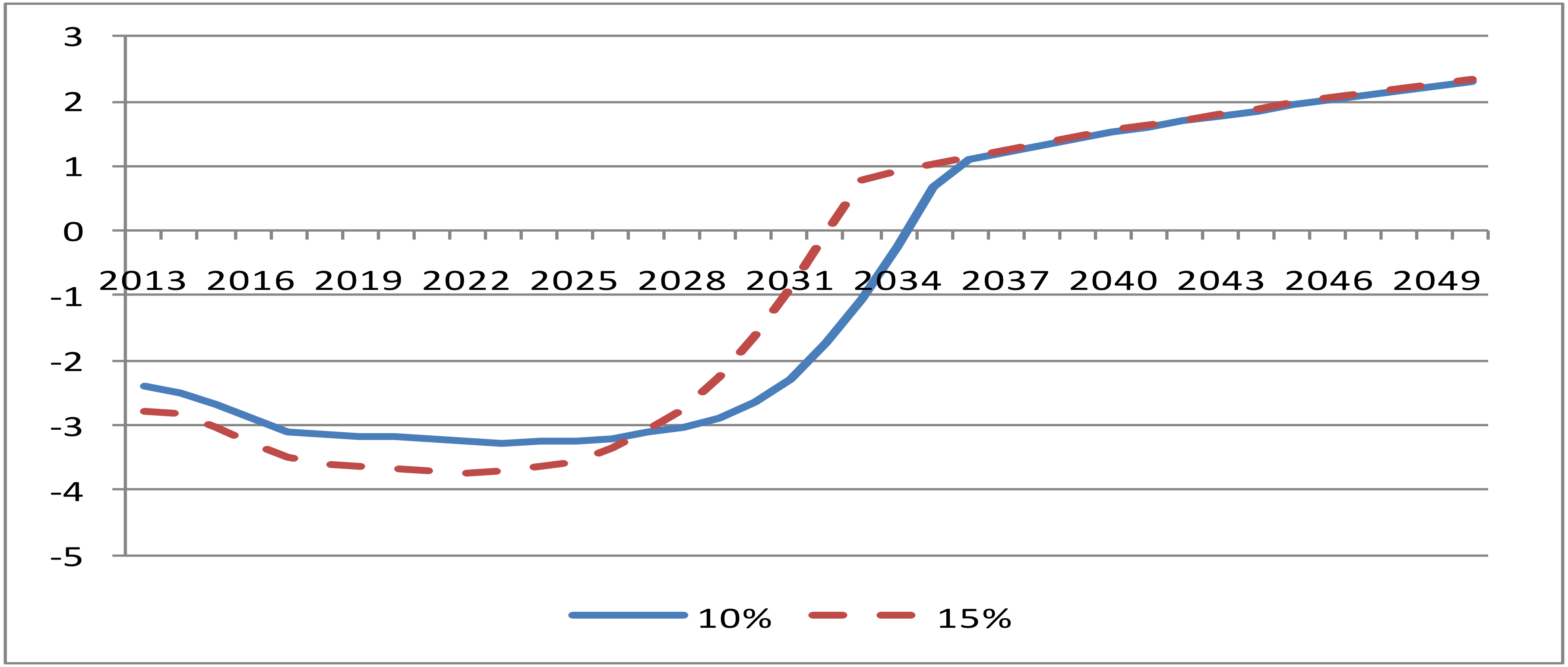


❖ Governing factors

- Crowding out effect, tax used for R&D investment
- Spill-over, decreased cost of abatement

4. Results

❖ **GDP level(%) with different R&D support**



❖ 15% scenario reduced time needed to catch up GDP level by 2 years

5. Conclusion

❖ Summary

- Without introduction of new technologies, economic loss from greenhouse gas reduction is likely to be highly significant
  - Abatement cost per ton is 455 ~ 403 thousand won with GDP loss of 1.5%(2020)~3.7%(2050)
- Government support for technological development makes Green Growth more likely to succeed
  - 15% scenario reduced time needed to catch up GDP level by 2 years
- Need policies to reduce the cost of new technology
  - The abatement cost for low cost scenario per tCO2 was less than 10,000 KRW(around 9$)

5. Conclusion

- **Policy implications**
  - Need to set up robust support programs and institutional foundation to promote technological innovation and commercialization
    - A lack of economic feasibility hinders commercialization of newly developed technologies
    - Further strengthening of regulations on greenhouse gases will enhance incentives to invest and commercialize new technologies by increasing prices of fossil fuels
    - However without government aids to compensate for GDP loss from greenhouse gas reduction, commercialization is not likely to reach an optimal level
    - Hence only with sufficient government support for R&D, the “Low Carbon & Green Growth” policy can be a reality
    - In addition, the likely emergence of a wide variety of novel technologies not considered in this study will add to economic validity of Green Growth
    - Economic feasibility of a new technology alone does not guarantee its successful commercialization due to irreversibility of investment, lengthy waiting periods, and steep learning curve associated with the new technology
    - As such, institutional foundation needs to be laid down to ensure smooth commercialization of a new technology

- **Thank you for your attention**

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