Global Emission Reduction Potentials and Scenarios in Energy Supply and End-use Sectors

Keigo Akimoto and Fuminori Sano
Systems Analysis Group
Research Institute of Innovative Technology for the Earth (RITE)
Contents

♦ Overview of the assessment framework: DNE21+
  (some model assumptions were modified from the report on May 8th, in order to harmonize the model results with the statistics in 2005.)

♦ CO2 emission outlook for “Technology-frozen Case” and “Negative-Cost-Achieved (NCA) Case”

♦ Regional emission reduction potentials in 2020
  - by cost
  - by cost and by sector

♦ Case studies considering differentiated responsibilities and capabilities for developed countries, major developing countries and other developing countries

♦ Conclusion

♦ Caveats
Assessment Framework: DNE21+ Model

- Linear programming model (minimizing world energy system cost)
- Evaluation time period: 2000-2050
  

- World divided into 54 regions
  
  Large area countries are further divided into 3-8 regions, and the world is divided into 77 regions.

- Bottom-up modeling for technologies both in energy supply and demand sides (Technology improvements and innovative technologies are also considered.)

- Primary energy: coal, oil, natural gas, hydro&geothermal, wind, photovoltaics, biomass and nuclear power

- Electricity demand and supply are formulated for 4 time periods: instantaneous peak, peak, intermediate and off-peak periods

- Interregional trade: coal, crude oil, natural gas, syn. oil, ethanol, hydrogen, electricity and CO2

- Existing facility vintages are explicitly modeled.

- The model has high resolutions in regions and technologies to analyze sectoral approach.
  - Consistent analyses among regions and sectors can be conducted.
Scenario Definition

<table>
<thead>
<tr>
<th>Case</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative-Cost-Achieved (NCA) Case</td>
<td>• Emissions Scenario where all the emission reduction measures below 0 $/tCO₂ are achieved.</td>
</tr>
</tbody>
</table>
| Technology-frozen Case      | • CO₂ intensity (CO₂ per GDP): Fixed at the level of 2005  
• Regional GDP growth rate: Set based on the prospects by World Bank  
• Industrial structure: Constant after 2005  
• This case is a hypothetical scenario to understand emission reduction potential from current technology level. |
The global CO2 emission in 2020 would increase by 86% (22.6 Gt: 8.3 Gt in developed countries; 9.0 Gt in major developing countries; 5.4 Gt in other developing countries) above the current level if intensity levels were fixed at the current level even in the future.

- Large efforts are required even for achieving the emissions in NCA Case (There are large opportunities for emission reductions of negative costs.).
- High emission growth in Non-annex I countries are estimated for the future.
- BAU (Business as Usual) Scenario is uncertain and would be b/w Tech.-frozen Case and NCA Case.
- Emission reduction potential from BAU depends on the definition of BAU.
Marginal costs for Annex 1 countries in 2020

- The marginal cost of CO2 emission reduction of –20% and –30% from the 1990 emission level in EU27 (–17.5% and –27.8% from the 2005 emission level) corresponds to around 50 and 75 US$/tCO2.
Regional Emission Reduction Potentials in 2020

Reduction Potentials from Sectoral Technology-frozen Case

Marginal costs → Emission reduction levels

- There are large potentials for emission reductions of negative costs and relatively low-costs (<25$/tCO2) in the world regions.
- Reduction potentials of United States below 25$/tCO2 have large share (43%) in those of Annex I & OECD.
- Reduction potentials of China and India below 25$/tCO2 have large share (90%) in those of Major developing countries.
- Countries which made continuous energy saving efforts, such as Japan, have relatively small reduction potentials of negative costs.
Sectoral Emission Reduction Potentials in 2020

≤0$/tCO₂

- United States
- EU-27
- Japan
- Russia
- China
- India
- Annex I & OECD
- Major developing countries
- Other developing countries

Note: emission reduction potentials of CCS excluded
Key Emission Reduction Measures in 2020

≤0$/tCO₂

♦ Power sector of Major developing countries:
  - Efficiency improvement of coal power plants

♦ Iron & Steel sector of all regions
  - Diffusion of energy saving equipment (CDQ; Coke Dry Quenching, TRT: Top pressure Recovery Turbine)
  - Diffusions of high-efficiency BF-BOF including next generation coke oven

♦ Residential & Commercial sector of all regions
  - Efficiency improvement of various appliances (space heating, lighting, etc)
Sectoral Emission Reduction Potentials in 2020

0–25$/tCO₂

- United States
- EU-27
- Japan
- Russia
- China
- India
- Annex I & OECD
- Major developing countries
- Other developing countries

- Elec.: Fuel switching among fossil fuels
- Elec.: Nuclear
- Elec.: Renewables
- Elec.: Energy saving
- Other energy conversion sectors
- Iron & steel
- Cement
- Paper & pulp
- Chemical
- Aluminum
- Other industries
- Transport
- Res. & com. sectors

CO₂ emission reduction potential (MtCO₂/yr)

Note: emission reduction potentials of CCS excluded
Key Emission Reduction Measures in 2020

0-25$/tCO₂

♦ Power sector of Major developing countries:
  - More introduction of high-efficiency gas power plants
    (Energy savings and fuel switching among fossil fuels)
  - Nuclear power expansion

♦ Power sector of Annex I & OECD
  - Nuclear power expansion
  - Diffusion of wind power generation
25–50$/tCO₂

- Reduction potentials at 25-50$/tCO₂ are much smaller, compared to those below 25$/tCO₂
- There are some potentials of nuclear and renewables (wind power) in power sector.
## Case Studies (for year 2020)

<table>
<thead>
<tr>
<th>Case</th>
<th>Developed countries (Annex I &amp; OECD)</th>
<th>Major developing countries (MEM)</th>
<th>Other developing countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCA Case</td>
<td>0 $/tCO2</td>
<td>0 $/tCO2</td>
<td></td>
</tr>
<tr>
<td>25-0</td>
<td>25 $/tCO2</td>
<td>0 $/tCO2</td>
<td></td>
</tr>
<tr>
<td>50-0</td>
<td>50 $/tCO2</td>
<td>0 $/tCO2</td>
<td></td>
</tr>
<tr>
<td>25-25a</td>
<td>25 $/tCO2</td>
<td>Macro CO2 intensity target</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>corresponding to 25 $/tCO2</td>
<td></td>
</tr>
<tr>
<td>25-25b</td>
<td>25 $/tCO2</td>
<td>CO2/energy intensity target</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>for selected sectors</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>corresponding to 25 $/tCO2</td>
<td></td>
</tr>
</tbody>
</table>

Major developing countries (MEM): Brazil, China, India, Indonesia and South Africa
Selected sectors: power, iron&steel, cement, aluminum and transportation sectors
- The reduction potential at 0–25 $/tCO2 in developed countries is about 4.1 GtCO2, but that at 25–50 $/tCO2 is about 1.0 GtCO2.
- The reduction potential at 0–25 $/tCO2 in major developing countries is about 4.5 GtCO2.
- Large-scale emission reductions of 3.8 GtCO2 could be achieved even if CO2 intensity targets for major sectors are assumed in major developing countries.
Conclusion (1/2)

By introducing the two Cases, **Negative-Cost-Achieved Case** and **Tech.-Frozen Case**, the emission reduction potentials of negative costs were estimated besides those of positive costs.

The global CO2 emission in 2020 would increase by 86% (22.6 Gt: 8.3 Gt in developed countries; 9.0 Gt in major developing countries; 5.4 Gt in other developing countries) above the current level if intensity levels were fixed at the current level even in the future.

Reduction Potential below 0$/tCO2 is large.
- Global potential in 2020 is 11.1 Gt CO2, 4.6 Gt in developed countries, 4.0 Gt in major developing countries, and 2.5 Gt in other developing countries.
- Potentials are mainly in the Power Sector, Transportation Sector and Iron & Steel Sector.

Countries which made **continuous energy saving efforts**, such as Japan, have relatively small reduction potentials of negative costs.
The **cooperative measures** between developed and developing countries are key to large emission reductions at low cost.

- The emission reduction potential at the cost of 0–25 $/tCO2 in developed countries is about **4.1 GtCO2**, but that at the cost of 25–50 $/tCO2 is about **1.0 GtCO2**.
- On the other hand, the emission reduction potential at the cost of 0–25 $/tCO2 in major developing countries is about **4.5 GtCO2**.

- Large-scale emission reductions of **3.8 GtCO2** could be achieved even if CO2 intensity targets for major sectors are assumed in major developing countries.

- This result is one example of the projections of emission path ways. The effort levels, e.g. marginal cost of $ 25/tCO2 etc., should be considered in further discussions.
Caveats

♦ Models are much simpler than real societies.
♦ There are large uncertainties of several assumptions, e.g., population, GDP, technology perspectives, in the model.

♦ The emission reduction potentials of CCS were excluded in this analysis due to large uncertainties. However, the potential at the cost below 50 $/tCO2 in the world is about 4.3 GtCO2 in 2020.

♦ Marginal cost of emission reductions is NOT the sole indicator to fair and reasonable emission reduction targets.
Appendix
Region Divisions of DNE21+

World divided into 54 regions
Technology Descriptions in DNE21+ (1/2)

**Fossil fuels**
- Coal
- Oil (conventional, unconv.)
- Gas (conventional, unconv.)

**Renewable energies**
- Hydro power & geothermal
- Wind power
- Photovoltaics
- Biomass

**Nuclear power**

**Energy conv. processes**
(oil refinery, coal gasification, bio-ethanol, gas reforming, water electrolysis etc.)

**Industry**
- Iron & steel
- Cement
- Paper & pulp
- Chemical (ethylene, propylene, ammonia)
- Aluminum
  - Solid, liquid and gaseous fuels, and electricity <Top-down modeling>

**Transport**
- Vehicle
  - Solid, liquid and gaseous fuels, and electricity <Top-down modeling>

**Residential & commercial**
- Refrigerator, TV, air conditioner etc.
  - Solid, liquid and gaseous fuels, and electricity <Top-down modeling>
Coal for steel sector

Type III: Current coke oven
- 24.1 GJ

Type III and IV: High-eff. Intersection
- Recyling of waste plastics and tires
  - 0.25 GJ
- Waste plastics and tires
  - 0.25 GJ

Type IV: Next-generation coke oven
- 22.5 GJ

Blast furnace, sintering furnace, BF, BOF, casting, and hot rolling

Electricity (grid)
- 455 kWh
- 91 kWh
- 111 kWh

Electricity power generation facility

Compressed CO₂
- 0.60 tCO₂

Carbon capture from BFG
- 91 kWh
- 111 kWh

Utility
- 4.1 GJ

Process gases recovery
- 8.6 GJ

Steel product derived from BOF steel
1 ton of crude steel equivalent for each type

BF: blast furnace, BOF: basic oxygen furnace, CDQ: Coke dry quenching,
TRT: top-pressure recovery turbine, COG: coke oven gas, LDG: oxygen furnace gas
Comparisons of Energy Efficiency (1/2)

Iron & steel (2000)

Energy consumption per unit production of crude steel (toe/ton-cs)

<table>
<thead>
<tr>
<th>Country</th>
<th>BF-BOF</th>
<th>scrap-EAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Canada</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>UK</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>France</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Germany</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Japan</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Australia</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Korea</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>China</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>India</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Russia</td>
<td>0.8</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Cement (2000)

Energy consumption per unit production of cement (toe/ton-clinker)

<table>
<thead>
<tr>
<th>Country</th>
<th>toe/ton-clinker</th>
<th>toe/ton-cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>0.16</td>
<td>0.02</td>
</tr>
<tr>
<td>Canada</td>
<td>0.18</td>
<td>0.04</td>
</tr>
<tr>
<td>UK</td>
<td>0.14</td>
<td>0.06</td>
</tr>
<tr>
<td>France</td>
<td>0.16</td>
<td>0.02</td>
</tr>
<tr>
<td>Germany</td>
<td>0.12</td>
<td>0.04</td>
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Note: Electricity is converted by using 1MWh=0.086/0.33toe.


Note: Electricity is converted by using 1MWh=0.086/0.33toe.
Waste biomass use is excluded in the energy efficiency.
Comparisons of Energy Efficiency (2/2)

Efficiency

Power sectors (2005)
Including CHP

Source: IEA, 2007
Assumptions of DNE21+ (1/3)

- Population: UN2006 Medium Scenario
Assumptions of DNE21+ (2/3)

♦ GDP


Assumptions of DNE21+ (3/3)

Iron & Steel
(Crude steel production)

Cement (Cement production)
Comparisons of Emission Reduction Potentials between DNE21+ and IPCC AR4

Note: emission reduction potentials of CCS excluded

- Y2020
- Y2030

CO₂ emissions (Y2000=100)
Comparisons of MAC in 2050 between DNE21+ and IEA ETP

IEA ETP2008

IEA ETP Baseline: 62 GtCO2

RITE DNE21+ (Oct. 2008)

The definition of Baseline by RITE

RITE DNE21+ Baseline:
Marginal cost = 0 $/tCO2
46 GtCO2

Marginal cost ($/tCO2)

2050 CO2 emissions reduction (Gt CO2/yr)

Technology Pessimism

Technology Optimism

550ppm (31GtCO2; Reduction of 15 GtCO2 from Baseline)
450ppm (23GtCO2; Reduction of 23 GtCO2 from Baseline)
50 by 50 (13 GtCO2; Reduction of 33 GtCO2 from Baseline)
Expected CO2 Emission Reduction (2/3)

Reduction Potentials by sector from Sectoral Technology-frozen Case

Annex 1 & OECD

Note: emission reduction potentials of CCS excluded
Expected CO2 Emission Reduction (3/3)

Reduction Potentials by sector from Sectoral Technology-frozen Case

Major developing countries

Note: emission reduction potentials of CCS excluded