Energy and Climate: Decarbonizing the Energy Supply in Northeast Asia

SH. Enkhbayar
Senior Research Fellow, Research Division, ERINA

1 Energy and Climate Change

1.1 Introduction

While the world's climate has always varied naturally, the vast majority of scientists now believe that rising concentrations of "greenhouse gases (GHG)" in the Earth's atmosphere resulting from economic and demographic growth since the industrial revolution over the last two centuries are overriding this natural variability and leading to potentially irreversible climate change. Scientists warn that the planet is warming faster than previously thought and in order to prevent dangerous climate change we must limit the global mean temperature rise to 2°C from the pre-industrial level. This means that the greenhouse gas concentration in the atmosphere must be stabilized below 450 parts per million (ppm). As the International Energy Agency (IEA, 2014a) noted: "Given the long lifetime of CO_2 in the atmosphere, stabilizing concentrations of greenhouse gases at any level would require a large reduction of global CO_2 emissions from current levels" (p. 7).

According to the Intergovernmental Panel on Climate Change[1] (IPCC, 2013), the global mean temperature rose by 0.85°C during the period from 1880 to 2012. The concentration of carbon dioxide (CO_2)—a major GHG—in the atmosphere has been increasing significantly over the past century compared to the pre-industrial era and it was 40% higher in 2013 than the mid-1800s level. Significant increases have also been observed in the levels of methane (CH_4) and nitrous oxide (N_2O).

Globally, the energy system—supply, transformation, delivery and use—is the dominant contributor to GHG emissions. CO_2 from energy represents almost 70% of global anthropogenic emissions (IEA, 2014a). Policies and actions aimed at significant reductions in GHG emissions by 2020 and beyond would entail drastic changes in the supply and use of energy. The global primary energy demand is expected to grow further by around 20% by 2030 from the 2013 level, whereas about 1.3 billion or 18% of the global population still have no access to electricity (IEA, 2015). Accordingly, the world community faces the dual challenge of the world's energy needs for development while contributing to GHG emissions reduction. This requires transformation of the energy sector toward cleaner energy sources, as the energy sector accounts for roughly two-thirds of all anthropogenic GHG emissions today.

1.2 A Brief History of the UNFCCC Process

The international political response to climate change began with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC, the Convention) in 1992 and it provides the foundation for intergovernmental efforts to address climate change. The Convention entered into force on 21 March 1994, and now has 196 parties. The countries that have ratified the Convention are called Parties to the Convention. The Convention divides countries into two main groups: those that are listed in its Annex I, known as *Annex I Parties* or the industrialized countries, currently numbering 43, and those that are not, known as *Non-Annex I Parties* or the developing countries, currently numbering 153.

As stated in the UNFCCC Article 2, "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".

Implementation of the Convention is reviewed at its annual Conference of the Parties (COP) to the UNFCCC, which is the supreme body for making the decisions necessary to promote the effective implementation of the Convention, and its interim sessions. The COP is held together with the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP) and hosted alternately by the regional groups. The permanent Secretariat of the UNFCCC was established in 1996 and located in Bonn, Germany.

The Kyoto Protocol (KP), which was agreed at the third session of the Conference of the Parties (COP3) to the UNFCCC which was held in December 1997 in Kyoto, Japan, supplements and strengthens the Convention. The Kyoto Protocol set legally-binding emissions' targets for the industrialized countries (*Annex I Parties*), under which they will reduce their combined GHG emissions by at least 5% from 1990 levels in the KP's first commitment period from 2008 to 2012. The Kyoto Protocol entered into force on 16 February 2005 and now has 192 parties. The *Non-Annex I Parties* have no legally-binding emission reduction targets under the KP, but the Protocol set flexible mechanisms, known as the Clean Development Mechanism

[1] The IPCC was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to assess the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts, and options for adaptation and mitigation.

(CDM), Joint Implementation (JI) and Emission Trading (ET) by which the industrialized countries can meet their emission reduction commitments at lower costs, while assisting the developing countries and the economies in transition to implement projects that reduce their GHG emissions. According to the International Energy Agency estimates, the Annex I Kyoto Parties with binding targets witnessed a collective reduction of CO_2 emissions from fuel combustion by 14% in 2012 compared to the base year of 1990, while those of the Non-Annex I Parties had almost tripled (i.e. went up by 171%) during the same period (IEA, 2014a).

A decision agreed at the sixteenth session of the Conference of the Parties (COP16) which took place in December 2010 in Cancun, Mexico, recognized the need for deep cuts in global GHG emissions in order to limit the global average temperature rise to 2°C above pre-industrial levels. Accordingly, the Parties agreed to review their long-term GHG emission reduction goals during a review period of 2013–2015 along with considering strengthening the goals to a 1.5°C temperature rise limit.

Then, at the seventeenth session of the Conference of the Parties (COP17) which took place in November–December 2011 in Durban, South Africa, the Parties also agreed to establish a second commitment period under the Kyoto Protocol from 2013 to 2020 and develop another legal instrument on GHG emission reduction targets under the Convention applicable to all Parties by 2015, when COP21 will convene in Paris, France. The deadline of the proposed new agreement entering into force was set at 2020.

The Agreement to establish a second commitment period under the Kyoto Protocol, as an Amendment to the KP, was adopted at the eighteenth session of the Conference of the Parties (COP18) which took place in November–December 2012 in Doha, Qatar. The Doha Amendment requires ratification by 144 countries (i.e. two-thirds of the Parties to the KP); however only 32 countries had ratified it as of 28 May 2015.

Further, at the nineteenth session of the Conference of the Parties (COP19) held in November 2013 in Warsaw, Poland, the Parties were invited to initiate or intensify domestic preparations for the universal, legally-binding climate agreement to be agreed at the upcoming 21st session of the Conference of the Parties (COP21), and submit their intended nationally determined contributions (INDCs) to the UNFCCC Secretariat. The INDCs are the pledged actions on mitigating their GHG emissions under the proposed new universal agreement to be adopted at COP21 in Paris. As of 14 July 2015, 20 INDCs representing 48 Parties were submitted to the UNFCCC Secretariat. Three countries in Northeast Asia, namely, China, the ROK and Russia were among these early actors.

1.3 CO_2 Emissions from Fuel Combustion in Northeast Asia (NEA)

The Northeast Asian countries, which represent more than a quarter of the world's economy and population, are diverse in terms of their socio-economic development and industrial structures. Thus, the region is home to both Annex I (Japan and Russia) and Non-Annex I (the ROK, China, Mongolia, and the DPRK) countries which are Parties to the Convention. According to the current Kyoto Protocol arrangements, two industrialized countries in Northeast Asia, Japan and Russia, had quantified, legally-binding emissions reduction targets for the first commitment period of 2008–2012, and Russia was undergoing the process of transition to a market economy. The other four countries in the region did not have such commitments during the first and second commitment periods of the KP, but as Parties to the UNFCCC, they are required to do so within the framework of the expected new, universal legal instrument to curb GHG emissions. In particular, China, as a fast growing and the top-emitting economy in the world, is drawing international attention in the Post-2020 negotiations. Also, the ROK, as an OECD member, was active in addressing the issues both domestically and internationally. In 2012, these four countries in the Northeast Asian region were among the top-ten emitting countries in the world, while Russia and Mongolia were among the top-ten emission intensive economies globally.

According to the International Energy Agency (IEA) estimates, the global CO_2 emissions from fuel combustion accounted for 31.7 billion tonnes in 2012, and the Northeast Asian region was responsible for 37% of the total or 11.8 billion tonnes. As compared to the 1990 level, the global emissions in 2012 were 51.3% higher, while those of the Northeast Asian region doubled. Collectively, the NEA countries were responsible for 60% of the growth in the global emissions level (Table 1.1).

China was responsible for more than two-thirds of total CO_2 emissions from fuel combustion in the region in 2012. Russia was the second largest emitter in the region, followed by Japan. But Russia's CO_2 emissions from fuel combustion were 23.9% lower in 2012 than its 1990 level, amounting to 1.7 billion tonnes. Japan's CO_2 emissions from fuel combustion amounted to 1.2 billion tonnes in 2012, 15.8% higher than its 1990 level, whereas Japan had to reduce its economy-wide GHG emissions by 6% during the KP's first commitment period of 2008–2012. Thus, collectively, the CO_2 emissions from fuel combustion of the Annex I Parties in NEA were 10.9% lower in 2012 compared to the 1990 level (Table 1.1, Figure 1.1).

However, the emissions of other Non-Annex I Parties in the region, who are Parties to the Kyoto Protocol but do not have legally-binding targets for their emission reductions, had substantially increased, with the exception of the DPRK. The total amount of the CO_2 emissions of these countries amounted to 8.9 billion tonnes in 2012, which was 238.1% higher from the 1990 level. This growth predominantly originated from China.[2] China's annual CO_2 emissions from fuel combustion had almost quadrupled during the period amounting to 8.3 billion tonnes in 2012, thus emitting an additional 6.0 billion tonnes from the 1990 level. At the same time, the combined emissions of the Northeast Asian countries in 2012 were higher by 5.9

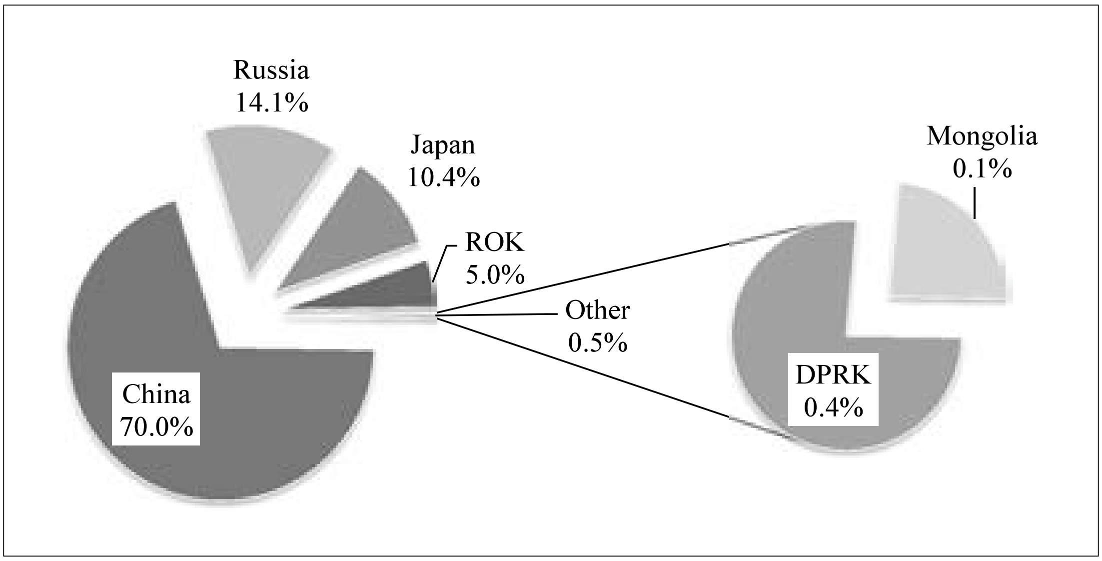
[2] Includes Hong Kong unless stated otherwise.

Table 1.1: CO_2 Emissions from Fuel Combustion in NEA in 2012

Country/Region	Amount, Million tonnes of CO_2	Change from 1990 level		
		Percentage change, %	Volume change, Million tonnes of CO_2	Share of volume change, %
Japan	1,223.3	15.8	166.6	2.8
Russia	1,658.9	−23.9	−519.9	−8.8
NEA Annex I Parties	2,882.2	−10.9	−353.3	−6.0
China	8,250.8	262.2	5,973.1	101.0
ROK	592.9	158.6	363.7	6.1
Mongolia	14.2	11.8	1.5	0.03
DPRK	45.4	−60.2	−68.6	−1.2
NEA Non-Annex I Parties	8,903.4	238.1	6,269.7	106.0
NEA Total	11,785.6	100.8	5,916.4	100.0
World Total	31,734.3	51.3	10,760.4	

Source data: IEA, 2014a.

Figure 1.1: CO_2 Emissions from Fuel Combustion by NEA Countries, 2012



Source data: IEA, 2014a.

billion tonnes compared to the 1990 level. The ROK had also witnessed a substantial growth of its emissions during the period and the country emitted 2.6 times more CO_2 from fuel combustion in 2012 than in 1990. Mongolia's CO_2 emissions from fuel combustion also increased and they were 11.8% higher in 2012 from the 1990 level. The DPRK was the only country in the region which witnessed a sharp decrease in its emission level. The DPRK's CO_2 emissions from fuel combustion amounted to 45.4 million tonnes in 2012, which was 60.2% lower than the 1990 level (Table 1.1, Figure 1.1).

The primary driving forces for CO_2 emissions can be discussed using the Kaya identity.[3] The Kaya identity states that the total level of emissions can be expressed as a product of four indicators: carbon intensity of energy supply; energy intensity of gross domestic product (GDP); per capita GDP; and population. The average annual changes in these indicators during the period from 1990 to 2012 are illustrated in Table 1.2.

Collectively, the level of CO_2 emissions from fuel combustion in the NEA region saw a 2.1% year-on-year increase during the period from 1990 to 2012, although the annual growth rates varied by country. China had the highest annual growth in its level of CO_2 emissions followed by the ROK. The average annual percentage changes in the emissions of China and the ROK were 6.1% and 4.4%, respectively, over the period, while those of Japan and Mongolia were 0.7% and 0.4%, respectively. At

[3] $C = P(G/P)(E/G)(C/E)$, where: $C = CO_2$ emissions; P = population, G = GDP, and E = primary energy consumption.

Table 1.2: CO_2 Emissions and Drivers (Kaya Decomposition): Average Annual Percentage Change between 1990 and 2012

(%)

Country/ Region	CO_2 emissions	Population	GDP per Capita	Energy intensity of GDP (TPES[4]/GDP)	Carbon intensity of energy supply (CO_2/ TPES)
Japan	0.7	0.1	0.8	−0.8	0.5
Russia	−1.2	−0.1	0.8	−1.4	−0.6
China	6.1	0.8	9.4	−4.2	0.4
ROK	4.4	0.7	4.4	−0.2	−0.4
Mongolia	0.5	1.1	3.0	−3.4	−0.1
DPRK	−4.1	0.9	−2.6	−2.2	−0.3
NEA*	1.1	0.6	2.6	−2.0	−0.1
World	1.9	1.3	2.1	−1.4	−0.0

Note: *estimated as average values of the countries' inputs; Source: IEA, 2014a.

Table 1.3: Total Primary Energy Supply (TPES) in 2012

Country/Region	TPES (Million tonnes of oil equivalent)	Share, %	% change on 1990 level
Japan	452.3	10.3	3.0
Russia	756.6	17.2	−13.9
China	2,908.9	66.1	230.8
ROK	263.4	6.0	183.5
Mongolia	3.9	0.1	15.7
DPRK	14.1	0.3	−57.6
NEA	4,399.2	100.0	

Source: IEA, 2014a.

the same time, Russia and the DPRK witnessed 1.2% and 4.1% annual declines in their emissions levels (Table 1.2).

According to the Kaya decomposition, the CO_2 emission increases were mainly driven by population and per capita GDP growth in the region, despite the fact that the energy intensities of GDP and carbon intensities of energy supply had been declining. During the period 1990–2012, the population in all of the NEA countries had been growing, except for Russia, although their living standards have been improving, but for the DPRK. At the same time, the energy intensity of GDP was declining in all the countries, although its extent varied by country. China was the top runner in reducing the energy intensity of its GDP. However, the carbon intensity of energy supply in China and Japan had increased by 0.4% and 0.5% per year, respectively, while in other countries it decreased (Table 1.2).

1.4 The Energy Mix in Northeast Asia

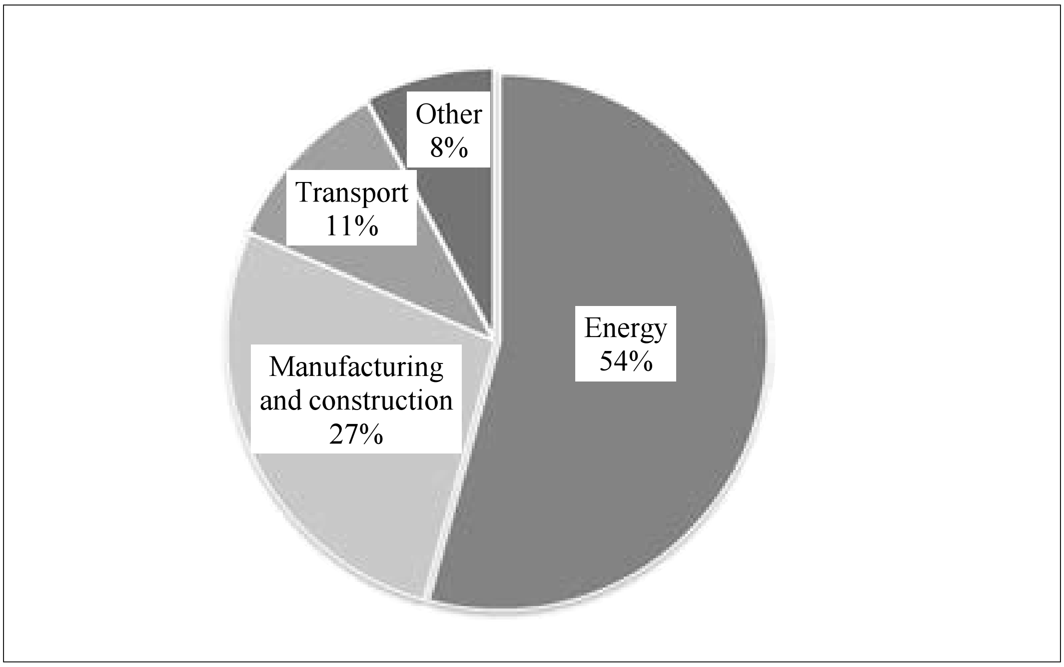
The TPES of the countries in Northeast Asia collectively amounted to 4.4 billion tonnes of oil equivalent in 2012, with China's TPES accounting for two-thirds of the regional total. China's TPES had more than tripled during the period 1990–2012 and equaled 2.9 billion tonnes of oil equivalent in 2012. Therefore, reducing the carbon intensity of energy supply in China is a significant factor for mitigating GHG emissions in the region. Among other things, energy efficiency improvements, massive deployment of renewable and clean energy sources, as well as shifting from coal to other cleaner energy sources, such as natural gas, are essential (Table 1.3).

The energy sector was responsible for more than half of the region's total CO_2 emissions from fuel combustion in 2012, followed by manufacturing and construction, accounting for 54% and 27% of the total. Therefore, in addition to energy industries, the manufacturing and construction sectors could be other potential target sectors for GHG emission reduction actions in the region (Figure 1.2).

The fact that non-renewables still dominate the energy mix, makes the energy system the largest contributor to GHG emissions. In 2012, non-renewables (coal, oil, natural gas and nuclear) supplied 91.6% of the TPES in the Northeast Asian countries collectively. The shares of non-renewables in the energy systems of the industrialised

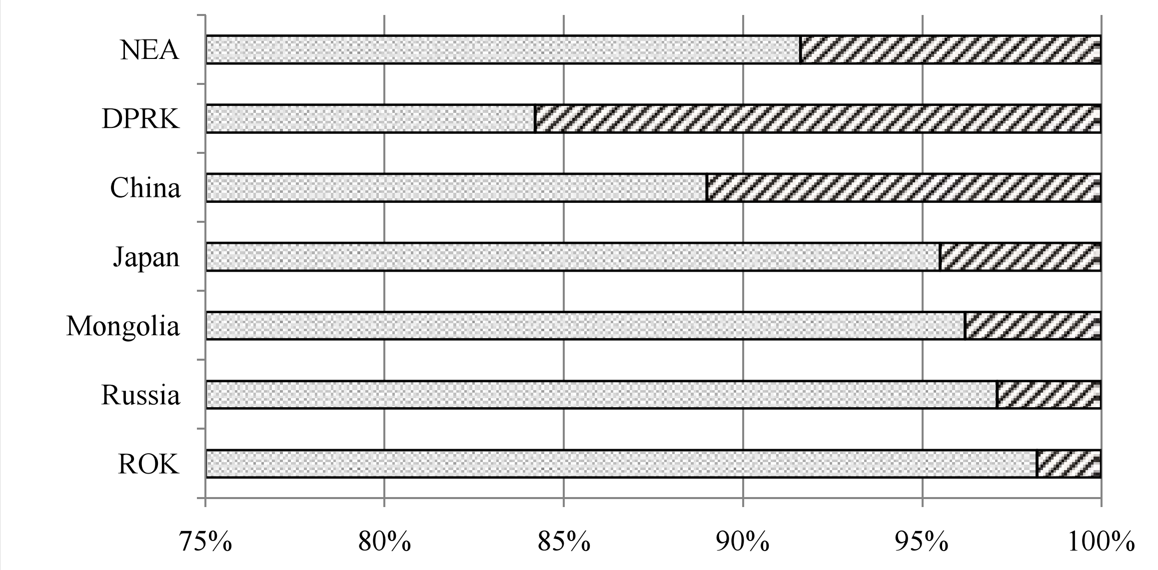
[4] Total Primary Energy Supply

Figure 1.2: Sectoral Composition of CO_2 Emissions from Fuel Combustion in NEA, 2012



Source: Estimated from IEA, 2014a.

Figure 1.3: TPES Composition in 2012



	ROK	Russia	Mongolia	Japan	China	DPRK	NEA
Fossil fuels	98.2	97.1	96.2	95.5	89.0	84.2	91.6
Renewables	1.8	2.9	3.8	4.5	11.0	15.8	8.4

Source: Estimated from OECD/IEA, 2014.

economies (Japan, Russia and the ROK) in the region were higher than the regional level, with the highest level, for the ROK, standing at 98.2%. China, which accounts for two-thirds of the regional TPES, generated 89% of its energy from non-renewables. The DPRK, the poorest economy in the region, was the regional leader in terms of decarbonising its energy supply, producing 15.8% of its TPES from renewables (Figure 1.3).

Coal, the most polluting among the fossil fuels, was still the dominant fuel for energy generation in the developing NEA countries, China, Mongolia and the DPRK, accounting for more than two-thirds of their TPES. However, in the industrialized countries, oil was the largest source of energy in Japan and the ROK, while natural gas

Table 1.4: Energy Mix Breakdowns in NEA, 2012

(% of TPES)

	Japan	Russia	China	ROK	Mongolia	DPRK
Coal	24.8	17.6	67.9	29.3	66.5	78.4
Oil	46.5	22.3	16	36.9	29.7	5.8
Natural gas	23.3	51.0	4.2	17.1	-	-
Nuclear	0.9	6.2	0.9	14.9	-	-
Hydro	1.4	1.9	2.6	0.1	-	8.2
Biofuels/waste	2.3	0.9	7.5	1.6	3.8	7.6
Geothermal/solar/wind	0.8	0.1	0.9	0.1	-	-

Source: OECD/IEA, 2014.

supplied more than half of Russia's TPES. Therefore, a shift from coal to natural gas is desirable in the region as a bridging action toward renewables and other clean and sustainable energy sources. More detailed discussion on this matter will be made in the latter sections (Table 1.4).

2. Decarbonizing the Energy Supply in Northeast Asia

2.1 The Intended Nationally Determined Contributions (INDC)

The countries in NEA have been making certain efforts toward reducing their GHG emissions since the inception of the UNFCCC and the Kyoto Protocol. As described earlier, the energy intensities of the economies in the region have been declining by 2% per annum since 1990, while the global rate was 1.4% (Table 1.2). Given that energy is responsible for most of the GHG emissions, this trend is an encouraging one. However, these efforts are as yet insufficient to curb the emissions and enable the shift to a zero-carbon world within this century. Therefore, it became of utmost importance to upscale emission reduction actions to a new level globally, where the Northeast Asian region would play a key role.

In advance of the new global climate deal to be negotiated at the upcoming UNFCCC COP21 in Paris, the major economies in the region, namely, Japan, Russia, China and the ROK, have submitted their Intended Nationally Determined Contributions (INDC) to the UNFCCC Secretariat. A summary of the key targets stated in these INDCs is given in Table 2.1. For comparison, the INDCs of the United States and European Union are also provided. The INDC emission reduction targets are as follows:

- Russia plans to reduce its GHG emissions within a range of 25%–30% by 2030 compared to the 1990 level;
- China plans to lower its emission intensity of GDP by 60%–65% by 2030, compared to the 2005 level;
- The ROK plans to reduce the level of its GHG emissions by 37% from the "business as usual (BAU)" level by 2030, and the BAU in 2030 would equal 850.6 $MtCO_2eq$[5]; and
- Japan aims to reduce its GHG emissions by 26% by FY2030 compared to the FY2013 level, which is equal to a 25.4% reduction in 2030 from the FY2005 level.

At the same time, the member states of the European Union (EU) are ready to commit to a binding target of a 40% reduction in GHG emissions by 2030 compared to the 1990 level, while the United States intends to achieve an economy-wide reduction of its GHG emissions of 26–28% below its 2005 level and to make its best efforts to attain the higher level of a 28% reduction.

The above stated targets on GHG emission reductions will be implemented domestically in all the countries, with the exception of Japan. Japan is not participating in the implementation of the second commitment period (i.e. 2013–2020) of the Kyoto Protocol as Japan and Russia left the Kyoto Protocol, rejecting the new Kyoto targets. However, Japan is implementing a bilateral mechanism called the Joint Crediting Mechanism (JCM) to facilitate GHG emission reduction projects in developing countries. The first JCM document was signed with Mongolia in January 2013.

2.2 The Carbon "Budget" for the Two-Degree Target

The Intergovernmental Panel on Climate Change (IPCC, 2013) stated that: "Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions" (p. 19). Scientists warn that in order to prevent dangerous climate change the global mean temperature rise from the pre-industrial level should be limited to 2°C, and at COP16 of the UNFCCC held in 2010 in Cancun, Mexico, global leaders agreed to ensure this limit. Then negotiations on a new legal, global agreement for the post-2020 climate regime began at COP17 held in Durban, South Africa, in 2011 and set the deadline for adopting this deal at COP21 to be held 30 November–11 December 2015 in Paris, France.

"Even by staying within our carbon budget[6] and keeping the global temperature rise to 2°C above pre-industrial

[5] Million tonnes of carbon dioxide equivalent.

[6] The carbon budget is the estimated amount of carbon dioxide the world can emit while still having a likely chance of limiting the global temperature rise to 2°C above pre-industrial levels. The international scientific community estimates this budget to be 1 trillion tonnes of carbon (WRI, 2015).

Table 2.1: Intended Nationally Determined Contributions (INDC) of Selected Countries

Country	Date Submitted	Key Points
Russia	1 April 2015	• Limit anthropogenic greenhouse gas emissions in the country to 70–75% of 1990 levels by 2030 (i.e. a 25%–30% reduction by 2030 compared to 1990 levels), subject to the maximum amount for the absorption capacity of forests (Russia's forests account for 25% of the world forest resources, whereas the share for boreal forests accounts for 70% of the global total); • The INDC indicator is to be achieved without use of international market mechanisms (Russia, 2015).
China	30 June 2015	• Achieve peak CO_2 emissions around 2030, while making its best efforts for earlier achievement; • Lower CO_2 emissions per unit of GDP by 60% to 65% from the 2005 level by 2030; • Increase the share of non-fossil fuels in primary energy consumption to around 20%; • Increase the forest stock volume by around 4.5 billion cubic meters from the 2005 level (China, 2015).
ROK	30 June 2015	• A 37% reduction of its "business as usual (BAU)" emissions by 2030, with the BAU in 2020, 2025 and 2030 amounting to 782.5 $MtCO_2eq$, 809.7 $MtCO_2eq$ and 850.6 $MtCO_2eq$, respectively; • Launched the GHG and Energy Target Management System (TMS) for the industrial sector; • Launched a nation-wide Emission Trading Scheme (ETS) in 2015 that covers 525 entities accounting for 67.7% of national GHG emissions; • Will strengthen the average emission standard for automobiles to 97 g/km in 2020 from 140 g/km in 2015 (ROK, 2015).
Japan	17 July 2015	• A 26% GHG emission reduction by FY2030 (i.e. by 31 March 2031) compared to the FY2013 level (i.e. a 25.4% reduction compared to the FY2005 level); • As the energy-originated CO_2 emissions in Japan account for 90% of the country's total GHG emissions, the above target implies that the energy-originated CO_2 will be reduced by 25% in FY2030 compared to FY2013 or a 24% reduction compared to the FY2005 level; • About 22–24% of total power generation in 2030 will come from renewables, with hydro and solar power accounting for 8.8–9.2% and 7%, respectively; • The Joint Crediting Mechanism (JCM) is not included as a basis for the emission reduction target, but the amount of emission reductions and removals acquired under the JCM will be counted as Japan's reduction (Japan, 2015).
EU	6 March 2015	• Commit to a binding target of an at least 40% domestic reduction in GHG emissions by 2030 compared to 1990 (EU, 2015).
US	31 March 2015	• Achieve an economy-wide reduction of its GHG emissions by 26–28% below the 2005 level in 2025 and to make its best efforts to attain a 28% reduction; • Does not intend to utilize international market mechanisms to implement its 2025 target (US, 2015).

Source: Compiled from the respective countries' INDCs (2015) submitted to the UNFCCC Secretariat.

levels, some regions will still experience an increased risk of sea level rise, forest fires, water shortages and other devastating impacts" (WRI, 2015, p. 1).

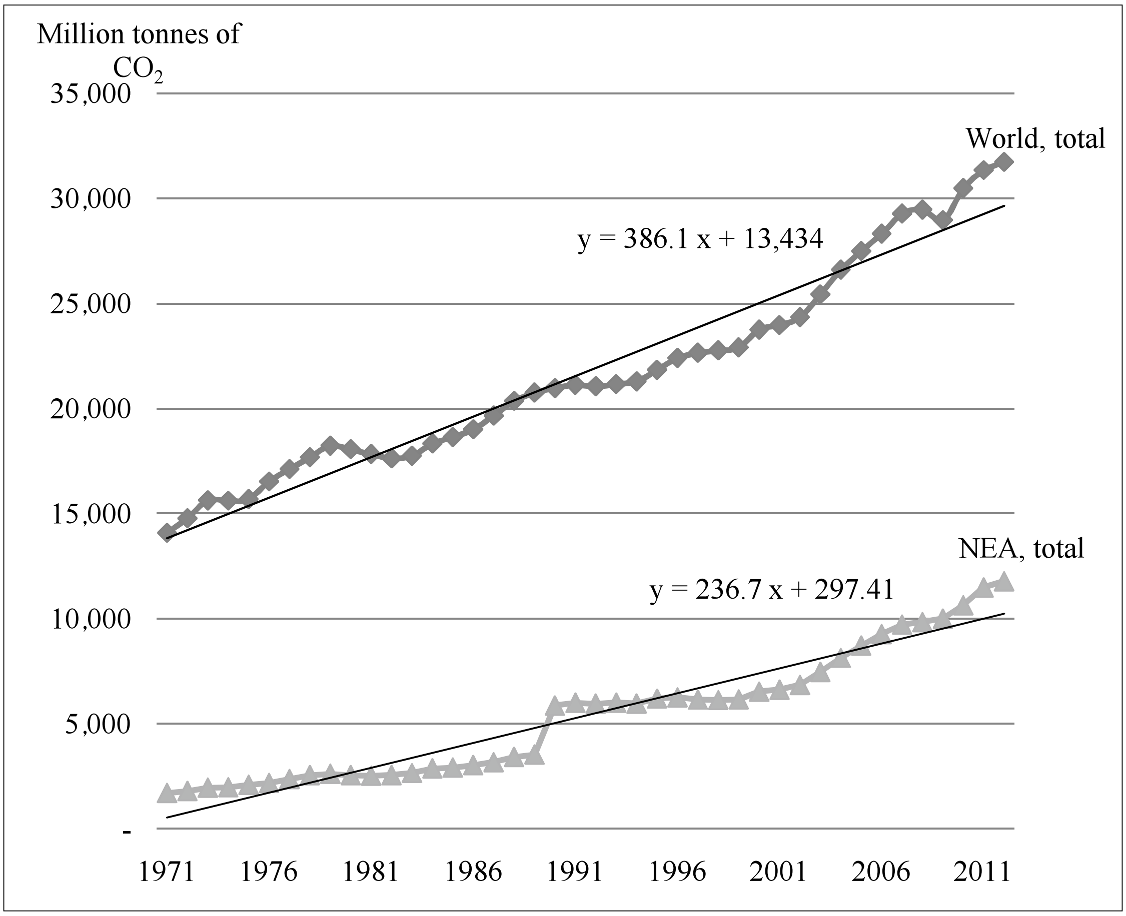
Hence, a key question is: What level of greenhouse gas emissions is consistent with the two-degree path? There are several answers to this question.

The World Resources Institute (WRI, 2015) stated that while the world is not on the 2°C path, the right amount of ambition for mitigating GHG emissions can still put into the 2°C path. One of the ambitions is that roughly three-quarters of the world's fossil fuel reserves must remain unburned.

Also, the United Nations Environment Programme (UNEP, 2014) noted that "…there is a medium likelihood to stay within the two degree limit if the following conditions are met:

- Global emissions peak sometime between 2015 and 2021;

Figure 2.1: CO_2 Emissions from Fuel Combustion Trends, 1971–2012



Source: IEA, 2014a.

- Global emissions in 2020 are approximately 40.0 to 48.3 Gt CO_2 eq/yr;
- By 2050 global emissions decrease by 48 to 72% relative to 2000" (p. 3).

However, global CO_2 emissions have been on an increasing trend since 1971, when global CO_2 emissions data became available, and there has been no indication of them levelling off soon. Similarly, the total emissions for the Northeast Asian countries are also increasing, although at a slightly slower pace than the global trend. This is due to the fact that although the NEA region is home to economies with high emissions growth, such as China and the ROK, it is also home to economies who witnessed substantial reductions in their GHG emissions levels due to their economic setbacks over the period, such as Russia and the DPRK (Figure 2.1).

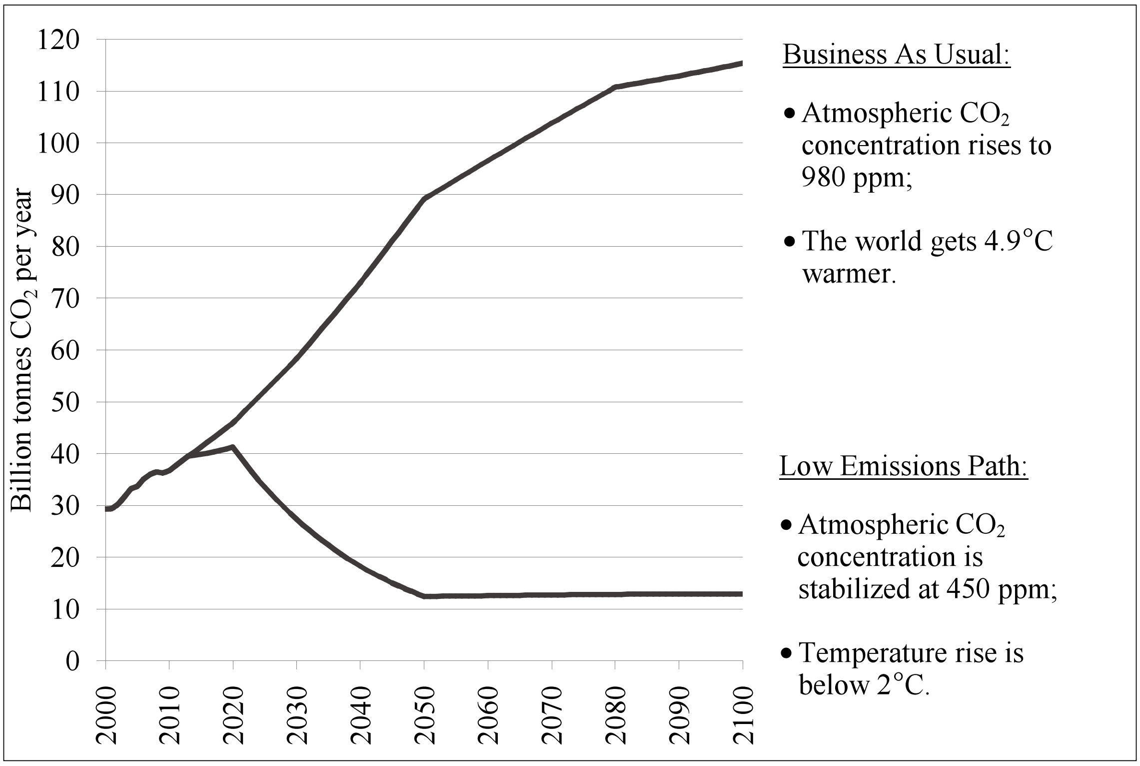
As the greenhouse gases have a long lifetime, remaining in the air for several centuries, the cumulative build-up of these gases in the atmosphere matters most. According to the IPCC estimates, the world can support a maximum carbon dioxide (CO_2) emissions "budget" of 3,000 gigatonnes (Gt) in order to preserve a 50% chance for staying below the 2°C limit, with 1,970 Gt having already been emitted before 2014. "Accounting for CO_2 emissions from industrial processes and land use, land-use change and forestry (LULUCF) over the rest of the twenty-first century leaves the energy sector[7] with a carbon budget of 982 Gt" (IEA, 2015, p.18). With the current level of more than 30 Gt of global CO_2 emissions the world would run out of the "budget" in just three decades. This means that after 2050 the world has no choice but zero emissions.

Furthermore, as mentioned earlier, limiting the global mean temperature to below a 2°C rise means that the greenhouse gas concentration in the atmosphere must be stabilized below 450 parts per million (ppm). According to the Climate Scoreboard (2013), only the low-emissions path of 450 ppm will be consistent with the 2°C limit, while the Business As Usual (BAU) path would lead to a global atmospheric CO_2 concentration of 980 ppm and a global mean temperature rise of 4.9°C over the pre-industrial level. The low emissions path requires levelling-off the global CO_2 emissions before 2025 and reducing the emissions by more than two-thirds of the current level (Figure 2.2).

In fact, this level of 450 ppm will not reverse the changing climate we are facing now. As pointed out by

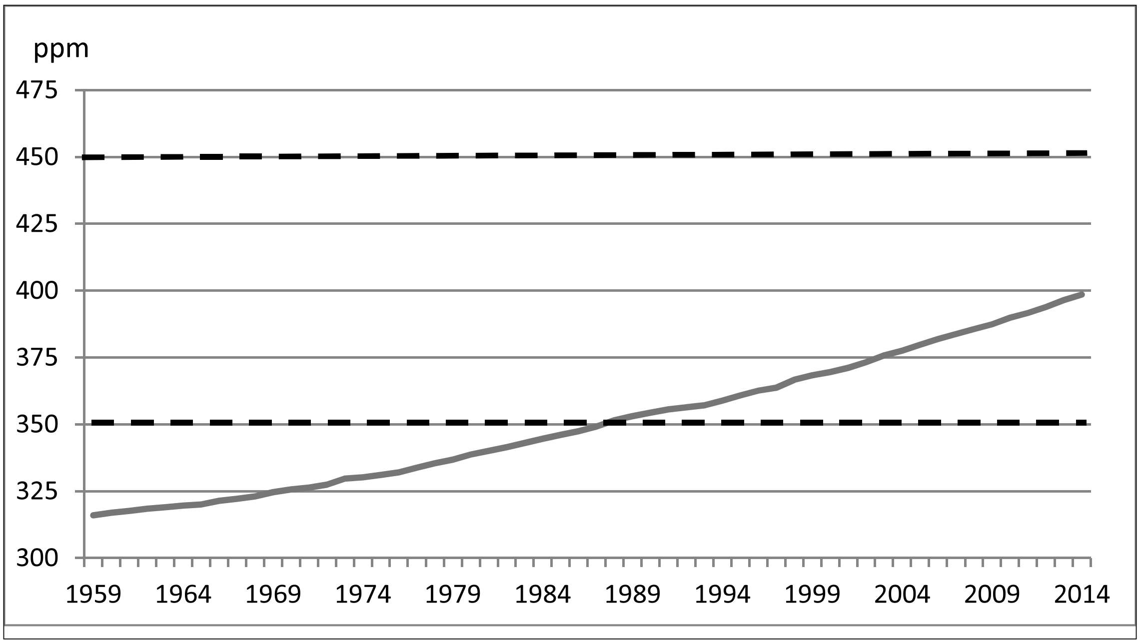
[7] Energy sector refers to energy supply, energy transformation, including power generation, and energy consuming sectors (including buildings, industry, transport and agriculture).

Figure 2.2: Global CO_2 Emissions



Source: Adapted from Climate Scoreboard © Climate Interactive 19 April 2013 www.ClimateScoreboard.org

Figure 2.3: Mean Annual CO_2 Concentrations in the Atmosphere, 1959–2014



Source: NOAA ESRL, 2015b.

James Hansen et al. (2015), if humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, the annual mean CO_2 concentration in the atmosphere needs to be stabilized below 350 ppm. But, we had already crossed over this threshold in 1987 and are witnessing various adverse effects of the changing climate worldwide. According to the Mauna Loa Observatory[8], the level of atmospheric

Table 2.2: Carbon Budget of Northeast Asia Consistent with the Low Emissions Path

Year	Global CO_2 Emissions Gt/year	CO_2 Emissions from Fuel Combustion					Annual Carbon "Budget" ($MtCO_2$)	
		World total Gt/year	Share of global total %	World, total, $MtCO_2$	NEA, total	NEA share, %	World	NEA
1990	27.64	20.97	76%	20,974	5,869	28%		
2000	29.36	23.76	81%	3,756	6,533	27%		
2005	33.72	27.49	82%	27,494	8,717	32%		
2010	36.7	30.48	83%	30,482	10,650	35%		
2011	37.7	31.35	83%	31,345	11,485	37%		
2012	38.6	31.73	82%	31,734	11,786	37%		
Average 2010–2012.	37.7	31.2	83%	31,187	11,307	36%		
2020	41.26	34.17	83%	34,174	12,385	36%	**2,987**	**1,077**
2030	27.37	22.67		22,669	8,215		−8,518	−3,092
2040	18.29	15.15		15,149	5,490		−16,038	−5,817
2050	12.46	10.32		10,320	3,740		−20,867	−7,567

Notes: 1. The annual carbon budget is estimated as the difference between the estimated and current levels of CO_2 emissions, and the current level is the average value of 2010–2012;
2. The share of CO_2 emissions from fuel combustion for 2020 and beyond is estimated to be equal to the current level of its share of global CO_2 emissions, i.e. 83%.
3. The NEA share of total CO_2 emissions from fuel combustion for 2020 and beyond is estimated to be equal to the current level of its share of world CO_2 emissions from fuel combustion, i.e. 36%.

Source: Estimated from Climate Interactive, 2015 and IEA, 2014a.

greenhouse gas concentration has been growing at an accelerating rate from decade to decade and it equaled 397.16 ppm in 2014 (NOAA-ESRL, 2015a). Thus, the remaining room for not crossing the next threshold is getting smaller (Figure 2.3).

According to the "Low Emissions Path" of Climate Interactive, illustrated in Figure 2.2, the global CO_2 emissions per year will peak at 41.26 gigatonnes (Gt) in 2020 and then decline to 12.46 Gt by 2050. This means that the world has an annual "extra" carbon budget of less than 3,000 tonnes a year until 2020 and then will have to reduce it to a level less than half of the emissions in 1990 (Table 2.2).

Similarly, the remaining "extra" carbon budget from fuel combustion in Northeast Asia is estimated to be 1,077 million tonnes of CO_2 a year until 2020 and they will then have to accelerate annual reductions to 7,567 million tonnes of CO_2 by 2050, that is, by 67% or two-thirds from the current level of 11,307 million tonnes of CO_2 (Table 2.2).

2.3 Substituting Coal with Natural Gas as a Bridge for Phasing Out Fossil Fuels

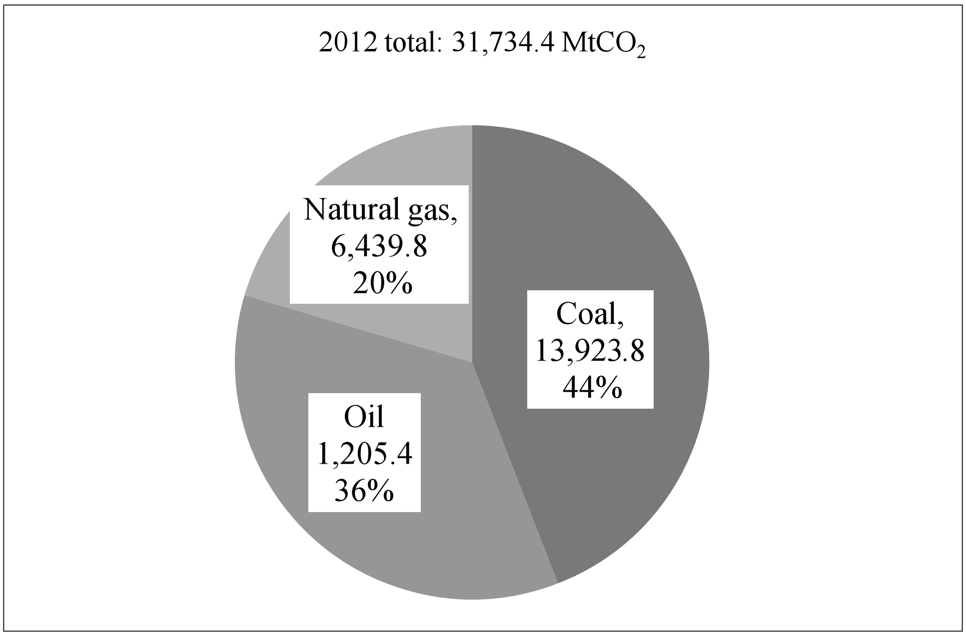
Energy efficiency improvements have great potential for GHG emissions reduction, especially in the manufacturing and construction sectors. Studies suggest that many efficiency improvements are priced at 1–3 cents per kWh—about one-fifth the cost of electricity generated from new coal- and natural gas-fired plants. Efficiency is not only cheaper than all other options, it also increases personal income by reducing energy bills and frees money that can be spent elsewhere to encourage employment.

As mentioned earlier, the NEA region has made a certain degree of progress in improving energy efficiency, and the energy intensities of all the economies declined in 2012 compared to their 1990 levels. Japan's Top Runner Program has helped the country boost the efficiency of refrigerators by 55%, air conditioners by almost 68% and computers by 99%. Japan's steel industry now uses a third less energy than it did 30 years ago. Converting China's cement industry to the most efficient dry kiln technologies, as used in Japan, could cut global energy use in the cement sector by 40% (International Rivers, 2009). According to the World Business Council for Sustainable Development (2010), buildings today account for 40% of the world's energy use and a path is available to achieve energy savings in buildings that can equal the total energy consumed in today's transportation.

However, energy efficiency improvements alone will be insufficient to curb GHG emissions and a bold move towards renewables and other clean energy sources for

[8] The Mauna Loa Observatory, located in Hawaii, is part of the National Oceanic and Atmospheric Administration (NOAA), Earth System Research Laboratory (ESRL), Global Monitoring Division (GMD) in the United States. The continuous, high-precision measurement of changes in atmospheric CO_2 concentrations was started at the observatory in March 1958.

Figure 2.4: World CO_2 Emissions Composition by Fuel Type



Source: IEA, 2014a.

Table 2.3: NEA CO_2 Emissions from Fuel Combustion by Fuel type, 2012

($MtCO_2$)

Country	Coal	Oil	Natural Gas	Total
Japan	419.7	535.8	259.8	1,215.3
ROK	291.2	183.6	106.0	580.8
Russia	425.2	350.0	864.9	1,640.1
DPRK	42.9	2.5	-	45.4
Mongolia	10.7	3.5	-	14.2
China, incl. Hong Kong	6,794.0	1,163.1	272.2	8,229.3
NEA Total	7,983.7	2,238.5	1,502.9	11,725.1
Share by fuel type, %	68%	19%	13%	100%

Source: IEA, 2014a.

Table 2.4: Selected Indicators of Fossil Fuels

Factors	Coal (Lignite)	Oil	Natural Gas
Default net calorific value (NCV), (TJ/Gg)	11.9	42.3	48.0
Default carbon content (kg/GJ)	27.6	20.0	15.3
Default CO_2 emission factor for combustion (kg/TJ)	101,000	73,300	56,100

Source: IPCC, 2006.

energy generation is indispensable. The countries in the region are making efforts to this end. The share of clean energy in China's energy mix keeps progressing and China is leading the global development of wind energy with 20 million kW of installed capacity annually. Moreover, China is among the global leaders for development and utilization of solar and renewable energy. Still, however, "China confronts the problem of optimizing its energy use structure, and in particular managing its shift away from low-efficiency, highly polluting sources" (Zhou, 2010, p. 31). Mongolia aims to increase the share of renewable energy in its energy generation to 20–25% by 2020 from the current 4% (MNETM, 2010). However, the results of these actions are still far from putting them on the global 2°C target path. Therefore all the countries in Northeast Asia need to take more robust action if they are to realize the global mission of arresting and eventually reducing the concentration of anthropogenic GHGs in the Earth's atmosphere.

An experts meeting held in Bonn on 3 June 2015 during the UN Climate Change Conference underlined that the "deep decarburization of global energy systems is technologically and economically feasible, but requires immediate and strong action" (UNFCCC, 2015). As indicated in the World Energy Outlook 2014 Factsheet, the share of renewables in total power generation rises to 33% in 2040, whereas energy demand grows by 37% and fossil fuels continue to dominate the power sector with a share of 55% of the total. "China sees the largest increase in electricity generation from renewables, more than the gains in the EU, US and Japan combined" (IEA, 2014b, p. 3).

But, as discussed in the previous section, the global carbon budget in 2050 will be 20,867 million tonnes of CO_2 ($MtCO_2$) less than its level in 2012, with coal accounting for 13,934 $MtCO_2$ or 44% of global CO_2 emissions from fuel combustion (Figure 2.4).

In Northeast Asia, coal accounted for 7,983.7 $MtCO_2$ or 68% of total CO_2 emissions from fossil fuel combustion in 2012, and the region's total carbon budget in 2050 will be 7,567 $MtCO_2$ less than this level. Therefore, if coal were completely phased out by 2050, there would be a chance for the region to stay on the low-emissions path (Tables 2.2, 2.3).

Due to cost and budget constraints, complete and immediate replacement of the current and expected coal-fired power plants with renewable energy sources will be a huge challenge for any country. Thus, as a transitional step, coal could be completely replaced by natural gas. Natural gas is the cleanest fuel among the fossil fuels and it has high calorific value and contains much less carbon than coal. Per unit of energy generated, natural gas emits half as much CO_2 than coal emits (Table 2.4).

In the NEA region, where potential gas resources, such as those in Russia, are located, this option could be a major transitional step in levelling off its GHG emissions earlier than is expected, especially in China. Coal accounted for 83% of China's total CO_2 emissions from fossil fuel combustion in 2012 (Table 2.3).

A recent move to build a major pipeline to transport gas from Russia, which has the world's second largest proven reserves of natural gas, to China, the largest energy consumer in the region, will be a substantial boost for replacing coal by natural gas. The planned pipeline would carry approximately 39 billion cubic meters of natural gas from Russia to China (Hanner, 2014).

3. Conclusions

Energy and climate change need to be addressed simultaneously within long-term energy security issues, and shifting energy generation from greenhouse gas intensive resources to lower or zero-emission alternatives should be considered. Scientists warn that the planet is warming faster than previously thought and we must limit the global mean temperature rise to 2°C from the pre-industrial level in order to prevent dangerous climate change. Aimed at achieving this climate goal, a universal, legally-binding climate deal is scheduled to be agreed at the upcoming 21st session of the United Nations Framework Convention on Climate Change (UNFCCC)–COP21 to be held later this year in Paris.

It is a fact that the aggregate GHG emissions in Northeast Asian countries have grown at a pace two-times faster than the world average over the period 1990–2012. This situation necessitates the countries in the region taking more robust action toward reducing their greenhouse gas emissions. During the period from 1990 to 2012, GHG emissions have been increasing in all Northeast Asian countries, except in Russia and the DPRK. These increases were mainly associated with population and per capita GDP growth, although energy and carbon intensities were on declining trends in all countries of the region, except in China and Japan.

The energy sector is responsible for more than half of total greenhouse emissions in NEA, with coal being the largest contributor to the region's CO_2 emissions from fossil fuel combustion. If the region is to stay within the boundaries of its carbon budget in compliance with the global 2°C target, coal needs to be completely phased out by 2050. Despite the fact that renewables are becoming technologically and economically more viable for energy generation, immediate implementation will be a huge challenge for the Northeast Asian countries. Therefore, as a transitional step, owing to potential resources of natural gas in the region, coal could be replaced by natural gas before 2050. Subsequently, all fossil fuels need to be replaced with renewable energy or other zero-emission alternatives.

References

China (2015). Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions. Available: http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx (accessed 24 July 2015)

Climate Interactive (2015). Scoreboard Science and Data (online). Available: https://www.climateinteractive.org/tools/scoreboard/scoreboard-science-and-data/ (accessed 24 July 2015)

EU (2015). Submission by Latvia and the European Commission on behalf of the European Union and Its Member States, 6 March 2015, Riga. Available: http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx (accessed 24 July 2015)

Factor CO_2 (2015). Factor CO_2 INDC Update. Available: http://www.factorco2.com/comun/docs/167-INDC%20UPDATE%203%20Factor_%20COP%2021_20150727.pdf (accessed 29 July 2015)

HANNER, I. (2014). Construction Giants Race to Win Contract for Gazprom's $70b China Pipeline. Available: http://www.explorationworld.com/pipelines/8/Construction-Giants-Race-to-Win-Contract-for-Gazproms-70b-China-Pipeline (17 August 2015).

HANSEN, James, Makiko SATO, Pushker KHARECHA, David BEERLING, Robert BERNER, Valerie MASSON-DELMOTTE, Mark PAGANI, Maureen RAYMO, Dana L. ROYER and James C. ZACHOS (2015). Target Atmospheric CO_2: Where Should Humanity Aim? Available: http://arxiv.org/ftp/arxiv/papers/0804/0804.1126.pdf (accessed 11 August 2015).

IEA (2014a). International Energy Agency, *CO_2 Emissions from Fuel Combustion: Highlights, 2014 Edition*. Available: https://www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-

combustion-highlights-2014.html
IEA (2014b). World Energy Outlook 2014 Factsheet. International Energy Agency. Retrieved from: www.worldenergyoutlook.org
IEA (2015). Energy and Climate Change: World Energy Outlook Special Report, OECD/IEA, Paris. Available: http://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf
International Rivers (2009). *International Rivers*: people. water.life. The Power of Megawatts. Efficiency: The Greenest Electricity Source. October 2009.
IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, EGGLESTON H.S., BUENDIA L., Miwa K., NGARA T., and TANABE K. (eds.). Published: IGES, Japan.
IPCC (2013). Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [STOCKER, T.F., D. QIN, G.-K. PLATTNER, M. TIGNOR, S.K. ALLEN, J. BOSCHUNG, A. NAUELS, Y. XIA, V. BEX and P.M. MIDGLEY (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Japan (2015). Submission of Japan's Intended Nationally Determined Contribution (INDC), 17 July 2015. Available: http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx (accessed 24 July 2015)
JERICHOW, R. (2009). Russia to halve emissions by 2050 (News dated on 13 July 2009 on Danish COP 15 host-country website). Available: http://en.cop15dk/news/view+news?newsid=1707 (accessed 20 October 2009)
JIANG, K. (2009). Options for China to join international climate change regime. Available: http://en.cop15.dk/blogs/view+blog?blogid=924 (accessed 27 October 2009)
MNETM (2010). *Mongolia Second National Communication* under the United Nations Framework Convention on Climate Change. Ministry of Nature, Environment and Tourism of Mongolia. 2010: Ulaanbaatar.
NOAA ESRL (2015a). National Oceanic & Atmospheric Administration, Earth System Research Laboratory: Mauna Loa CO_2 Annual Mean Data by Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph KEELING, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/). Retrieved from: http://www.esrl.noaa.gov/gmd/ (11 August 2015)
NOAA-ESRL (2015b). Mauna Loa Observatory Data. Available: http://co2now.org/ (accessed 14 July 2015)
OECD/IEA (2014). IEA Energy Statistics: Retrieved from: Statistics on the web: http://www.iea.org/statistics/
ROK (2015). Submission by the Republic of Korea: Intended Nationally Determined Contribution, 30 June 2015. Available: http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx (accessed 24 July 2015)
Russia (2015). Russia's Intended Nationally Determined Contribution (INDC) and Clarifying Information, 1 April 2015. Available: http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx (accessed 24 July 2015)
UNEP (2014). The Emissions Gap Report 2014. Available: http://www.unep.org/publications/ebooks/emissionsgapreport2014/portals/50268/pdf/EGR2014_LOWRES.pdf (accessed 24 July 2015)
UNFCCC (2009). *Ideas and proposals on the elements contained in paragraph 1 of the Bali Action Plan: Submissions from Parties, Part II*, FCCC/AWGLCA/2009/MISC.4 (Part II), 119 pages. Available online.
UNFCCC (2015). Bonn Expert Meeting on Renewable Energy: Massive Renewable Action Can Meet 2°C Target. Article on 3 June 2015. Retrieved from: http://newsroom.unfccc.int
UNFCCC (2015a). SUMMARY OF THE LIMA CLIMATE CHANGE CONFERENCE: 1-14 DECEMBER 2014. Available: http://www.iisd.ca/download/pdf/enb12619e.pdf (accessed 10 July 2015)
UNFCCC (2015b). SUMMARY OF THE GENEVA CLIMATE CHANGE CONFERENCE: 8-13 FEBRUARY 2015. Available: http://www.iisd.ca/download/pdf/enb12626e.pdf (accessed 10 July 2015)
UNFCCC (2015c). SUMMARY OF THE FORTY-FIRST SESSION OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE: 24-27 FEBRUARY 2015. Available: http://www.iisd.ca/download/pdf/enb12627e.pdf (accessed 10 July 2015)
UNFCCC (2015d). SUMMARY OF THE BONN CLIMATE CHANGE CONFERENCE: 1-11 JUNE 2015. Available: http://www.iisd.ca/download/pdf/enb12638e.pdf (accessed 15 July 2015)
USA (2015). The United States' Intended Nationally Determined Contribution, 31 March 2015. Available: http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx (accessed 24 July 2015)
World Business Council for Sustainable Development (2010). Energy Efficiency in Buildings: Transforming the Market. CD-ROM. Also, available at: www.wbcsd.org/web/eeb-roadmap.htm.
WRI (2015). Understanding the IPCC Reports. Infographic: The Carbon Budget. World Resources Institute, Available: http://www.wri.org/ipcc-infographics (11 August 2015)
ZHOU, D. (2010). "Energy Transformation on a Roll" in *China Today*, Vol. 59, No. 11, November 2010, pp. 30–31.