Asian Research Policy

Volume 7 Issue 2
December 2016

Contents

ICT Convergence in Creative Economy for Policy Coordination:
A Case Study of Unmanned Vehicle Research for Developing Digital Platform and Ecosystem

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Abstract
This study is to examine markets and policies of sectoral Information Communication & Technology (ICT) convergence, focusing on a case study of policy coordination with ICT convergence from the perspective of building a digital platform and ecosystem to enhance synergy effects in the industrial sector. Based on general, theoretical studies on digital platforms and ecosystems, unmanned vehicles (or ICT convergence of autonomous vehicles) were selected to design a model and draw practical implications. With AHP survey targeting experts and researchers (including graduate students) working in the field, the design of policy and systems, and the basic direction for policy coordination were investigated. This introductory study was conducted to verify whether digital platform and ecosystem are being realized as in developed countries. In particular, the present study's policy implications were suggested with respect to policy mediation through the case study. Core values of digital platform and ecosystem are 1) ICT convergence ecosystem (systems and policy establishment); 2) economic development and industry growth (economic and industrial support); 3) social entitlements (social contribution); and 4) technological development (cooperative research and technology development). Based on these factors, priorities were analyzed from each sub-factor. The finding shows that policy coordination should pursue ICT-based industries, concentrating on the artificial intelligence industry; and should develop intelligent cars that prevent accidents with a view to reducing social costs while realizing the creative economy in the future.

Keywords: Creative Economy, ICT convergence, autonomous vehicles, AHP, digital platform, ecosystem

1. Introduction

The need for policy-relevant research on new technology to provide a blueprint for future science and technology policy has been heightened due to growing uncertainty and unpredictability arising from technological development and social change. Since the mid-2000s, discussions have been ongoing across academic and industrial fields on reinforcing the positive cycle between policy and information and communication technology (ICT), as represented by a hyper-connected society[1], Internet of Things (IoT), and Big Data, to enable quality service for people and foster future industries. In particular,

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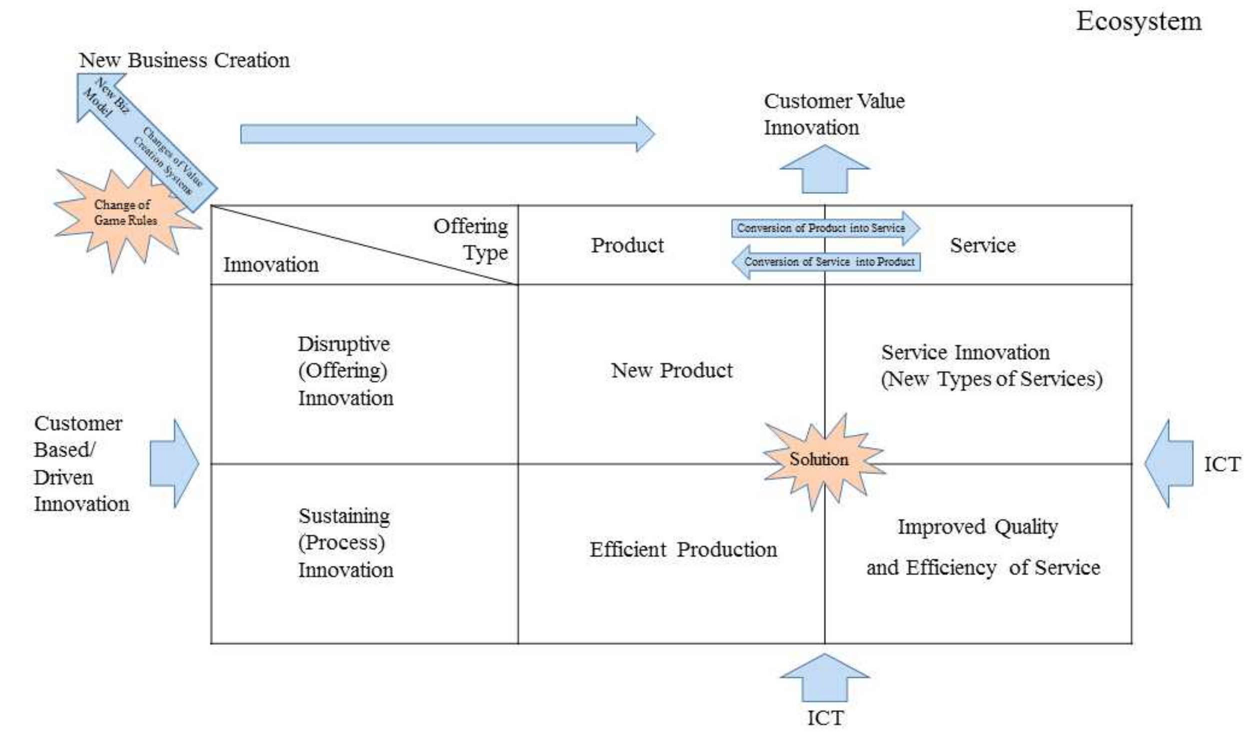
1 ICT is emerging as a key means of realizing 'creative economy' to generate new businesses and jobs through convergence with other industries. The development of ICT includes machine to machine (M2M), IoT, and IoE, which is expected to enter the era of hyper-connected society (Ju and Kim, 2014).

Figure 1. Definition of ICT convergence



ICT has dramatically developed, opening up a new era of Internet of Everything (IoE) which connects humans, processes, data, and things. In addition, the importance of ICT convergence in realizing a creative economy for policy coordination is being emphasized.

While the definition of ICT convergence technology varies, it mainly refers to blending technology in different fields with ICT, which causes essential changes in products and services to give rise to new ones. The keyword ‘connection’ that has come to define ICT refers to relations between humans, things, and the world. Convergence is an important concept in the sense of a hyper-connected society, which connects a variety of data, systems, and services. As indicated in Figure 1, ICT convergence can be defined as creating new business models and ecosystems.

As defined in Figure 1, ICT convergence leads to creation of products and services through new processes and a wide range of cooperation with manufacturing and service sectors to meet the needs of customers. Consequently, ICT convergence fundamentally reforms existing value creation systems and relations between actors in the market (such as cooperation and competition). As such, new business models or industries can be created, allowing a transfer to a different ecosystem of ICT.

To adapt to social changes at a national level, an innovation ecosystem as well as digital platform need to be established to foster new products and services, facilitating convergence among technologies, industries, and markets. The digital platform represents the era of convergence in the areas of ICT, science and technology, and industrial policy. Major countries are pushing ahead with plans to establish innovative digital platforms and ecosystems, including drastic reforms of regulations to increase the flexibility of the existing industrial ecosystems.

Therefore, this study is to examine market and policy trends, and case studies for policy coordination of ICT convergence from the perspective of digital platform and ecosystem, and draw policy implications. To design a theoretical model and draw empirical implications on developing digital platform and ecosystem, unmanned vehicles in Korea have been analyzed. The AHP survey and interviews were conducted with ICT convergence experts in the area of unmanned vehicles and researchers (mostly graduate students) working in the field. The findings obtained through these methods may be used as basic data to promote and coordinate policy. In other words, this study analyzes the feasibility of digital platform and ecosystem for ICT convergence in Korea, and investigates its implications from the perspective of policy coordination.

2. Previous Studies

Growth of technology-based e-Government has reached its limit as the role of ICT has shifted from means to ends. In this regard, a new approach toward science and technology is necessary to meet future changes. In this study, previous studies are reviewed from a critical point of view. A study by Johnston et al. (2008) emphasizes that maximizing efficiency in public sectors helps to establish consumer-centered policy as digital platforms with ICT convergence technology are developed due to SNS-based networks. Another study by Huang and Benyoucef (2014) shows that usability[2] and credibility[3] are integral parts of public service. Accordingly, the present study also emphasizes the growing need for user-oriented research. As stated by McCarthy and Wright (2007), ICT is no longer something encountered in a specialized environment, but an essential tool in our daily lives. The present study also accepts the idea that future policy implications arise from the current state. Recent studies have stressed the importance of the qualitative growth focusing on the idea that the citizens “do not just use technology; we live with it.” In this regard, the study examines policies, strategies, and the current state of market of ICT convergence from the perspective of creative development of ICT convergence technology. In addition, as an analytical framework and concept, digital platform, ecosystem, and policy coordination are also investigated.

2.1. ICT Convergence Policy and Strategy

ICT convergence policy is expected to transform the existing markets or contribute to the creation of new markets and jobs. As such, major countries have established strategies to boost convergence industries, and promote science and technology policy based on ICT convergence to widen opportunities to realize creative economy. ICT convergence industries are expected to have a great impact by merging ICT with various fields such as materials, electronics, optics, energy, space, and medicine. While enormous investment needs to be made for new technology R&D in the medium and long term, the probability for success remains low in the market. In this regard, major governments are actively supporting relevant industries. The US focuses on four categories such as IT, NT, BT, and CS (Cognitive Science), a relatively narrow range of convergence technology. However, R&D for e-healthcare, bio-chip, and bio-informatics is being made through the world’s best IT industry and venture ecosystem (Ha and Lee, 2012).

The US strategy for convergence focuses on gaining a competitive edge of technology to improve individual, collective, societal, and security capacity. Main areas are 1) expanding personal perception and communication skills, 2) improving personal health and physical capabilities, 3) enhancing

2 A study of ‘Changes of Policy Paradigm for future e-government and Tasks (2009)’ emphasizes Easy Government, introducing a case of EU council which shows positive economic effects of e-government when marginalities (the elderly, the disabled) are able to access to it.

3 If credibility is discussed based on the truth, not trust, this concept can be expanded to We/Me on-offline projects, Life Event evaluation index, innovative team management to suggest new experiences, privacy protection and transparent monitoring system (Kim, 2015).

performance of group and society, 4) strengthening national security, and 5) integrating science and education (Kim et al., 2013). The characteristics of the US strategy for convergence technology development include 1) the leading role of federal government in technology development by promoting national projects, 2) federal government's independent contribution or multilateral cooperation with other agencies in technology development, and 3) active participation of enterprises and universities during the phase of R&D and commercialization to maximize impact and put outcomes to practical use (Ahn and Jeong, 2008).

EU started the discussion on convergence from "Converging Technologies-Shaping the Future of European Knowledge Societies (CTEKS)" in 2004. This plan aimed to promote social science approaches to "Knowledge NBIC" and convergence technology from 2006 to 2009, and introduce interdisciplinary research according to the 7th Framework Programme (FP7) from 2007 to 2013 as a means of expanding R&D for convergence technology (Kim, 2010). EU set the targets to utilize convergence technology in five areas: health, education, information and communications, environment, and energy. Based on this strategy, EU is pushing forward to develop technology, establish research environments, and strengthen social and ethical responsibilities.

The features of EU strategy for convergence technology development include 1) enhancing inter-disciplinary activities to include social science and humanities in the area of convergence, 2) considering review and regulations about ethical and social issues, 3) conducting systematic research to develop as well as utilize convergence technology, and 4) providing relevant education in middle schools, high schools and universities. In addition, major countries execute various policy in relation to Internet of Things (IoT). The US, EU, China, Japan are establishing R&D centers and industrial complexes to carry out government-led R&D for IoT and smart grids.

The US has few policies specialized for IoT, but recognizes its importance and focuses on technology and service development. In 2007, the Department of Defense applied M2M-based tracking systems to transport facilities. New York City has also made it mandatory for all taxis to adopt telematics since 2007. In April 2008, National Intelligence Council selected IoT as a key technology affecting national competitiveness. From 2009 to 2020, the US plans to implement IT New Deal policy to distribute smart grids, healthcare, and broadband networks. Efforts to lay the foundation are being made, such as through a public hearing on IoT regulations organized by the Federal Communications Commission in 2013 to assimilate the opinions of participants from various fields (Ju and Kim, 2014).

EU has actively carried out IoT policy compared to the US In 2006, EU made plans to prepare for the era of IoT by drawing up "i2020—A European Information Society for growth and employment." In 2008, research on IoE began through CASAGRAS project supported by the FP7 (2007-13). In July 2009, 14 action plans on IoT (Internet of Things: An Action Plan for Europe) were suggested in terms of R&D, service, infrastructures, privacy protection, information security, legal systems and evaluation systems. In 2010, CASAGRAS project II was implemented to support 40 projects that will lay the grounds for IoT. In August 2013, EU reported the outcome of "Europe's policy options for a dynamic and trustworthy development of the Internet of Things" which had been studied from 2005 (Ju and Kim, 2014).

South Korea has implemented various ICT convergence policies. They can be divided into phases of prior to Lee Myung-bak government, the first half term of Lee Myung-bak government, the second half term of Lee Myung-bak government, and Park Geun-hye government. Prior to Lee Myung-bak government, convergence of BT, CT, NT, ET, IT, and ST was discussed in association with Next

Generation Growth Engines or New Growth Engine Industries. The organizing ministries drew up strategies as follows: Development Strategies for Convergent Components for Industrial Products (Ministry of Commerce Industry and Energy, 2006), Strategies for Digital Convergence New Industry (Ministry of Commerce Industry and Energy, 2006), Basic Policy of Convergence Technology Development (cooperation between 7 ministries, 2007), and Basic Plans for National Convergence Technology (NSTC, 2008; Kim et al., 2013). During the first half term of Lee Myung-bak government (08-11), New IT policy (Ministry of Knowledge Economy, 2008) focusing on IT-based convergence in all industries, and Basic Plans for National Convergence & Technological Development (Ministry of Education, 2008) were established to promote convergence in the areas of automobile, ship building, construction, fabrics, machinery, medicine, national defense, energy, lighting, and robots.

During the second half term of Lee Myung-bak government, "Industrial Convergence Promotion Act (2011)" was established in accordance with global trends of convergence. As such, ministries set up implementation systems of industrial convergence and promoted basic plans for industrial convergence development, including humanities and social sciences. The convergence policy of Lee's administration aimed to create high value-added business through large scale ICT-based manufacturing in order to increase competitiveness in the world market, though it faced criticism for excessive support for conglomerates.

Park Geun-hye government has established the Ministry of Science, ICT and Future Planning to promote commercialization of ICT-based convergence industries for realization of creative economy. Besides online Creative Economy Town, Creative Economy Centers were established to support business in the area of convergence industry in 17 cities around the country through early 2015. In addition, Creative Vitamin Project was promoted to address current issues and support creation of new businesses. The 68 projects selected by March 2015 contributed to increasing industrial vitality through IoT related projects and cooperation, solving social issues utilizing ICT, and stimulating the economy. In January 2015, strategies for new IoT industry were established to lead development in 6 areas (home electronic appliances, automobiles, education, distribution, industrial safety, and energy) with a view to creating new convergence industry (Ministry of Science, ICT and Future Planning, 2015).

In particular, immediate support for unmanned vehicles among ICT convergence policy was brought up at the 3rd ministerial meeting on regulatory reform in May 2015. With a view to commercialize unmanned vehicle by 2020 (Level 3 of automated driving)[4], the administration planned to establish systems and infrastructure early to accelerate

4 Levels of driving automation can be categorized from Level 0 (non-automation) to Level 4 (full self-driving automation). Our goal is to reach Level 3 by 2020, which is limited self-driving automation. In this level, drivers must be available to take over controls in case of emergency (source: NHTSA).

Characteristics	Automation system has no vehicle control	Involves one or more specific control functions	Involves automation of at least two primary control functions working in unison	Limited self-driving automation	Safe self-driving automation
Examples		Cruise control, pre-charged brakes, lane keeping	Adaptive cruise control in combination with lane keeping	Enables all critical functions to be automated. Driver must be ready to take over control in case of emergency	Vehicle is designed to perform self-driving in all circumstances

commercialization of unmanned vehicles although development of technology has started later than in developing countries. In this regard, policy was to focus on 1) regulatory reform and system maintenance, 2) support for unmanned vehicles technological development, and 3) increasing infrastructures for unmanned vehicles. Detailed plans are as follows (MOLIT, 2015).

First, regulatory reform of test-runs on the road and commercialization systems were taken into consideration in regulatory reform and system maintenance. Second, development of core technology, establishment of experimental city for autonomous vehicles (K-City), support for technological development and training against hacking, and trial services for short distances were suggested in support for unmanned vehicles technological development. Lastly, developing global positioning systems, producing digital maps for lane markings, establishing road infrastructures for autonomous driving (V2I), providing frequencies for inter-vehicular communication, and forming a popular consensus were determined as detailed plans for increasing infrastructures for unmanned vehicles, which is the most important policy (MOLIT, 2015).

Based on these goals, visions, and detailed plans, Korean government has accelerated the establishment of infrastructures to conduct test-runs for the Pyeong Chang 2018 Winter Games Olympics. The government, in particular, focuses on technology development (such as guidelines to protect vehicles from hackers, test operation at university campuses) and infrastructures (digital maps for lane markings, GPS adjustment information transmission, test beds for expressways, frequencies for inter-vehicular communication) to take a step towards commercialization.

As shown with above-mentioned policies, unmanned vehicles can be an important example of ICT convergence sector. With new ITS technology and GPS technology, as well as digital maps for lane markings, autonomous driving can be tested from Seoul Tollgate to Hobeop JC through real-time road transport informatics.

Therefore, this study examines ICT convergence strategies and policy for unmanned vehicles as a case of policy coordination about ICT convergence in creative economy. It also draws core values and implications of digital platform and ecosystem. As mentioned before, the study analyzes future creative industry and markets to find strategies for building innovative ecosystems and platforms. The main purpose of this study is to look into implications for policy coordination.

2.2. The Size and the Trends of the Market

ICT convergence features networked ICT, intellectualization, and internalization. In the course of new convergence, it attains characteristics of continuity, additionality, extendibility, and multiplicity, which allows multi-dimensional value chain in the evolving ecosystem, instead of one-way value chain[5]. As such, the market of ICT convergence science and technology industry has drastically grown. The size of the market was 10,946 billion dollars in 2010, and 18,851 billion dollars in 2015. The market is expected to grow to 37,796 billion dollars in 2020 (Table 1).

Similar to the growth rate of the world market, the domestic market is expected to increase in size. The size of domestic market was USD 39 billion in 2010, USD 73.9 billion in 2015, and is expected to grow to USD 148.3 billion in 2020. Therefore, the need for appropriate policy and policy coordination is heightened with the development of ICT convergence industry (MKE, 2011).

5 Continuity refers to continually evolving features. Additionality means new technology, products, and services can be applied to existing convergence to create new convergence. Extendability means the existing convergence can expand horizontally or vertically. Multiplicity means a consumer can experience various platforms through a device, which in turn, interaction between a variety of actors enables to connect each other, leading to multi-dimensional interaction. More details are stated in: Ha and Lee (2012); KIET (2012)

This change arises from a shift in ICT paradigm. ICT used to be supplier-oriented, focusing on technology, while current ICT is consumer-oriented. In addition, ICT dissemination was emphasized through networks and mobile devices in the past, but the practical utilization of ICT is expected to be more important as applications such as IoT develops. ICT itself was a goal to achieve, while now it is considered as a means and a foundation. Based on ICT development, appropriate policies will enable enhancement of people's quality of lives and find new engines for growth.

2.3. Digital Platforms and Ecosystems

Recently, major international companies have launched a new product or service based on ICT. For example, Google, well-known for its search engine, has been developing convergence-based products for a long time. Google Car is one of them. It is equipped with sensors, processors, and software for autonomous driving, and utilizes video cameras, laser sensors, laser range finders, and GPS.

Many studies state that these changes have occurred due to digital platforms which enabled establishment of innovation ecosystems. In the case of Google, it has established its own innovation ecosystem to provide digital space, or a digital platform, to freely communicate and interact (play) with content providers, consumers, advertisers, and innovators (Fishenden & Thompson, 2012).

The importance of platform governance has been emphasized. According to a study by Fishenden and Thompson (2012), having its own innovation ecosystem was the reason behind Google's rise to international success, although it did not have tangible products. The platform which allowed content providers, consumers, advertisers, and innovators to communicate and interact each other was the key to success. In this regard, the role of the future government is to provide innovation ecosystem in administration in order to enable various actors to communicate with a creative mind. The new e-government is one method of establishing such a platform (Fishenden & Thompson, 2012).

In addition, global ICT companies are competing in the wearable device markets to lead the post-smartphone era. The market is already formed for Google Glass, Apple Watch, and mobile payment systems (Samsung Pay, Apple Pay, etc.). Notable changes in ICT companies can be found in the area of unmanned vehicles. This study conducted a case study focusing on ICT convergence in the area of unmanned vehicles among convergence industries in Korea and major countries[6].

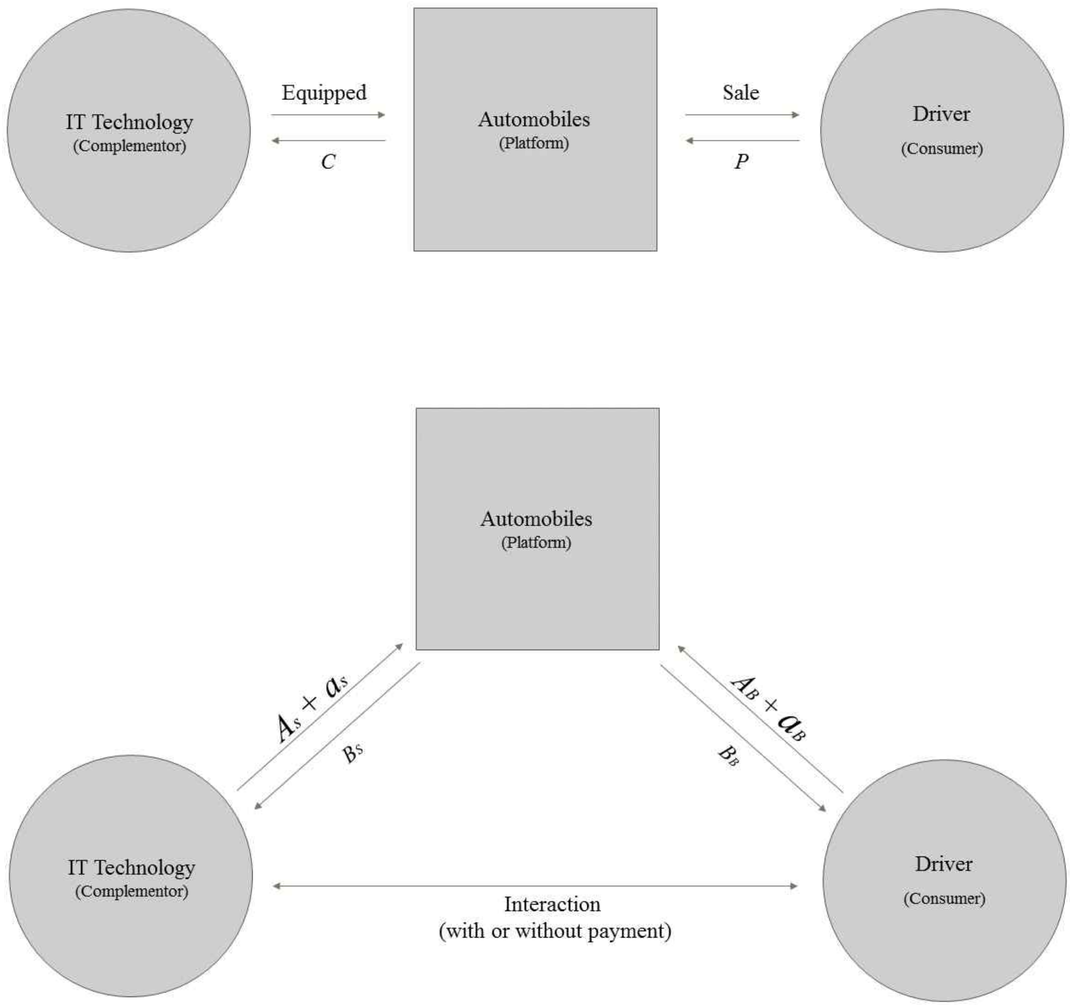
Table 1. Markets and prospects of IT convergence industry (billion USD)

Year	Cars	Ship Building	Construction	Fabrics	Medicine	Machinery	Lighting	Energy	National Defense	Total
2010	146.6	20.8	264.0	173.7	120.0	160.0	35.6	1.3	172.6	1,094.6
2015	211.2	26.0	330.7	203.3	233.0	290.0	103.0	6.9	481.0	1,885.1
2020	266.2	35.1	414.1	247.3	500.0	521.3	300.0	12.7	1,482.9	3,779.6

6 Looking at launched cars, Tesla, Benz, Nissan, Google take the lead in the market. In 2013, Benz succeeded in 100 km self-driving in urban area, with a goal of commercialization by 2020. Nissan operated Leaf for a test drive, and is concentrating on research to enable commercialization by 2018. Google plans to launch complete autonomous vehicles (level 4) in 2-5 years (MOLIT, 2015).

Automobiles can be considered as a kind of platform, equipped with ICT technology (complementor), and provided to drivers (consumer). This is a linear process that constitutes a conventional transaction of a one-sided market (cost and profit are created through transaction), where chances of a new ecosystem are slim. However, interaction between IT technology and drivers based on automobiles (platform) enables formation of a structure from which both complementor and consumer benefit and double the creative value (two-sided market).

Figure 2. Value chain of cars as IT convergence platform: one-sided vs. two-sided markets



This study examines unmanned vehicles in the context of four core values: ICT convergence ecosystem (establishing systems and policy), economic development and industry promotion (economic and industrial support), social entitlements (social contribution), and technological development (focusing on cooperative research and technology development). In regards to ICT convergence policy, especially unmanned vehicles policy, the most important sectors and contents are examined with Analytic Hierarchy Process (AHP) technique. Before examining the outcomes, the methodology of AHP will be described in the following session.

2.4. Policy Mediation: Success and Failure in Policy

This study defines policy mediation as a process of finding mediation tools that help to integrate policy and to seek communication strategies, which derive collective intelligence in the nonlinear, interactive model of "cognition ↔ judgment (decision) ↔ act (acceptance)." As such, policy mediation is fundamentally analyzed with AHP technique and survey targeting experts and graduate students. This study is significant as a basic research for offering policy mediation. Another purpose is to verify whether ICT convergence policy in the area of unmanned vehicles follow a linear process that is stated in the rational model.

3. Methods

3.1. Background and Basis of Case Selection

This study focuses on autonomous vehicles (or unmanned vehicles) as they are an example of policy mediation that will be discussed in the present study. First of all, the area of cars and ICT convergence technology can be investigated from different perspectives in regards to platform and ecosystem. In terms of technology and service, AUTOSAR (AUTomotive Open System Architecture), a standard platform of software used for car electronic devices, ISO26262 certifications, an international standard of car safety function; GENIVI, a multimedia platform for automobiles; and AGL (Automotive Grade Linux) were discussed (Han and Lee, 2014). However, these discussions are limited to the concept of platform at a technological level. Therefore, this study intends to go beyond the conventional concept and to extend the concept to include establishing policy and systematic platforms and ecosystems based on policy mediation. Thus, the case of autonomous vehicles was selected to study the comprehensive concept of a policy platform that encompasses various perspectives, and a digital platform, to draw meaningful implications.

3.2. The Necessity and Introduction of AHP Analysis

The hierarchical analysis in this study is Analytic Hierarchy Process (AHP) which was developed by Thomas Saaty in 1980. AHP is a supporting tool for decision making processes through multi-dimensional evaluation when there are many alternative solutions. The process is important in AHP, which helps to make decisions in a more rational way through repetitive analyses. These repetitive analyses target experts, which is useful in looking at experts' opinions comprehensively. AHP helps to gain a better insight in complex decision-making problems. It classifies alternative solutions based on the goal, evaluation standards, and alternative choices, and allows comparison of results based on hierarchical surveys conducted by experts. AHP comprises three levels. At the highest level, decision-making is the goal. Factors that affect decision-making and make up the higher targets are determined at the middle level.

At the lowest level, evaluation factors are identified, and each factor can be compared to determine its priority and weighted value. The weighted value is not put forth as a question in the survey, but is determined in the process of prioritization. Respondents' consistency is crucial in AHP. AHP questionnaires are designed to conduct a comparative analysis of evaluation factors (alternatives) to set priorities. When there are multiple evaluation factors (alternatives), a comparative analysis needs to be made in every case. The problem is that this process makes questionnaires complex, and respondents may lose consistency. Loss of consistency, which can be found even in straightforward questionnaires asking priorities, may intensify in a comparative analysis of multiple alternatives. Decision-makers' consistency is a key to AHP, and should be ensured when deciding influential issues like national policy.

To ensure respondents' consistency, AHP utilizes consistency index. Consistency index (CI) shows how consistent the alternatives are. In general, consistency index of 0 indicates the greatest consistency. Practically, however, it is highly unlikely to see 0 as the consistency index. Based on empirical data, analysis is considered to be consistent when consistency index is below 0.1. Unlike other surveys that require a varied set of respondents, AHP targets experts in a specific area to find priorities. AHP provides quantitative data for decision making, and is thus being used in various fields.

This study examines domestic (Korean) and foreign markets in the sense of ICT convergence policy and digital platform/ecosystem to find policy implications. Based on these findings, interviews and AHP are used to analyze the new paradigm of ICT convergent autonomous vehicle industry, and the impacts of innovation ecosystem and digital platform, which are the possible ways of realizing creative economy.

AHP questionnaires are prepared with a method of qualitative clustering that divides research results from literature research and interviews into factors/sub-factors/details based on similarity, importance, tendency, and directionality. To enhance applicability of clustered research in policy practice, AHP was conducted in each case to figure out priorities and importance. The comparative analysis of AHP helps to understand priorities of detailed factors in regard of digital platform and ecosystem because this method shows complex decision-making problems hierarchically.

The First AHP: The comparative analysis enabled evaluation of "relative importance," comparing two questionnaires based on the results of expert interview. The case study focused on ICT convergence in the area of domestic unmanned vehicles. The survey included open answer questions to gather other opinions. This enabled respondents to suggest different opinions, which ensured the opportunity to adopt better ideas. After contacting respondents, questionnaires were sent via email and then collected.

The Second AHP: Based on the first survey, modified online surveys were developed and redistributed to the experts who responded to the first survey. Through modified, improved questionnaires, the level of convergence and divergence among experts' opinions was analyzed with a qualitative method. For this analysis, unlike the first survey, the consensus ratio, average, standard deviation, and quartile deviation were used.

The Final Analysis: The degree of convergence or divergence over two rounds of AHP analyses was verified, and if needed, further survey was conducted. To find out the level of agreement and consent, CI was used to decide whether to accept or reject the priorities, and the most appropriate factors were finally chosen.

3.3. Targeting Group

For this study, AHP was targeted to researchers of Kookmin University and Intelligent Car Research Team. Kookmin University Research Team is currently performing research on autonomous vehicles equipped with PC and H/W. A total of 12 researchers participated in the survey, and their responses were consistent according to the feedback. To ensure objectivity and minimize influence of personal preferences, the persons who gave the highest score and the lowest score were excluded from analysis. Therefore, 10 responses out of the total 12 were used for the final analysis.

3.4. AHP Structure and Analysis Items

The AHP structure is divided into 4 categories, which are based on previous studies and FGI interviews targeting experts. It can be largely understood in an aspect of technology, society, economy/industry, and ecosystem (ICT convergence ecosystem). Each aspect has four different factors. Detailed AHP analysis criteria are as shown in Table 2.

4. Findings

4.1. Foundation of Core Values

Based on the various issues stated in the previous studies, 4 aspects of core values were suggested: First, ICT convergence ecosystem (establishing systems and policy), second, economic development and industry promotion (economic, industrial support), third, social entitlements (social contribution), and lastly technological development (focusing on cooperative research and technology development). These 4 aspects show the importance of ecosystem which was emphasized in the case study of Google, a leading company of ICT convergence (Fishenden & Thompson, 2012). In addition, a case study of IT convergence in industrial areas (Kim and Kim, 2013) was reflected in economic development and industrial promotion. The idea that virtual goods in cyberspace evolve and provide solution and S/W in the real market to increase social benefits was also reflected (Min, 2013). As indicated in the study of ICT convergence policy in the field of domestic/foreign car industry (Kim, 2015), technological development was taken into account as well, and sub-factors were defined. This study intends to analyze priorities of core values with AHP technique to figure out positive direction for future policy, and to examine appropriate means of policy mediation. The sub-factors were first analyzed, following priorities of factors.

Table 2. AHP analysis criteria

Core Values	Contents
ICT Convergence Ecosystem[7] (Establishing systems and policy)	Car Industry (chassis module, automotive electric parts, terminals, V2V (vehicle to vehicle) communication security), ITS Industry (road-side equipment, operation agency, control center, Vto Communication Security), ICT Industry (mobile, cloud, LBS service, new generation communication security), Fundamental Industry (embedded SW, HMI device, smart sensor)
Economic Development and Industry Promotion (Economic, industrial support)	SW/Information Industry, Artificial Intelligence Industry, Communications/Security Industry, Sensor/Navigation Industry
Social Entitlements (Social contributions)	Based on the existing supply chain, expansion of new industry growth engine, Reducing the social cost due to decrease in car accidents (Best Safety) (insurance, medical expenses), low cost and high accessibility in transportation service (improving convenience for the disabled and the weak (Infinite Convenience)), Eco-friendly transportation system through efficient control of the volume of traffic
Technological Development (Focusing on cooperative research and technology development)	Intelligent Cars which prevent accidents, Communication-enabled Cars, Human-oriented Cars, Creating synergy effects through convergence

7 For ecosystem, various technologies in industries are integrated in a way of convergence. Subsidiary equipment of keeping a safe distance, keeping driving on the road, autonomous control, and steering for parking has been developed to the extent of level 3.

4.2. AHP Analysis Result: Sub-factors

As indicated in the methodology based on above-mentioned factors, the research on autonomous vehicles has core values in the aspect of 1) ICT convergence ecosystem (platform), 2) economic development and industry promotion, 3) social entitlements, and 4) technological development. With AHP surveys, opinions of experts were gathered. The results regarding final ranks and weighted values in each aspect are as follows.

Table 3. AHP analysis results: sub-factors

Areas	Sub-factors	Consistency Index* (Rank)
ICT Convergence Ecosystem (Establishing systems and policy)	Car Industry (chassis module, automotive electric parts, terminals, V2V communication security)	0.235 (3)
	ITS Industry (road-side equipment, operation agency, control center, V2 communication Security)	0.265 (2)
	ICT Industry (mobile, cloud, LBS service, new generation communication security)	0.337 (1)
	Fundamental industry (embedded SW, HMI device, smart sensor)	0.164 (4)
Economic Development and Industry Promotion (Economic, industrial support)	SW/Information Industry	0.203 (4)
	Artificial Intelligence Industry	0.355 (1)
	Communications/Security Industry	0.229 (2)
	Sensor/Navigation Industry	0.212 (3)
Social Entitlements (Social contributions)	Based on the existing supply chain, expansion of new industry growth engine	0.168 (3)
	Reducing the social cost due to decrease in car accidents (Best Safety) (insurance, medical expenses)	0.500 (1)
	Low cost and high accessibility in transportation service (improving convenience for the disabled and the weak (Infinite Convenience))	0.085 (4)
	Eco-friendly transportation system through efficient control of the volume of traffic	0.247 (2)
Technological Development (Cooperative research and technology development)	Intelligent Cars which prevent accidents	0.582 (1)
	Communication-enabled Cars	0.187 (2)
	Human-oriented Cars	0.129 (3)
	Creating synergy effects through convergence	0.101 (4)

*CI (consistency index) <0.1. It is calculated by counting the weighted average in a dataset: n=10

The analysis showed that the first priority of ICT convergence ecosystem was ICT Industry (0.337), followed by ITS Industry (0.265), Car Industry (0.235), and Fundamental Industry (0.164). These findings indicated that ICT industry comes first when establishing an ICT convergence ecosystem. Although Korea is a latecomer to the market for autonomous vehicles, it is expected that ICT industry will enable Korea to take the lead in the future considering its importance.

The first priority of economic and industrial promotion was Artificial Intelligence Industry (0.355), followed by Communications/Security Industry (0.229), Sensor/Navigation Industry (0.212), and SW/Information Industry (0.203). Except Artificial Intelligence Industry, the differences between the rests of the industries are minor, which indicates that they require similar levels of interest and attention.

The first priority of social entitlements was reducing the social cost due to decrease in car accidents (0.500), followed by eco-friendly transportation system through efficient control of the volume of traffic (0.247), expansion of new industry growth engine based on the existing supply chain (0.168), and low cost and high accessibility in transportation service (improving convenience for the disabled and the weak) (0.085). As an overwhelming majority selected reducing the social cost as a priority, this part needs to be considered in establishing policy.

The first priority of technological development was Intelligent Cars which prevent accidents (0.582), followed by Communication-enabled Cars (0.187), Human-oriented Cars (0.129), and Creating Synergy Effects through Convergence (0.101). The differences between these factors suggest that policy makers pay attention to the results to mediate policy and solve problems.

4.3. AHP Analysis Result: Factors

The first priority of the comparative analysis about factors was technological development (focusing on cooperative research and technology development) (0.3946), followed by social entitlements (social contributions) (0.2275), economic development and industrial promotion (economic, industrial support). The lowest one was ICT convergence ecosystem (establishing system and policy) (0.1757), which shows the current state in South Korea.

Table 4. AHP analysis results: factors

Areas	Factors	Consistency Index* (Rank)
ICT Convergence Policy and System in relation to Autonomous Vehicles	ICT Convergence Ecosystem (establishing systems and policy)	0.1757 (4)
	Economic Development and Industry Promotion (economic, industrial support)	0.2020 (3)
	Social Entitlements (social contributions)	0.2275 (2)
	Technological Development (focusing on cooperative research and technology development)	0.3946 (1)

*CI (consistency index) <0.1. It is calculated by counting the weighted average in a dataset: n=10

5. Conclusion

5.1. Policy Implications

Altogether, Digital Platform and Ecosystem in ICT convergence policy on autonomous vehicles in Korea have not been fully established, and require technological development. The fact that technological development placed as a top priority in the area of autonomous vehicles is an evidence of difficulty in establishing Digital Platform and Ecosystem. Therefore, policy implications are discussed in this chapter based on group interviews of AHP questionnaires. In terms of technology, South Korea has not reached the international level (failed to get high scores at DARPA[8] Challenge). The leading universities are Kookmin University, Seoul National University, KAIST, and Hanyang University. KAIST focuses on drones, and Hanyang University does not stand out relatively due to a growing number of retired professors. Therefore, Kookmin University and Seoul National University[9] take the lead in research, followed by Keimyung University, Chungbuk National University, and Sungkyunkwan University. These universities participated in the autonomous driving festival of Creative Korea Expo, organized by the Ministry of Science, ICT and Future Planning at Coex, November 2015. The competition of Hyundai-Kia autonomous vehicles is organized as a preliminary for DARPA. As the competitions are divided into business-organized and government-organized ones, it is necessary to integrate and build ecosystem from the viewpoint of policy[10]. In addition, the need for R&D investment in technology development is heightened considering Europe (Benz), China, and Japan invest heavily in automobile R&D. According to the group interviews with experts, the technological level remains low in Korea, which requires further research in cooperation with the existing car manufacturing as well as electronics/IT companies[11]. From the perspective of industry/economy, the area of autonomous vehicles is promising, while various infrastructures and policy improvements are also necessary. Experts have also said that training professionals is an important issue because information sharing, cooperation, and platform in regards to technology have not been active. The autonomous vehicles are expected to come into the spotlight in the sense of convenience, safety, and environment effect, while take 50 years to put to practical use (to the extent of entire people receiving benefits, not high prices). Further discussions need to be involved in ethical problems (who will bear the responsibility of car accidents?). The finding has many implications for ICT convergence technology policy. Technological development which lags behind is the priority in the sense of ICT convergence ecosystem. The demand for government response is increasing as indicated in the survey results. Therefore, policy toward creative economy should be established and coordinated in accordance with priorities considering core values.

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8 DARPA is organized by the US Department of Defense. The third DARPA competition was the most recent one, with a mission in urban areas. In the first competition, no team completed the whole course. In the second competition, held in the dessert, only 6 teams completed the course, which showed the differences between unmanned vehicles technologies (based on FGI interview).

9 Unmanned vehicles, authorized by MOLIT, are being operated for a test drive under the guidance of Professor at SNU, Kyeongsu Lee (based on FGI interview).

10 The KATECH, MSIP, and ETRI are supporting R&D without considering connectivity (based on FGI interview).

11 In terms of driving ability on the road, it ranks 5th in the world. In Korea, cars like Genesis EQ900 have been launched, which enable limited self-driving in low-risk areas, a 2.5 level. Various technologies are applied to domestic products and put to practice. For radar technology, all products used to be imported from Delphi, but now Hyundai Mobis has completed development and commercialization. In terms of cameras, both domestic and foreign products are utilized. Android operation system for cars is developed in cooperation with Hyundai-Samsung and Hyundai-Google. In addition, Hyundai-SK T-map as well as Kookmin University-Hyundai-Kia cooperation is also active.

In the future, factors which cause policy change in ICT convergence technology need to be examined further to set priorities, and be reflected in the government policy. To realize creative economy, features of factors should be continuously studied to make policy. Public-private sectors as well as civil society should cooperate to achieve our goals. Without concerted efforts, balanced policy of ICT convergence technology is some way off.

5.2. Limitations and Future Research Plans

This study is distinguished by the fact that areas and factors in priority are examined for realizing creative economy and digital platform/ecosystem through a comparative analysis with AHP. Unlike other surveys which require many respondents, AHP targets experts in the field to figure out priorities, providing qualitative data in decision-making, and is thus widely used in various sectors[12]. The study focuses on the latest trends to provide insight in terms of creative economy, and utilizes AHP to increase objectivity. Based on this study, further practical research can be applied to the real world, and open up an opportunity to connect with a variety of follow-up research. The case study helps to provide detailed, practical implications, and emphasizes the need for support and development of digital platform and ecosystem in the market of autonomous vehicles.

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As this study only focuses on Kookmin University unmanned vehicle research team, there are limitations to generalize the results. However, as Kookmin University research team takes the lead in unmanned vehicle studies, it is a worthwhile study to understand national ICT convergence policy regarding autonomous vehicles and to lay the ground for follow-up studies. In this regard, the loose ends may be tied up through future studies, in particular, on policy demands of consumers, markets, and companies, through AHP analysis on future consumers of autonomous vehicles.

12 AHP is used in cases where statistical analysis is impossible. This is widely used as a way of combining experts' opinions. This study does not adopt an absolute evaluation, but comparative analysis to maximize the strengths of AHP. In this regard, AHP as well as interviews are to be conducted to find out priorities of policy strategies that are necessary to building ICT digital platform and ecosystem in the area of unmanned vehicles in Korea.

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Regional Economic Development
—A Survey of Theories in the Past Two Centuries (1800-2000)

Xiaohong Quan

Abstract
The purpose of this paper is to survey the evolution of theories in the field of regional economic development in the past two centuries (1800-2000) before the new millennium. Theories from the 'spacial' dimension and from the 'economic' dimension are understood as the classical foundation of the field. Important theories are identified and discussed for regional economic development. Specifically, the topics examined here first center around the mechanisms behind regional economic growth, answering questions such as why growth happens in certain regions, why growth can shift to other places, and what factors or environments can foster growth in certain regions. Then the more recent discussions focus on theories regarding globalization and spatial division of labor, industrial districts, and social institutions that foster the growth of regions. The paper closes with a brief discussion of the spatial views from the mainstream economists in the late twentieth century. Future research needs to examine main theories in the twenty-first century in the field of regional economic development to complete the picture.

Keywords: regional economic development, regional development, regional growth, theoretical review

Introduction

The study of regional development is twofold. One aspect is "regional," which implies a spatial focus; the other is "developmental," which implies an economic focus. Thus, two classical foundations are identified for this field. The first one, represented by theories from Von Thunen, Weber, Christaller and other scholars, seeks to uncover economic reasons for certain spatial layouts; the second came from orthodox economics such as that of Smith, Ricardo, Marshall, and Keynes. These two classic foundations are discussed in the next section. What bridges the two traditions is the understanding of "agglomeration," which means, simply put, that economic activities tend to agglomerate in certain regions for growth. "Trade," due to its inherent spatial attribute (i.e., the exchange of goods among different locations), can be another bridging factor. Many scholars have dedicated their work to exploring the mechanisms behind regional economic growth (see section 2), to answering questions such as why growth happens in certain regions (2.1), why growth can shift to other places (2.2), and what factors or environments can foster growth in certain regions (2.3). As the world is undergoing dramatic changes

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in technology, production organization, and markets under the halo of "globalization," scholars from different fields are investigating new justifications and new patterns for regional development (section 3). The overall review paper is developed chronologically, although not strictly so, with a slight focus on more recent theories.

1. Classical Foundations

1.1. Theories from the "Spatial" Dimension

1.1.1. Theories of Firm Location

Associating rent (land price) with the distance of concentric rings having specific functions from the city, Von Thunen (1826) advanced a theory of the location of agricultural production under his assumption of a totally isolated economic system. Almost one century later, Alfred Weber (1909) developed a theory of industrial location. In his book, Weber believes that transportation costs are theoretically the most important factor determining industrial location, and labor costs are identified as the second geographically important factor influencing the location decision. Agglomeration is added as the third factor of importance for industrial location. Hotelling (1929), from the view of maximum market share, pointed out that firms tend to co-locate through an example of competing ice cream vendors on the beach. Hoover (1948), in his book, *The Location of Economic Activity*, summarized location factors from the views of both market access and production cost, and discussed the shift of locations. Another summary was done later by William Alonso (1975). Based on minimizing transportation costs and adjusted by other factors such as tax and labor costs, he applied the method of overlaying "isotims" to show how to locate firms in several concrete analytical scenarios.

1.1.2 Models of Urban Systems

Walter Christaller (1933) first moved the scale for these spatial-dimension discussions up to a larger level. He explored whether there are economic-geographical laws determining the number, size, and distribution of towns. In his central place theory, Christaller built his central place system of hexagonal regions with different orders (i.e. different market size) based on the range of central goods, or Market Principle. Thus he formed the first purely theoretical spatial order of towns. As supplements to this market principle-based spatial order, he added the Traffic Principle and the Separation (administrative) Principle to further adjust the spatial layout. Drawing on Christaller's ideas, August Lösch (1938) formed his ideal economic region by throwing nets of hexagons, with each net representing the trading area of a certain product, over the vast homogenous plain. The self-sufficient, systematic arrangements of the nets of market areas of the various commodities "at the same time provide for the best lines of transportation" (Losch, 1938: 101).

In the exploration of regional development from spatial dimension, Walter Isard made a breathtaking and ambitious effort. In his magnum opus, *Location and Space Economy* (1956), Isard tried to "improve the spatial and regional frameworks of the social science disciplines, particular of economics, through the development of a more adequate general theory of location and space-economy," which embraces "the total spatial array of economic activities, with attention paid to the geographic variations in prices and costs" (Isard, 1956: viii, 53). His comprehensive equilibrium model, using a system of mathematical equations, "seeks to bring the separate location theories into one general doctrine, ⋯ and to fuse the resulting doctrine, ⋯ with existing production, price, and trade theory (in the economic field)" (Isard, 1956: 23). However, despite his effort, he failed to bring the spatial concept to mainstream economists' attention[1].

1 See Krugman, Development, Geography, and Economic Theory (1995). PP56-57.

1.2. Theories from the "Economic" Dimension

This tradition arose from economic theories at the macro level. Economic growth theory can be traced back to Adam Smith. In his prominent work *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776), Smith defined wealth as production (supply) for purposes of consumption (demand) and sought its sources in division of labor, capital accumulation, and trade. Later, David Ricardo (1817) stressed that free international trade is very important for economic growth. Different from Adam Smith's "absolute advantage" trade, Ricardo proposed his "comparative advantage" theory, which asserts that countries should export goods that their labor produces with relative high productivity and import goods that their labor produces with relatively low productivity. Following Ricardo on the discussion of international trade, Bertil Ohlin (1933, 1967) explored a theory of interregional trade. Defining regions as the area within which factors are fully mobile, he believed that regions have different factor endowments, and interregional trade is necessary because "each region has an advantage in the production of commodities into which enter considerable amounts of factors abundant and cheap in that region" (Ohlin, 1967:12).

In his highly influential book *The General Theory of Employment, Interest and Money*, John Maynard Keynes (1936) pointed out that overall demand determines the supply of production and the level of employment, not the other way around[2]. One significant contribution of Keynes is his initiation of the theory of government's role in economic development to remedy market inefficiency. According to him, it is necessary for government to combat unemployment using tools such as expansionary fiscal policy (Hirschman, 1981). It was Keynes' theory that laid a solid foundation for state intervention, which is also one important school of thought in regional development theories (section 2.3).

Alfred Marshall was another extremely influential economist contributing to regional development theory, who coined the distinction between external scale economy and internal scale economy. Whereas internal scale economy is realized on the individual firm level, external scale economy is based on "the general development of the industry", providing advantages in the use of highly specialized machinery, a local market for special skills, subsidiary trades. "The mysteries of the trade… are as it were in the air" (Marshall, 1890: 271-314). Marshall (1890) was also the first to explicate increasing return, diminishing return and constant return. The law of increasing return means that "an increase of labor and capital leads generally to improved organization, which increases the efficiency of the work of labor and capital" (Marshall, 1890: 318). Increasing returns can be both internal to firms and external to firms, which induce internal scale economy and external scale economy respectively. However, increasing returns is not the only factor causing external economy. To a large degree, it is the understanding of increasing returns that explains the economic mechanism behind the most essential foundation of regional development theories: agglomeration economy.

2. Mechanisms of Regional Development —Modern Debates

2.1. Agglomeration and Uneven Development

As mentioned above, the concept of "agglomeration" bridges the spatial dimension theories and the economic dimension theories, and agglomeration economy is the foundation of regional development studies. Agglomeration economy is realized both at firm level and regional level. Firm

2 "The propensity to consume and the rate of new investment determine between them the volume of employment, and the volume of employment is uniquely related to a given level of real wages" (Keynes, 1936: 30).

level agglomeration economy, known as economy of scales, can be explained by increasing returns, while regional level agglomeration is explained by external economies.

Allyn Young (1928), based on Adam Smith's arguments on division of labor and Alfred Marshall's understanding of internal and external economies, systematically proposed and analyzed increasing returns. Young argued that they are mainly the result of "economies of capitalistic or roundabout methods of production"[3] within firms and are secured by the progressive division of labor, which then depends upon the extent of market[4]. Increasing returns are reflected in both industrial integration and industrial differentiation.

Later, Hoover (1948), in his book *The Location of Economic Activity*, gave a clear classification of agglomeration economy:

1) Larger-scale economies within a firm, consequent upon the enlargement of the firm's scale of production at one point;
2) Localization economies for all firms in a single industry at a single location benefit from local labor pool, knowledge sharing and intermediate inputs;
3) Urbanization economies for all firms in all industries at a single location enjoy public infrastructure, urban services, etc. (Hoover, 1948; Isard, 1956: 172). The latter two can be considered as external economies.

Raymond Vernon (1960) explored the kind of industries that greatly enjoy external economies. Using New York as an example, Vernon proposed that industries facing great uncertainties tend to concentrate together due to external economies: the need to share certain common facilities, the need to tap these facilities at top speed, and the need for face-to-face contact. Feeling that most discussions on external economies had been limited to intra-industry or industries with direct supply relationship in terms of production, Benjamin Chinitz (1961), through the contrasts in agglomeration in New York and Pittsburgh, put forward the importance of interindustry external economies due to factors such as entrepreneurship, capital, labor, land, and intermediate goods and services, from the supply side view.

Taking a macroeconomic perspective, North (1955) sought the reason why regions grow. He emphasized that export is the engine of regional growth through the determining contribution of the export industries or "economic base" to regional income. Tiebout (1956) disagreed with North's export base proposition by arguing that export is not the sole determining factor for regional income. Jane Jacobs (1984) further critiqued North's point by showing the failures of supply regions (or export regions in North's words). Instead, she proposed that the basis for economic expansion is the activity of city import-replacing, which induces five growth forces—markets, jobs, transplants, technology, and capital—necessary for further economic expansion.

Carrying on Ricardo's comparative advantage theory, neoclassical trade theory proposes that countries are different in endowments of factors of production, and a country will produce and export goods whose production makes intensive use of factors of production which are relatively abundant (cheap) before trade. Neoclassical trade theorists hold a very optimistic view that trade will diminish cross-national differences in factor prices and that trade makes all nations better off. North (1955) also argued, in keeping with neoclassical models of interregional and international trade, that "with long-run factor mobility more equalization of per capita income and a wider dispersion of production"

3 See Young, 1928: 531. "Roundabout methods of production imply the use of more capital in relation to labor." (Nicholas Kaldor, 1985: 65).

4 Young believed that "division of labor depends in large part upon the division of labor." This seemingly tautological statement arises because "the division of labor depends upon the extent of the market, but the extent of the market also depends upon the division of labor" (Young, 1928).

will be expected, since the export bases of regions tend to become more diversified and lose their identity as regions' income grows and spills over into new activities. Thus, ultimately, equilibrium is achieved.

Gunnar Myrdal (1957) held a different view that the development of regional economies will be uneven spatially, and lead to disequilibrium, due to the principle of "circular and cumulative causation." Although the "spread effects," operating through ways such as increased demands for products from backward regions, give benefits to the relatively poor, the negative impacts, termed "backwash effects" by Myrdal, help the rich regions to accumulate more wealth by attracting selective labor, capital, goods and services from the poor regions. Similarly, breaking down the influences of developed regions to underdeveloped regions into trickling-down and polarization effects, Albert Hirshman (1958) believed that "international and interregional inequality of growth is an inevitable concomitant and condition of growth itself." "Trickling-down" takes effect mainly by the purchase and investment of developed regions to underdeveloped regions, while "polarization" is realized by the former's depriving the latter of their talents as well as capital (however little). As a policy proposition, the government can intervene in the growth balance between rich and poor regions by making public investments.

Nicholas Kaldor also addresses disequilibrium development. He made three important points: First, the continuous economic process is driven by endogenous forces, which can be explained by increasing returns, not exogenous forces. Indeed, the only truly exogenous factor is the "heritage of the past." Second, the economic process, enabled by increasing returns, tends to cluster around geographic centers. Third, "there is no inherent tendency to anything that could be called an equilibrium, or an equilibrium path" (Kaldor, 1985). The benefits from free trade cannot be equally shared among regions or countries, thus leading to "cumulative causation" whereby some regions gain at the expense of others, resulting in increasing inequalities between relatively prosperous and relatively poor areas (Kaldor, 1970, 1972, 1985).

Additional important arguments for "disequilibrium" are found in Francois Perroux's works (1988). Perroux argued that all development is generated by "clustering, cumulative, and propulsive" effects rendered by growth poles or development poles. However, he believed that there are two different phases after establishing a pole: attraction (or clustering) and expansion, which corresponds to Myrdal's "backwash effects" and "spread effects," respectively, but occurring sequentially. Economic policies thus should be able to facilitate the growth of such poles, and the choice of the growth-inducing industry poles is to be given priority to those industries whose propulsive effects can be anticipated on existing industries and the environment. This growth pole strategy is especially encouraged in developing countries. However, few successes have been observed in attempts to creating growth poles in practice.

2.2. Technology, Cycles, and Growth

While growth happens only in certain regions and there is uneven development, as discussed in the last subsection (2.1), the group of regions benefiting from the uneven development will not always remain constant. In other words, the relative position of core and periphery can change. This subsection discusses theories on why growth can shift to other places.

One main explanation for the shift can be found in the theory of economic cycles. The concept of cycle was first developed on a historical scale known as "long wave" theory. By charting the wholesale price level, the rate of interest, wages and foreign trade, and some other index from the early nineteen-century, Kondratieff (1924) discovered the existence of cyclical long waves of an average length of about 50 years in the capitalistic economy. This article inspired further thoughts from other scholars later. Joseph Schumpeter related the cycles with technology revolutions in history. He proposed his well-known argument that the process of "creative destruction [which can be caused by innovation[5] such as new commodities, new technologies, new sources of supply, and new types of organization] incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one." Each of those revolutions, occurring actually in discrete rushes which are separated from each other by spans of comparative quiet, propels a new "business cycle" (Schumpeter, 1939; 1942: 83, 84). For Schumpeter, the first cycle was caused by the Industrial Revolution, and occurred from 1785 to 1842. The second one was based on the revolution of railroads and the Bessemer process in steel; it ran from 1842 to about 1895. The third revolution, from the mid-1890s to 1930s, was based on the chemical industry and on the beginnings of the electrical and auto industries (Hall, 1985). Later, Peter Hall (1985) defined the fourth wave which can be dated from World War II until approximately the mid-1980s. The concept of "long wave" was explicitly applied to a geographical scale[6] (spatially), also by Peter Hall. He further analyzed the characteristics of the places where new industries, and thus new development, can be triggered. Rostow (1960) offered a historical view on regional development in his stages-of-growth theory. He believed that all societies lie within one of five categories: the traditional society, the preconditions for take-off, the take-off, the drive to maturity, and the age of high mass-consumption. He also recognized that a surge of technological development is a primary stimulus for take-off.

"Product cycle" theories explain economic growth shift from a micro level, contrasting with the macro perspective of "long wave." The concept of "product cycle" dates back to Kuznet (1930) and Burns (1934), who identified that industries experience "a period of experimentation, a period of rapid growth, a period of diminished growth, and a period of stability or decline" (Norton and Rees, 1979: 145). Vernon (1960) emphasized the spatial aspects of any new industry's development cycle. Using New York as an example, he believed that industries in different stages prefer different locations. In the early stages, uncertainty makes firms concentrate in a favored location for external economies; "then, as maturity sets in, these industries are likely to spread out to lower-cost locations" (Vernon, 1960). Norton and Rees (1979) applied the idea of product cycle to explain the decline of the core ("manufacturing belt") and the rise of the periphery regions in the United States and associated these regional industrial shifts to technological changes[7]. Later on, in 1979, Vernon extended his understanding to an international scale[8]. By investigating MNCs (Multinational Companies), he found that to reduce production costs and to offset the loss of technology advantages in home countries, subsidiaries of the firms are built in other countries facilitated by the standardization of products on an international scale or the localization of products in other countries. Furthermore, "the interval of time between the introduction of any new product in the

5 Innovation is defined as the setting up of a new production function (Joseph Shumpeter, Business Cycles, 1939: 87). Innovations are carried out by entrepreneurs (102).

6 "The first and second waves were dominated by Great Britain, though the United States and Germany began to emerge during the second; the third was dominated by these two countries; in the fourth…the Unites States was predominant with Japan just beginning to appear on the stage" (Hall, 1985).

7 The growth industries in the periphery regions are "high technology" sectors (Norton and Rees, 1979).

8 The idea of product cycle also laid a foundation for international spatial division of labor, which is further explored in section 3. Developed countries move the factories to developing countries when their products reach a maturity stage.

United States and its first production in a foreign location has been rapidly shrinking" (Vernon, 1979).

Emphasizing the effects of corporate strategies, especially those by oligopolies, Ann Markusen (1985) proposed the theory of "profit cycles" (in comparison with product cycles), which is based on the idea that "regional shifts in production and employment are not simply the product of changing factor endowments or shifting consumer demands but of disparate strategies undertaken by corporations experiencing different historical moments of long-term profitability cycles." Firms undergo a cycle of four sequential profitability stages from "superprofits" to "profit squeeze," and five spatial patterns corresponding to profit cycle stages: concentration, agglomeration, dispersion, relation, and abandonment (Markusen, 1985:1-7, 43-55).

2.3. Institutions, State and Regional Growth

Aside from suggestions to promote regional development by developing technologies, fostering export-oriented industries, adopting import substitution strategies, or creating growth poles, a considerable amount of work has also stressed the significant roles of institutions and the state in development.

Polanyi (1957) highlighted the importance of institutions in economic development in his paper "The Economy as Instituted Process." He argued that "the industrialization of underdeveloped countries involves, on the one hand, alternative techniques; on the other, alternative methods of instituting them," and "the human economy is embedded in institutions" (Polanyi, 1957: 249, 251).

Gerschenkron (1962) told the story of European industrialization of then backward countries such as France, Germany, and Russia in the nineteenth century. In face of the scarcity of capital, technology, and matured labor in backward countries, institutions (such as financial institutions, i.e. banks) and the state are found to be great forces in promoting the industrialization process. However, the roles of these factors are changing with regard to conditions and degrees of backwardness. Moreover, "in every instance of industrialization, imitation of the evolution in advanced countries appears in combination with different, indigenously determined elements" in backward countries (Gerschenkron, 1962). Through his observation of the American economy, Alfred Chandler (1977), from a micro-level view, proposed that the modern business enterprise was the institutional response to the rapid pace of technological innovation and increasing consumer demand in the United States during the second half of the nineteenth century.

Chalmers Johnson (1982) deemed the Japanese economic "miracle" not as the result of several separated institutions such as the lifetime employment system and the seniority wage system, but the result of a strong "developmental state." To guide and drive the industrialization of Japanese society, the Japanese developmental state (or plan-rational state) set substantive social and economic goals, built close relationships between government and business, and made and executed industrial policies. Developmental state is very important for late industrialization countries. However, borrowing a few Japanese institutions would be futile or even harmful if the institutions were not understood within the whole economic system.

Similar to Johnson's "developmental state," Alice Amsden (1989) attributed Korea's success in its industrialization process to an "interventionist state," which intervenes "with subsidies deliberately to distort relative prices in order to stimulate economic activity." In the case of Korea, big business, *chaebol*[9], consolidated its power in response to the government's performance-based incentives. Amsden also characterized Korea's mode of

9 Diversified business groups with especially large size (Amsden, 1989).

industrialization as learning, which is appropriate for industrialization of "backward" countries in the twentieth century based on borrowed technology.

Later scholars argued that the state has an only limited role. Richard Doner (1992), through his five Asian auto cases, argued that "states may not offer the sole or the best institutional responses to collective dilemmas inherent in industrialization". Business groups, producer's associations, and/or public-private consultative bodies may be better suited for this purpose (Doner, 1992). Ash Amin (1999) stressed his institutionalist perspective on regional development, which tends to favor bottom-up, region-specific, longer-term and plural-actor based policy actions such as strengthening networks of associations, building clusters of interrelated industries, learning to learn and adapt, and broadening the local institutional base, in order to attain regional economic competitiveness in the globalization context.

A historical view of institutions was provided in Zysman's work (1994). He argued that "there are historically created, institutionally rooted national development trajectories." Historically rooted institutions generally include the character of the state, the character of the labor relations systems, the organization of the financial system, and the legal/regulatory system. They establish markets, structure how buying, selling and the very organization of production take place, and generate patterns of policy, patterns of trade and distinct organizational styles in government and corporations by setting down patterns of constraints and incentives which shape behaviors of individuals, workers, corporations and government. This historical perspective of institutions echoes both the earlier path dependency arguments of Rostow, and those of later mainstream economists (section 3.3).

3. Regional Development Theories in the New Era

New regional development theories are the results of undergoing profound technological, economic, and social transformation, which can be traced back to the reorganization of industrial capitalism in the late 1960s and 1970s. The most striking feature of this reorganization of industrial capitalism is the internationalization of production, which manifests itself clearly in the spatial division of labor. Since the late twentieth century, a more profound transformation, under the name of "globalization," is becoming evident, which brings us to the era of the "new economy." Section 3.1 discusses these new trends and new justifications for "spatial" concerns, followed by section 3.2, where new regional development patterns and strategies are investigated under the "new economy" context. Finally, the "spatial" concerns of economic activities find repercussions in mainstream economists' works, where efforts are made to formalize (or mathematicalize) traditional industrial location theories (section 3.3).

3.1. Globalization and Spatial Division of Labor

3.1.1. Spatial Division of Labor in 1970s, 1980s, and the "Globalization" Era

The concept of spatial division of labor was explored during the reorganization of production in the 1960s and 1970s, which was mainly characterized by a transition from mass production to flexible production[10], or from 'Fordism' to 'post-Fordism.' According to Massey (1979), "spatial division of labor" means that "any economic activity will respond to geographical inequality in the conditions of production, in such a way as to maximize profits" and this way of response to geographical unevenness varies greatly with changing conditions of production

10 Flexible production has been experienced in two forms: flexible specialization (defined by Piore and Sabel) and high-volume flexible production (defined by Cohen) (see Castells, 1996: 154; Cohen, 1993: 112).

(Massey, 1979: 234). Furthermore, Massey made a major contribution by identifying two different forms of spatial division of labor: sectoral spatial specialization, and functional spatial specialization. The latter, known as new spatial division of labor, results from changes in the form of organization of production such as, most importantly, the increasing size of individual firms and the separation of production based on different functional modules (Massey, 1979: 235-239).

Folker Frobel et al. (1978) discovered that starting from the late 1960s and early 1970s, a "new international division of labor" was replacing the classical international division of labor, that is, the contrast between the industrialized center countries producing capital and consumer goods, and the nonindustrialized periphery countries supplying raw materials. The new international division of labor, driven by capital's minimizing production cost for its expansion and accumulation, is characterized by the increasing relocation of manufacturing in underdeveloped areas, and is shaped by three factors: a huge worldwide labor pool, modern transport and communication technology, and the fragmentation of production tasks.

Viewing this notably new division of labor and the increasingly competitive Japanese economy characterized by its flexible production, Cohen and Zysman (1987) pointed out a possible crisis underlying the United States economy because manufacturing matters. They argued that "a substantial core of service employment is tightly tied to manufacturing" (Cohen & Zysman, 1987: 3). Furthermore, R&D has to be tightly tied to the manufacturing of the product in order to keep the cutting edge of incremental innovation. Besides the fact that "production is where the lion's share of the value is realized," the service industry also cannot serve as a main export resource to sustain the productivity and high wage of the United States due to reasons such as the small scale service trade, a less liberal international trade environment for trade in services than for trade in goods, and so on (Cohen & Zysman, 1987).

Profound technological, economic, and social transformations since the late twentieth century impels a "new economy." In this new economy, fast economic growth is being experienced, and "sources of productivity are increasingly dependent upon the application of science and technology, as well as upon the quality of information and management, in the process of production, consumption, distribution, and trade" (Castells, 1993). This new economy is evolving to be increasingly informational, global, and networked. Here, "informational" means the fundamental role of information and communication technology; "global" means that "the core activities of production, consumption, and circulation, as well as their components (capital, labor, raw materials, management, information, technology, markets) are organized on a global scale" (or, as we term it, "globalization"). By "networked," we mean that the organizational logic of this new economy is networked, flexible, and horizontal (Castells, 1993, 1996).

Gereffi and Korzeniewicz believe that the "globalization" economy needs to be reconceptualized from a global-commodity-chain perspective, instead of a nation-states perspective. From the global-commodity-chain perspective, industries and firms constitute its primary analytical units. Either a producer-driven chain or a buyer-driven chain, as they define them, can help explain the governance structures of coordination and control in global industries (Gereffi and Korzeniewicz, 1994, see Gereffi, 1997). This global-commodity-chain view, as a matter of fact, echoes Massey's "functional" spatial specialization.

While people are surrounded by statements on the overwhelming influences of "globalization," critiques come as well. Robert Wade (1996), for instance, after listing his data analysis from aspects such as trade, foreign direct investment, finance capital, behaviors of multinational corporations, and technology production, stated that "the world economy is less internationalized, less integrated" than "globalization" suggests and national economies are still the primary unit for economic activities.

Despite the "globalization" critiques, it is clear that international spatial division of labor in the new era not only differs markedly from the old center-periphery model, but also cannot be explained by Massey's functional spatial specialization. It is hard to categorize a whole nation into one or the other side of the division. Hence it comes as no surprise that Gereffi and Korzeniewicz use the global commodity chain method to analyze the new international production system (1994), and Castells proposes a new international division of labor where he specifies "triad power, the rise of the pacific, and the end of the Third World" (1996: 107).

3.1.2. New Justifications for Regions under "Globalization"

Contrary to the commonly held view that new transportation and communication technologies are beginning to subvert the legitimacy of cities and regions, we see that metropolitan areas continue to expand at a remarkable rate. Scott, after his data analysis, claimed that because "production and work depend upon myriad detailed exchanges, dealings, flows, and webs of association that cannot be sustained effectively over long distances," "the geography of industrial and service development displays a widespread proclivity to locational clustering in the form of dense polarized complexes of producers on the landscape," and this spatial clustering serves as the unit of his "global mosaic" (Scott, 1998: 48, 63). Later, Scott further explored these spatial units under the name of "global city-regions" and demonstrated the continued importance of urban concentration in the globalization context. Globalization actually has accentuated the process of clustering: clustering enables firms to respond to fast-changing global challenges by allowing them greater levels of operational flexibility and by enhancing their innovative capacities. "Large city-regions are coming to function as territorial platforms from which concentrated groups or networks of firms contest global markets" (Scott, 2001: 14). In particular, in developing countries, global city-regions represent highly productive and innovative economies, which enable continuous attraction of more efficient economic activities, thus connecting them to the vibrant globalization network.

In their Splintering Urbanism (2001), Graham and Marvin classify the urban landscape into three types: 1) the 'sticky' places of global capitalism, or global and second-tier cities; 2) routine production, service, and extraction centers; and 3) subordinate and bypassed territories. The first type produces high value-added goods, services and knowledge outputs with examples such as global financial capitals, high-tech industrial districts, government complexes, and cultural production centers. The second type "may be global nodes for the production of high-volume manufacturing goods; or places that can deliver routine services online or via telephone links to the core city regions; or sources for the extraction and production of various types of raw materials" (2001: 306). The labor and the assets possessed in the third type are ignored or bypassed by the logics of the 'network society.' In order for places to develop, it is crucial for them to be directly or indirectly connected to those 'sticky' places (Graham and Marvin, 2001; Castells, 2002).

3.2. Regions, Industrial Districts and Social Institutions

Successful regional development in the "globalization" context is characterized by flexibility. These flexible regions usually have a large amount of small- and medium-sized firms with very close interrelationships among them, manifested mainly as intense cooperation and competition.

The Emilia-Romagna region in Italy was first observed as successful by Sebastiano Brusco (1982). One significant feature of his Emilian model is the large number of small firms, which are "frequently grouped in relatively small zones according to their product, and give rise to monocultural areas in which all firms have a very low degree of vertical integration and the production process is carried on through the collaboration of a number of firms" (Brusco, 1982: 169). This large number of flexible small firms adds much flexibility to the regional economy by absorbing redundant labor force, building competitive environment, providing advanced technology, and establishing a cooperative basis for the region.

Sabel believed that the re-emergence of the region as an economic unit is a dramatic response to the continuing instability of international markets, which makes the once-dominating mass-production mode outdated. Contrasting with the failures of those "growth pole" or export-oriented regions, the success of new industrial districts such as the Emilia-Romagna region and Silicon Valley manifests the vigor of flexible economies under an unstable global environment. The main feature of the flexible economies is flexible specialization, which is not only a flexible production method contrasting to mass production, but is also defined as a system in which firms (a large proportion of which are small- and medium-sized firms) "know that they do not know precisely what they will have to produce, and further that they must count on the collaboration of workers and subcontractors in meeting the market's eventual demand" (Sabel, 1988: 53).

The capability to collaborate depends on trust. In his innovative paper on economic action and social structure, Mark Granovetter (1985) illustrated that economic behavior is embedded in structures of social relations to a degree that is lower than that explained by the oversocialized school represented by sociologists, but higher than is allowed for by the undersocialized school represented by new institutional economists. He stresses the crucial role of concrete interpersonal relations and structures (or networks) of such relations in generating trust in economic behaviors.

Bennett Harrison (1992) notes that "industrial districts," which have gained increasing attentions since the 1970s and are represented by regions such as Emilia, cannot be seen as a contemporary theoretical construct which is ultimately explicable by conventional neoclassical economic categories of "agglomeration" and "externality" originating from Marshall (1890). Standard agglomeration theory, he argues, "follows neoclassical economics in conceptualizing local economies as collections of atomistic competitors, formally aware of one another solely through the intermediation of price/cost signals," while modern industrial district theory "emphasizes the interdependence of firms, flexible firm boundaries, co-operative competition and the importance of trust in reproducing sustained collaboration among economic actors within the districts." Trust, being crucial both when decisions to redesign interfirm linkages are being made and once a link has been forged, needs spatial proximity to nurture the experience essential to building trust.

Sable also stresses the significance of trust. He believes that flexible economies rely on high-trust relations which they reinforce through their operation but cannot generate themselves (1988). Trust, according to Sabel, is the "mutual confidence that no party to an exchange will exploit the others' vulnerability" (1993). Although it takes a long time to build trust, mutually suspicious groups in the region can redefine their relations and "study" their industries jointly so that they may "discover new sources of vitality that could serve as models for collective reorganization." Moreover, local government can help in building this "studied trust" (1993: 121, 130).

Robert Putnam (1993) builds a broader concept of "social capital," which refers to "features of social organization, such as networks, norms, and trust, that facilitate coordination and cooperation for mutual benefit." In his influential paper, Putnam illustrated the importance of "social capital" for economic development based on his studies of Italian regions. According to him, social capital is a precondition for economic development as well as for effective government, and tends to be self-reinforcing and cumulative.

Through her analysis of the high-tech industry development in Cambridge, Saxenian (1988) pointed out that "creating a dynamic high-tech region is not a matter of combining ingredients" (such as research university, venture capital, funding, etc.), but of "building institutions and relationships that support innovation." Her book (1994) was the first to systematically explain the vibrant regional economy of Silicon Valley through three perspectives: local institutions and culture, industrial structure, and corporate organization. Important actors identified for the innovative economy include entrepreneurial firms, government, venture capitalists, universities and research institutes, specialist suppliers and service providers, business associations, and so forth. Their interconnections or relationships can be framed by institutions that provide capital, research, managerial and technical education, training and assistance to entrepreneurs, and market information. Intense competition and cooperation is taking place on a network platform and those actors are the nodes of that network. The most important feature of the Silicon Valley network is that it is dynamic, which is represented not only by the fast changing market and technology but also by the continuous recombination of differently specialized resources. It is in this dynamic network that actors and their relationships are kept updated and innovated, and a rich array of technological and organizational alternatives can be generated and pursued.

From a strategic perspective, Michael Porter put forward one of the most popular concepts in the 1990s—"cluster"—in order to understand regional economy and location. "Clusters are geographic concentrations of interconnected companies and institutions in a particular field" (Porter, 1998: 78). Because anything that can be efficiently sourced from a distance through global markets and corporate networks is nullified as a source of competitive advantage in the globalization context, clusters are seen as a key competitive advantage for any region. "Clusters" emphasize the relationships among firms and between firms and local institutions, which promote firms' productivity as well as innovation capability through building a helpful local business environment[11], and in particular competition and cooperation. He also stressed that policies at the regional level are important and local government should help identify local specializations to reinforce existing and emerging clusters rather than attempt to create entirely new ones.

3.3. Spatial Views from Mainstream Economists

Mainstream economists began to write about location, trade and development in the 1990s. Most of their works echo traditional location theories and path dependency theories.

Paul Krugman was the first to realize the neglect of space, and explained that it was because economists "lacked the analytical tools to think rigorously about increasing returns and imperfect competition." As long as economists can use certain technical tricks such as "Dixit-Stiglitz, icebergs, evolution, and the computer" to produce models in which there are increasing returns and markets are

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11 Porter put forward his "diamond theory" in his book *The Competitive Advantage of Nations* in 1990. He modeled the effect of the local business environment on competition in terms of four interrelated influences, graphically depicted in a diamond: factor conditions, demand conditions, the context for firm strategy and rivalry, and related and supporting industries (Porter, 1998).

characterized by imperfect competition, scholars such as Krugman, Fujita, and Venables attempt to formalize the classical location theories (Krugman, 1991, 1995, 1998). Krugman, using his model and the example of the US manufacturing belt, illustrates the importance of history and increasing returns. In his belief, “an accident led to the establishment of the industry in a particular location, and thereafter cumulative processes took over” (Krugman, 1991: 62).

Brian Arthur tried to prove historical path dependence for industry location and economic development using mathematical models. He concluded that “we cannot explain the observed pattern of cities by economic determinism alone without reference to chance events, coincidences, and circumstances in the past. And without knowledge of chance events, coincidences, and circumstances yet to come, we cannot predict with accuracy the shape of urban systems in the future” (Arthur, 1988: 96). In another paper, Arthur (1989) showed that insignificant historical events may by chance give a certain technology an initial advantage, and later on, due to increasing returns, this technology may eventually lock the economy in to this outcome, which is not necessarily superior to alternatives, not easily altered, and not entirely predictable in advance. Similarly, Paul David, through his study of the story of QWERTY, pointed out the importance of “path dependence.” He stressed that temporally remote events or historical occurrences can exert important influences upon the economic outcome, which can then be “locked in” to this development trajectory due to positive feedbacks caused by, for example, economies of scale, Marshallian externalities and local network externalities, and endogenous technical progress through learning-by-doing and learning-by-using (Paul David, 1985, 1993).

Another group of economists who attempted to model increasing returns (or imperfect competition) are the “endogenous growth” theorists[12] represented by Paul Romer. Their work, emerging in the 1980s, distinguished itself from neoclassical growth by emphasizing that “economic growth is an endogenous outcome of an economic system, not the result of forces that impinge from outside” (Romer, 1994: 3). The key in their models is how to formalize the technological residual in the production function. Romer (1994) proposed a model in which the residual is determined by knowledge spillovers, and can be represented as a function of labor input and capital investment. In an earlier paper, Romer especially stressed how using and producing ideas are important for economic growth (Romer, 1992). No matter what form in the formulation they adopted, they all take imperfect competition into consideration. As Christaller said in 1933, “that each economic relationship and each economic event are, without exception, related to space and that the spatial relation is also a constituent element of these relationships are facts of which only a few economists are fully aware” (Christaller, 1933: 6). Luckily, with the tools to model increasing returns, mainstream economists had finally started to catch up.

4. Conclusion

In this paper, regional development theories have been surveyed from their two traditions (“spatial” and “economic”) to their new progress in the past two centuries’ development. Although the legitimacy of regional development field has been continuously challenged, it has grown stronger under the new globalization context where regions and spatial economic relationships have increasing significance. Scholars from Isard to Krugman have been trying to create or resurrect this field in mainstream economics by attempting to formalize the relevant

12 This line of inquiry can be can traced in Arrow (1962), Romer (1986, 1987, 1990), Lucas (1988), Grossman and Helpman (1989), etc. (see Romer, 1994).

issues in mathematical models. However, the challenges may not be resolved solely by new methodology. Future research shall be conducted to examine the more recent theoretical trends of regional economic development since the dawn of the 21^{st} century to complete the picture. The current paper can help prepare future scholars in the field.

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Science and Technology Trends
Greenhouse Gas Reduction and Climate Change

Post-2020 Greenhouse Reduction Target of Korea: An Evaluation and Its Implications

Sangjun Lee

1. Introduction

It is era of New Climate Regime. The Paris Agreement was officially entered into force on November 4 this year. Following the Paris Agreement last year, ratification of Parties have been proceeded at a faster pace than anticipated[1]. The official entry into force of the Paris Agreement shows that the era of the New Climate Regime is within reach.

Compared with the Kyoto Protocol, in which only some developed countries are obliged to reduce greenhouse gas (GHG), the new regime is a new system in which all countries participate in actions in response to climate change. As of the end of November, 190 countries that accounted for more than 96% of the world's total emissions have submitted "Intended Nationally Determined Contribution" (INDC) which is the basis for the new regime. Especially, during the ratification process of the Paris Agreement, the United States, China and India, which are world's largest emitters, actively participated in the process. Therefore, the new era should be read as a signal that climate change is a global problem and that the world has come to have a consensus on urgent needs to react to climate change problem.

Climate change is an environmental problem, but reacting to climate change is fundamentally an economic problem. As proved by sluggish negotiation progress over the years until the Paris Agreement, any actions mitigating and adapting to climate change are closely linked to economic interests of Parties. It is widely accepted that GHG emissions from energy consumption have been inevitable in the process of economic growth. Therefore, the new regime means that the whole world supports the transition of the paradigm of existing economic growth toward a low carbon economy.

Prior to the Paris agreement, Korea announced its goal of reducing emissions by 37% below Business-as-Usual (BAU) scenario by 2030 last year (Joint Announcement by related Ministries, 2015). Since the agreement is fundamentally a bottom-up approach based on Nationally Determined Contribution (NDC), it is important to set GHG emission reduction targets and implement

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1 Conditions for entry into force have been achieved on October 5, 2016. According to Article 21.1 of the Paris Agreement, If at least 55 Parties and Parties that accounts for more than 55% of global emissions ratify, the Agreement will officially enter into force after 30 days.

corresponding policies by individual country. It is also a challenge for Korea to set reasonable policy measures for greenhouse gas reduction and foster new growth engines. Accordingly, it is highly likely that the existing GHG reduction policies will be adjusted or strengthened or various policies and support measures will be introduced in the course of implementing the targets. In the end, Korea's GHG reduction target has a significant impact on Korea's overall economy. The impact on the manufacturing sector, which is the core of our economy, is expected to be significant. In this article, we will evaluate the post-2020 GHG reduction target and examine implications of the target.

2. The New Climate Regime (Paris Regime)

2.1. Overview of the New Climate Regime

A series of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), which was published in 2014, shows trends in observed climate change, climate change impacts and adaptation, climate change mitigation strategies. The report clearly demonstrates that climate change is attributable to human activities. It also lays down the impacts of climate change, which is evident throughout human life to ecosystem and so on (IPCC, 2014).

Global efforts to recognize the effects of climate change and curb climate change is not a recent development. The international community's efforts to mitigate climate change have been relatively long. The United Nations Framework Convention on Climate Change (UNFCCC) is the starting point for the international community's efforts to response climate change problem. Since then, the Kyoto Protocol, which was usually referred to as the Kyoto Regime, was signed in 1997 and efforts by the international community to reduce greenhouse gas emissions have been started.

However, the Kyoto Regime had many limitations. First, the Kyoto regime was an imperfect system imposing a reduction obligation only on 38 countries classified as Annex I countries. At the time of the Kyoto Protocol, it was natural for countries with historical responsibilities to climate change, especially developed countries, to have a duty to cut down emissions. However, as the Kyoto Regime lasted for more than 10 years, imbalance of the Regime has been amplified since it failed to limit emission growth from developing countries. Specifically, emerging economies such as China and India have rapidly increased their GHG emissions due to rapid economic growth and the participation of developing countries in GHG reduction has become a necessity for global mitigation efforts.

Second, the problem of top-down reduction approach was exposed. The top-down goal setting had to be questioned as to whether the appropriate targets were imposed and implemented reflecting the capabilities and circumstances of the Parties involved in the reduction. Developed countries that felt overly burdened had to withdraw from the Kyoto Regime or refuse to ratify the Protocol. As a result, the Kyoto Protocol became titular (Roh, 2014)[2].

The discussions to improve the incompleteness of the Kyoto Regime continued, but the progress of the agreement was sluggish due to the significantly different standpoints between developed and developing country Parties[3]. Here, we will introduce relatively recent negotiations for the sake of simplicity of discussion.

The basic framework for the new regime was agreed at the 2011 Durban Conference (COP 17)

2 The absence of major developed nations and China has resulted in the emission of greenhouse gases from countries participating in the Kyoto Protocol second commitment period, which is only 14% of the global emissions.

3 As a representative example, the failure to reach an agreement in the Copenhagen Conference of Parties (COP 15) is often mentioned. It is possible to refer to Roh (2014) for the process of discussion under the Convention on Climate Change for the establishment of a new climate regime as a follower after the Kyoto Regime.

and the 2013 Warsaw conference (COP 19). The Durban Conference agreed to form a new climate regime, in which all developed and developing countries will participate following the Kyoto Protocol. In other words, it is clear that the new regime is the system in which all the Parties participate. At the Warsaw conference, countries agreed to set a GHG reduction target through a bottom-up approach called INDC. Through the negotiation process, the Lima conference in 2014 (COP 20) agreed on the guidelines for the preparation of the INDC and the components of the new regime.

Compared with the Kyoto Regime, the characteristics of the new regime can be easily deduced from the limitations of the Kyoto Regime discussed above. First, it is a system in which all parties participate[4]. GHG mitigation actions are similar to the provision of public goods with properties of non-rivalry and non-excludability. If a country is to faithfully reduce GHG emissions, as is the general nature of public goods, all countries benefit from it as well as the country. Therefore, all countries are tempted to take free riding on greenhouse gas reduction and global mitigation actions will fall short of optimal level. In this respect, the nature of the system in which all nations participate is of importance. If there are a number of countries outside the new system, these countries can easily enjoy the fruits of other countries' efforts within the regime. Hence, the system itself will be vulnerable inevitably.

Second, the bottom-up reduction approach is important for robustness of the new regime. The INDC-based bottom-up reduction target setting has been able to avoid the possibility of debate over individual countries' reduction capabilities or national circumstances, which has been pointed out as a limitation in the top-down approach. As each country voluntarily submitted its reduction targets in accordance with the national conditions of the country, the proof of the ambition of the reduction targets and the conditions of the countries were passed to each Party. Because it is a self-determined goal, the individual countries have responsibility for the implementation of the goal. Therefore, the possibility of avoiding the responsibilities of implementing the reduction obligations due to the climate regime itself, as in the case of the Kyoto system, has been reduced. Therefore, the bottom-up approach is the basis for enhancing the robustness of the New Climate Regime[5].

2.2. Implications of the New Climate Regime

The Paris Regime will be an inflection point that confirms the global willingness to respond to climate change. The complexity of the interests of developed and developing country Parties is evident in the process of negotiations, but the new Regime will be an opportunity to demonstrate global commitment to the need to respond to climate change.

Therefore, the new system will be an important turning point to suggest a new paradigm of economic development. The new economic development paradigm is aimed at a 'low carbon economy.' Transition to the low-carbon economy is already occurring worldwide. Recent developments such as low-carbon technology development and the spread of renewable energy are becoming more prominent. For example, EU and China is planning and

4 The COP 17 decision clarifies that the new regime is a system in which all Parties participate. Decision 1/CP.17 para 2. states "develop a protocol, another legal instrument or an agreed upon outcome with legal force under the Convention **applicable to all Parties**..." <http://unfccc.int/resource/docs/2011/cop17/eng/09a01.pdf#page=2>

5 The bottom-up approach, in which countries voluntarily set and submit reduction targets, is similar to the voluntary decision to supply public goods. In other words, the bottom-up system is likely to show a level of GHG reduction at a level that is lower than the global target of 2 °C, such as the problem of supply of public goods at a level lower than the socially optimal level. A comprehensive report on the INDC already published by the UNFCCC points out that the INDCs submitted by each country are not sufficient for the goal of the second degree. In light of the limitations of this bottom-up approach, future climate negotiations is likely to focus on 'review' process. Therefore, this system is sometimes called 'pledge and review' process.

implementing bold investment in the clean energy sector. The emergence of the new system will surely accelerate this transition.

Considering that most of the greenhouse gases are emitted from the energy sector (fuel combustion), the new system will have the greatest impact on the energy sector. In other words, the foundation of the low-carbon economy supported by the Paris Regime will rely on innovation and transformation in the energy sector. Changes in the energy industry and the market are already underway and new markets and industries are emerging. The trend of this change can not be easily accommodated in the export-oriented economy based on the manufacturing sector such as Korea. In particular, the intensive energy-consuming industries such as steel and petrochemicals account for a considerable portion of the Korean manufacturing industry, which will challenge the Korean economy and require fundamental innovation and transformation.

3. GHG Reduction Target of Korea

In order to set the goal of reducing GHG emissions in Korea, related ministries such as the Ministry of Trade, Industry and Energy, the Ministry of Foreign Affairs, the Ministry of Environment and the Ministry of Land set up a Joint Climate Change Task Force (April 2014). In addition, the Post-2020 Joint Working Group was established, in which research institutes such as the Korea Energy Economics Institute, the Korea Transportation Research Institute, and the Korea Rural Economic Institute participate (May 2014). The task force is responsible for monitoring of the process and the coordination of issues. The working group is responsible for carrying out practical empirical analysis for establishing reduction targets such as GHG emission predictions and reduction potential analysis.

Based on the analysis results of the working group, the government prepared four reduction target scenarios through consultation with related ministries. Also the four scenarios were discussed through public hearings. Korean government completed the submission of the INDC to the UNFCCC on June 30, 2015.

3.1. Greenhouse Gas Emission Predictions

3.1.1. National GHG Emission Predictions

GHG emission forecasts serve as an important basis for setting GHG emissions targets. Even if a country do not set a greenhouse gas reduction target against the emission estimates (BAU), it is difficult to set a reduction target arbitrarily without information on the future emissions. Setting estimates of GHG emissions is an essential process for estimating whether a reduction target is achievable or not.

Korea has also been involved in long discussions through the joint working group to derive reasonable greenhouse gas emission estimates prior to setting greenhouse gas reduction targets. The GHG emission forecast for the post-2020 reduction target in Korea was based on the 2nd Energy Basic Plan announced and published in January 2014 by the government. Since the energy sector accounts for more than 85% of the GHG emissions (87.2% in 2012), and the energy basic plan includes the predictions of up to 2035, the government decided to utilize the plan. Industrial processes, agriculture and livestock sectors that are not included in the basic plan are newly estimated and supplemented the plan.

The forecasts for the energy sector was based on the KEEI-EGM (Energy and Greenhouse Gas Modeling) System, which has been developed and operated by the Korea Energy Economics Institute. Briefly the energy sector projections calculate the energy demand by multiplying the activity data forecasts (e.g. crude steel production) by energy efficiency variables representing energy demand per activity and applying the emission factor to calculate the greenhouse gas emissions. For the non-energy sector, GHG emission estimates are generated by directly applying emission factors for each sector based on activity forecasts.

Table 1. GHG emission prediction by 2030

(Unit: mil. tCO_2eq)

	2013	2020	2025	2030	Annual Average Growth (%) '13~'20	Annual Average Growth (%) '13~'30
Energy	592.2	677.5	700.5	738.9	1.94	1.32
Non-Energy	87.7	104.9	109.1	111.7	2.59	1.43
Total	679.8	782.5	809.7	850.6	2.03	1.33

Source: Post-2020 Joint Working Group

Table 2. GHG emission predictions by sector

(Unit: mil. tCO_2eq)

Sector	2013	2020	2025	2030	Annual Average Growth (%) '13~'20	Annual Average Growth (%) '13~'30
Energy						
Transformation	233.4	295.5	303.9	333.1	3.43	2.11
Industry	211.7	225.8	234.6	239.1	0.93	0.72
Transportation	86.0	95.4	100.5	104.1	1.49	1.13
Household, Commercial etc.	54.3	53.1	53.6	54.1	-0.32	-0.02
Fugitives	6.8	7.7	8.0	8.4	1.79	1.25
Energy Subtotal (A)	592.2	677.5	700.5	738.9	1.94	1.32
Non-Energy						
Industrial Processes	50.9	68.7	72.8	75.6	4.38	2.35
Wastes	14.9	15.4	15.5	15.5	0.47	0.23
Agriculture	21.9	20.9	20.9	20.7	-0.67	-0.33
Non-Energy Subtotal (B)	87.7	104.9	109.1	111.7	2.59	1.43
Total (A+B)	679.8	782.5	809.7	850.6	2.03	1.33

Source: Post-2020 Joint Working Group

As a result of GHG emission estimates, the emission estimate for 2030 is 850.6 million tons ($CO_2eq.$), which is an annual average increase of 1.33% during the forecast period. The energy sector accounted for 86.9% of total emissions and predicted 738.9 million tons in 2030, with an average annual increase of 1.32% over the forecast period and a slight decrease after 2020. Meanwhile, emissions from the non-energy sector are expected to reach 111.7 million tons in 2030 with an annual average increase of 1.43%.

3.1.2. Emission Predictions by Sector

The results of GHG emission forecasts by major sectors can be summarized in the Table 2. First, in the transformation sector, GHG emissions before 2020 are expected to increase slightly faster than the next decade with annual average of 3.4%. But after 2020, the growth would slow down. So the growth rate is calculate by annual average of 2.1% for the whole period. This trend is due to the rapid growth of the fabricated metal product industry (e.g. semiconductors, electronics) which has high demand for electricity in the production process.

Energy intensive industries such as petro-chemicals, primary metals, and non-metallic minerals are expected to exhibit stable growth during the projection period. Hence, GHG emissions from industrial sector is expected to grow at an annual average rate of 0.7%, which is less than the transformation sector. Meanwhile, the transportation sector is expected to increase gradually, but the growth rate is expected to decline gradually.

The building sector (e.g. household and commercial sectors) is expected to have a slight decline in emissions due to stabilization of economic growth and the impact of population stagnation. On the other hand, the industrial process emissions are expected to increase at a faster rate due to the growth of major emitting industries such as semiconductors, displays, and electronics. Looking at other non-energy sectors, emissions from the waste sector are to increase moderately while emissions from the agricultural sector are expected to decrease moderately.

3.1.3. GHG Reduction Target of Korea

Before public hearing process, Korean government proposed four reduction scenarios compared to the emission estimates for setting the post-2020 national greenhouse gas reduction targets. The scenarios are based on GHG reduction technologies, which are expected to be applied at a future point in time, and mitigation policies and costs. Also, the government conducted economic impact assessments on the reduction scenarios. Details of four proposed scenarios are provided in the table below (Table 3).

The first scenario is equivalent to 5.5% above 2012 emission level (14.7% below BAU). It has been derived by assuming to strengthening the current and planned GHG reduction policies for each sector such as industry, power generation, transportation, and buildings. Also available cost-effective mitigation

Table 3. Post-2020 GHG reduction scenarios of Korea

Reduction Scenarios		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Target Emissions (mil. tCO_2eq)		726	688	632	585
Reduction Rate (%)	Compared to BAU	△14.7%	△19.2%	△25.7%	△31.3%
	Compared to 2012 level	5.5%	0%	△8.1%	△15.0%
Intensity Improvement Compared to 2012 (%)	per GDP (ton/mil. won)	△38.6%	△41.8%	△46.6%	△50.5%
	per Capita (ton/pop.)	0.9%	△4.4%	△12.3%	△18.8%
GDP decline (2030 outlook)		△0.22%	△0.33%	△0.54%	△0.78%

Source: Post-2020 Joint Working Group

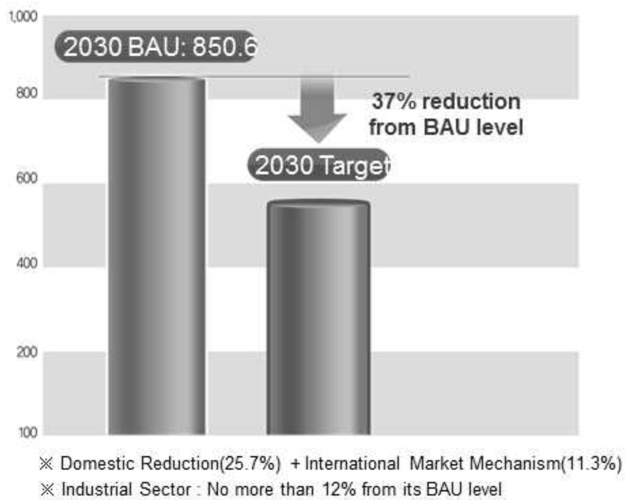
technologies were reflected in the scenario. The second scenario is reducing 2030 emissions below the predicted emission up to 2012 emission level (19.2% below BAU). In addition to the first scenario, additional reduction measures are included in the second scenario including some costly measures. For example, reduction measures such as shutdown of some coal-fired power plant, introduction of building and factory energy management system are included in the scenario. The third scenario is a level of 8.1% reduction compared to the 2012 emissions (25.7% below BAU). With all measures up to the second scenario, additional reduction measures were applied in this scenario. Especially, measures which require relatively large-scale financial investment and public expenditure were considered. These are increasing the share of nuclear power, introducing and commercializing carbon capture and storage (CCS) technology, speeding up green car supply. In addition to the reduction measures in the third scenario, the fourth scenario is to reduce 15% of the emissions below 2012 level (31.3% below BAU) including all additional mitigation measures. Additional measures considered include the addition of nuclear power (conditional on public acceptance), further applications of CCS, and replacing coal-fired power generation with gas.

Based on the four reduction scenarios, the government announced its target of reducing GHG emissions by 37% compared to BAU (851 million tons) in 2030 after collecting diverse public opinions from all sectors (Figure 1).

In the process of public hearings on the four targets, industry and civil society expressed opposing views. The industry has argued that the reduction burden should be relaxed in consideration of the structure of Korean economy (e.g. high share of manufacturing) and the high energy efficiency of the industry. On the other hand, the international community and the civil society suggested to set a progressive reduction target reflecting Korea's climate action leadership among developing countries and Lima decision of no-backsliding.

Finally, the government proposed a reduction of 37% below BAU as in scenario 3 (25.7% reduction) with 11.3% reduction utilizing international markets. The government has set its reduction target to a higher level than the four scenarios proposed, taking into consideration the opinions raised in the process of public hearings and the international status of Korea. The government also considered emergence of new energy industries and fostering these industries for new growth engine. In order to create new energy industries and innovate the manufacturing industry while maintaining the national stance to respond positively to the climate change, National Green Growth Committee recommended to strengthened previous 30% reduction target from BAU by 2020. The government finally adopted this recommendation and determined the goal of reducing 37% below BAU.

Figure 1. Post-2020 GHG reduction target of Korea



Source: Joint Announcement by related Ministries (2015)

Table 4. Evaluation of Korea's GHG reduction target

Emission Estimate 2030 (mil. tCO_2eq)	Emission Target	Target Emissions (mil. tCO_2eq)	Compared to 2012 (688.3 mil. tCO_2eq)		
			Reduction Rate	Per GDP Intensity (2012: 0.623 ton/mil. won)	Per Capita Intensity (2012: 13.8 ton/pop.)
850.6	△37% below BAU	536	△22%	△54.7% (2030: 0.282 ton/mil. won)	△25% (2030: 10.3 ton/pop.)

Note: Author's calculation
Source: Post-2020 Joint Working Group

The government also announced various complementary measures to alleviate the burden on the industry during the process of implementing the GHG reduction target, reflecting industry sector's concerns raised during the public hearings. As a representative example, the government proposed a plan to secure additional reduction potential for by utilizing the international carbon market mechanism.

It also expressed intention that the industrial sector reduction rate would not exceed the level of 12% from its sectoral BAU according to scenario 2. The government expressed intention to improve of related laws and policies such as the GHG Emission Trading Act and others. These changes aim to improve the institutional basis so as to reduce GHG emissions reasonably. The government proposed to consider additional nuclear power plant, to develop GHG technologies in transportation and building sectors, and to promote the transition to a low-carbon economy.

4. Evaluation of Korea's GHG Reduction Target and Its Implications

4.1. Evaluation of Korea's GHG Reduction Target

As discussed above, Korea's post-2020 reduction target was set above scenarios originally proposed by the government. This is the result taking into consideration of the international responsibility of Korea and its leadership of climate actions among developing countries.

Table 4 summarizes some evaluations of the target. Reducing emissions by 37% compared to BAU emissions by 2030 translates to a 54.7% reduction in emissions per GDP and a 25% reduction in emissions per capita. As of 2012, Korea is ranked 7th in the global carbon dioxide emission, 16th in the cumulative GHG emission, and 6th in the OECD in the emissions per capita. Considering the Korea's status in global GHG emission, the government decided to raise ambition to the international community.

The reduction target can be assessed through examining the national circumstances, of which the industrial composition of economy of Korea is considered to be the most important part[6]. Korea's industrial structure can be characterized by its high share of manufacturing sector. Korea maintains a high proportion of manufacturing and energy intensive industries of country's total value-added. The share of manufacturing in Korea is 31% as of 2013, indicating that the manufacturing sector maintains a high proportion of the sector compared to major developed countries. Looking at the share of manufacturing in major countries, the US, Japan, and EU account for 12.9%, 15.3%, and 18.2% in 2013. In China, where manufacturing has grown rapidly in recent years, manufacturing accounts for 31.8% in 2013, which is similar to Korea.

In addition, the proportion of energy intensive

6 In 2013, Korea's industrial sector emitted 350 million tons of CO_2eq, accounting for 50% of the country's total emissions (including indirect and industrial process emissions).

industries in the manufacturing sector is also high. Of the total value added in Korea in 2013, energy intensive sectors (oil refining, chemicals, primary metals, rubber and plastics) account for as much as 6.8%. Therefore, it is difficult to expect a short-term reduction effects due to the high proportion of manufacturing and energy intensive industries. Reducing GHG emissions in the short-term progressively, it seems inevitable to pay high abatement costs which may weaken industrial competitiveness.

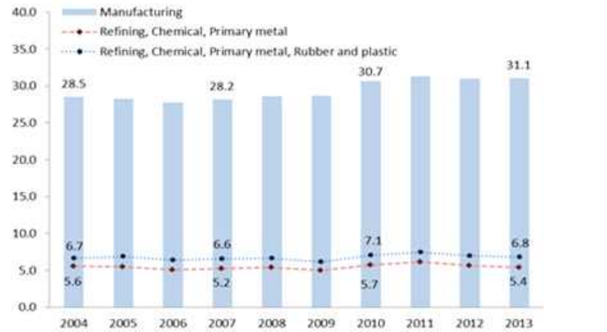
Although a country maintains a high proportion of manufacturing, if the energy efficiency level of the sector is low, it can reduce greenhouse gas emissions with relatively low costs. However, Korea's manufacturing sector, especially the energy intensive sector, has already achieved world-class energy efficiency level and has been continuously improving its efficiency.

The energy efficiency level of Korea's energy intensive industries has already achieved the highest level in the world. Let us look at the steelmaking industry and the petrochemical industry, which have the highest greenhouse gas emissions in the manufacturing sector as a representative example. Comparing the energy efficiency of the steelmaking and petrochemical industries with other countries, the energy efficiency of the industry is confirmed to be among the highest in the world. In addition, energy efficiency levels of Korea's major industries such as display, pulp and paper are also beyond other countries (FKI, 2012).

Korea's manufacturing sector has been the main driver of rapid GHG growth, but it should also be taken into account that the manufacturing sector was the driving force of economic growth. The contribution rate to economic growth of Korean manufacturing industry is more than 30% each year, and manufacturing has played a leading role in breaking economic recession by recent global

Figure 2. Share of manufacturing and energy intensive industries in Korea

(Unit: %)



Note: Author's own calculation based on national account data from Bank of Korea

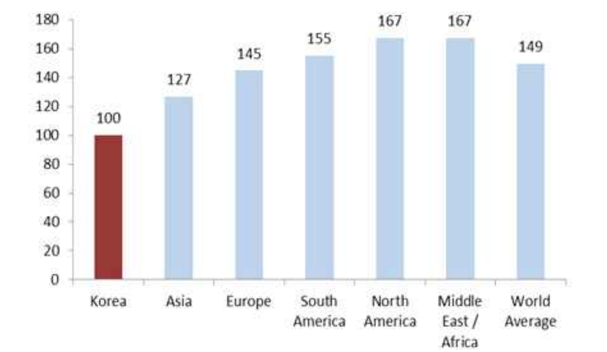
Source: Economic Statistics System, Bank of Korea (ecos.bok.or.kr)

Figure 3. Energy efficiency comparison of steel-making industry

Note: Energy usage index producing one unit of product

Source: APP Steel T/F (2010), recited from FKI (2012)

Figure 4. Energy efficiency comparison of petrochemical industry: NCC (Naphtha Cracking Center) process

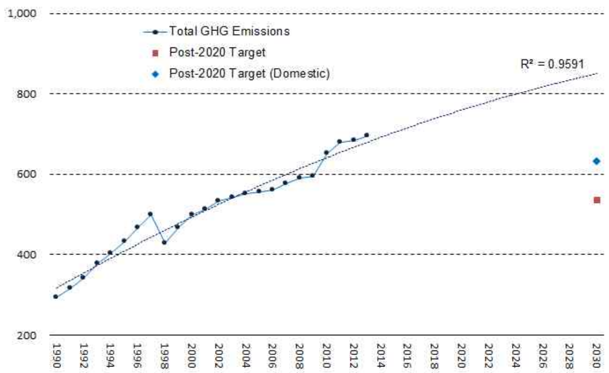


Note: Energy usage index producing one unit of product

Source: Solomon Associates (2009), recited from FKI (2012)

Figure 5. Total GHG emissions in Korea and 2030 reduction target

(Unit: mil. tCO_2eq)



Note: Author's own work
Source: GIR (2015)

economic crisis in Korea[7]. However, China's manufacturing competitiveness index has been rapidly catching up every year at the world's fourth-highest level (UNIDO, 2013).

In order to evaluate the post-2020 reduction target of Korea, we can also compare Korea's target with other countries. GHG reduction targets included in the INDC are diversified because they are determined voluntarily in consideration of the national circumstances of each country. More specifically, advanced countries that have reached the peak of GHG emissions often set absolute targets against the base year, while developing countries that do not have stabilized GHG emission targets have set targets for relative reduction (reduction compared to BAU, intensity target)[8]. Looking at the details of each country's INDC, the differences between countries are more prominent. It is not easy to compare the reduction targets between countries. However, it is necessary to compare and evaluate GHG reduction targets among countries, and it is necessary to try from various perspectives. In this paper, in order to compare the ambitions embodied in each country's reduction target, the type of the national reduction target was evaluated on the basis of GHG emission trends and per GDP intensity trends. Although the trends do not fully show ambitiousness of each country's reduction target, we can deduce efforts needed to reach the targets by investigating where the target is located from the current trend[9].

Korea's Post-2020 reduction target is slightly strengthened compared to the 2020 reduction target set in 2009. However, comparing the post-2020 reduction target with the total GHG emissions trend in Korea shows that it requires a significant reduction than the GHG emission trend in Korea (Figure 5). Given current emissions trends, it can be inferred that to achieve the Post-2020 GHG emission reduction target, the GHG emissions peaked before 2030 and must shift to a declining trend. Looking at the trend, it seems that the decline in the short term can not be achieved. Also if it reaches its peak in the vicinity of 2030, it may be difficult to achieve the reduction target. Hence, it will be necessary to aggressively reduce greenhouse gas emissions, and this will explain Korea's ambition as well as difficulty to meet the target.

When the reduction target of Korea is converted to per GDP intensity, it seems that there is a burden to accelerate the improvement of the emission intensity in order to achieve the target in 2030 (Figure 6). It is natural for any country to pursue energy efficiency improvements, and in this process, the emission intensity generally tends to decline year

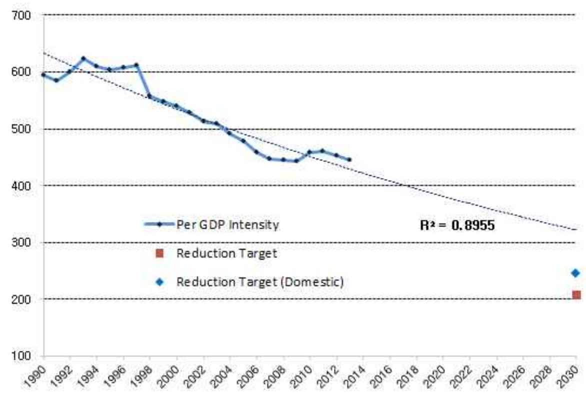
7 In the midst of the global financial crisis, the share of manufacturing in growth rate in 2010 was 55.4%. It has played a key role in breaking the manufacturing crisis in Korea.

8 Up-to-date information of each country's INDC can be found in the UNFCCC INDC portal. <http://unfccc.int/focus/indc_portal/items/8766.php>

9 A comparison of countries based on the absolute amount of reduction compared to baseline is also a way to easily compare the reduction targets of various countries. In this paper, no comparison was made on the basis of absolute quantity. This is because it is easier to compare reduction targets on an absolute basis, but it does not indicate the size of the reduction effort required by a particular country.

Figure 6. Per GDP emission intensity and 2030 reduction target of Korea

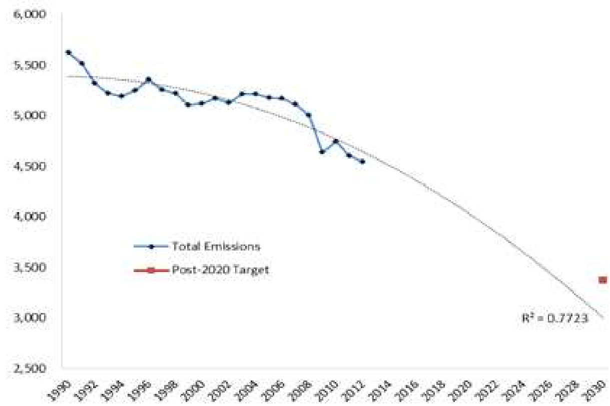
(Unit: tCO_2eq./2005 mil. USD)



Note: Author's own work
Source: GIR (2014), OECD

Figure 7. Total GHG emissions and 2030 reduction target of EU

(Unit: mil. tCO_2eq)



Note: Author's own work
Source: UNFCCC

by year[10]. In other words, when the per GDP emission intensity is plotted for each country, it shows a downward trend. However, it should be noted that this trend is not a spontaneous improvement, but it should be continuously manifested through various efforts such as efficient energy use, energy saving, and a transition to a low carbon economy. Given this point, we can deduce from the fact that Korea needs to further strengthen its efforts to improve the intensity from the current trend (Figure 6).

However, as mentioned above, considering the high energy efficiency level of Korea's major industries, it seems that the marginal abatement cost to further improve the intensity will not be low. Here, there are difficulties facing Korean economy in relation to GHG reduction.

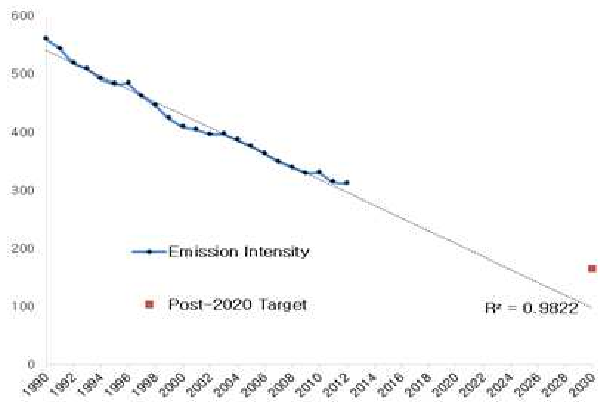
If we evaluate the GHG reduction targets of other countries in the same way, it can be compared with Korea more systematically. As a representative example, EU 2030 GHG reduction targets was reviewed. Comparing the EU's target with current GHG emissions trends, it seems that it can be achieved if the current trend is maintained. As shown in Figure 7, if the trend line is derived from the existing total GHG emission trend and the EU's 2030 target is depicted. We can easily find that the EU's reduction target is located above GHG emission trend line. Therefore, we may conclude that if the current trend is maintained, the reduction target can be achieved. Of course, future trends of GHG have many uncertainties, but if EU maintains current reductions, it seems highly likely that it will achieve the reduction targets.

Converting the EU's reduction target to per GDP intensity leads to the same conclusion. Figure 8 compares the EU GHG reduction target with the intensity improvement trend. Contrary to the case of Korea, it is confirmed that the EU's 2030 greenhouse gas reduction target is located higher than the unit improvement trend line. If they maintain current intensity declining trend, the EU's reduction targets will be easily achievable, and therefore the EU's reduction targets do not seem to be highly ambitious.

10 Emission intensity can be assessed in a number of ways. Typically, there is per GDP intensity, which means greenhouse gas emissions per unit of GDP, and a per capita intensity, which means greenhouse gas emissions per person. In this paper, we use the unit of GDP which represents GHG emissions per unit of value added of a national economy as a representative index.

Figure 8. Per GDP emission intensity and 2030 reduction target of EU

(Unit: $tCO_2eq.$/2005 mil. USD)



Note: Author's own work
Source: UNFCCC, OECD

Of course, the EU has been faithfully implementing its greenhouse gas reduction efforts so far, and it is reasonable to assume that such efforts have already been reflected in the EU's trend of total emissions and the improvement of per GDP intensity. However, existing reduction efforts can not serve as a basis for judging the ambition of 2030 targets. It is reasonable to interpret the ambitiousness of the target as a reduction efforts which will be added to the previous GHG reduction efforts. Because the efforts so far have been faithful, it can not be justified not to make additional reduction efforts in the future.

In general, the more GHG reduction efforts are undertaken in a country, the lower the means of reduction and the more expensive means of reduction. A relatively high economic cost is required to achieve additional greenhouse gas reductions. Taking this into account, the EU seems to have set its reduction targets in view of the future achievability of GHG reduction, which is expected to be relatively costly, considering the existing greenhouse gas reduction efforts.

In addition to the EU, greenhouse gas reduction targets of major developed countries have a similar pattern. For example, the GHG reduction targets in the United States and Japan are either higher or near the trend line of the current GHG emission and per GDP intensity[11]. In short, the target of reducing GHG emissions by major countries seems to be set by taking into account the possibility of achieving their targets. In a similar way to this paper, BNEF (2015) assessed whether the reduction targets of major countries are ambitious based on the submitted INDC. It should be noted that the BNEF indicated that Korea has a higher rate of reduction compared to the US or EU when converted to the reduction rate compared to BAU. The reduction rate compared to BAU is the best indicator of how much reduction effort is needed compared to the current situation. The fact that Korea has been rated as the most ambitious reduction target means that Korea needs to make the most significant reduction effort. In addition to that, BNEF (2015) pointed out that the efficiency of Korea's industrial sector is at the highest level in OECD, and therefore there is no cheap GHG reduction options. As pointed out earlier in this article, it is reaffirmed that the reduction of the industrial sector in Korea is not easy.

4.2. Implications of Korea's Post-2020 GHG Reduction Target

The advent of New Climate Regime are considered to be an opportunity as well as a threat to Korean economy. In order to preemptively respond to recent changes induced by the Regime, appropriate policy coordination and implementation will be necessary in accordance with changes. In other words, it is important to boldly adjust direction toward a low carbon economy to meet the Korea's GHG reduction target.

It is worth noting that to solve these recent

11 For the sake of brevity of the discussion, we will not show the figure showing the GHG emission trends and intensity trends in comparison with GHG reduction targets for the US and Japan.

challenges requires a convergent approach between the industry and the energy sector. For example, it is true that the impact of the Regime is deeply linked not only with climate change and energy sector but also with industrial restructuring and strengthening competitiveness. Since GHG emissions are directly related to economic activities such as manufacturing, the GHG reduction cannot be away from the industrial transformation. Thus, recent changes suggest that energy policy should not be considered independently of industry, but should be pursued in consideration of linkages with industry and energy.

GHG reduction targets are the result of various policies such as energy policy, industrial development policy and GHG emission regulations. Looking through the GHG reduction targets of major countries, it seems that the targets have been established from two points of view: definite reduction strategy and emission peak. However, Korea has many blank spaces in the two points.

As discussed above, there are two broadly contradictory views on the setting of GHG reduction target in Korea. The first is the aspect of ambition. It has been asserted that it is necessary to show sufficient ambition to the international society in consideration of Korea's climate action leadership among developing countries, Korea's economic status, and historical GHG emissions. On the other hand, it has been suggested that we must consider aspects of achievability. The achievability indicates a level that can be reached through appropriate policies or investments while moderately managing the economic impact. As a result, Korea's GHG reduction target seems to be mixed between ambition and achievability. The government set the target beyond the proposed four scenarios. On the other hand, the government show intention to utilize international mechanism and limit reduction rate in the industrial sector. Also the government suggested to foster new energy industry as a new growth engine (Joint Announcement by related Ministries, 2015).

On December 6, Korean government finalized the "Basic Climate Change Action Plan" and "2030 National Greenhouse Gas Reduction Basic Roadmap." The Basic Plan established is the first comprehensive plan to address Korea's mid- to long-term climate change strategy and specific action plans including GHG reduction, adaptation and international cooperation. The Roadmap contains systematic measures to effectively achieve the national GHG reduction target of 37% compared to BAU in 2030 (Joint Announcement by related Ministries, 2016).

It is worth noting that both reports stressed the role of market and technology. Korea has expressed its intention to induce voluntary reduction actions through market and technology rather than direct regulations. In line with the changes induced by New Climate Regime, where the linkages of industry, trade, and energy are increasing, energy policy should be in consideration of linkages between the various sectors.

First, GHG reduction policy should be implemented through harmonization of GHG reduction and industrial competitiveness. Policy development that attracts voluntary reduction of companies is necessary through market and technology development that can reflect 'climate change mitigation' and 'industrial reform (strengthening competitiveness of manufacturing sector)' in a integrated manner.

Second, energy demand management policy is a key alternative to meet energy supply-demand stability and response to climate change. Changes in the global market environment due to the development of ICT-energy convergence technologies are demanding rapid changes of the energy system from the supplier-oriented to the consumer-oriented and from the centralized to the decentralized energy system. In order to accelerate the transition of the policy paradigm, it is necessary to expand the market basis of demand management policies. To this end, demand management industry should be activated.

Third, new energy industry need to emerge and grow quickly in Korea. Basically, it is necessary to build an energy system in which the price is determined by the demand and supply of energy and the appropriate resource allocation by price is needed. To do this, it is important to reform the regulated energy tariff system so that it is more flexible to follow the supply and demand of the market. In order to activate the new energy industry, it is necessary to increase the role of consumers, focusing on deregulation of the entire energy system and market opening.

Finally, the importance of market-oriented R&D should be stressed. In order to cope with the New Climate Regime, it is necessary to expand the energy R&D. There is a need to approach energy technology R&D as a integrated view of responding to climate change and increasing industrial competitiveness. This is because through energy technology R&D we can pursue not only GHG reduction but also creating new growth engines by enhancing factor productivity and taking advantage of the global market.

Rational and fair game rules are needed to make GHG reduction an opportunity rather than a burden. In order to make all players voluntarily participate in the GHG reduction, it should be noted that it is a priority to provide an proper environment where the players can demonstrate their maximum capabilities.

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Science and Technology Trends
Greenhouse Gas Reduction and Climate Change

An Overview of Japan's Climate Change Mitigation Policy

Kentaro Tamura

1. Introduction

In fiscal year (FY) 2015, Japan further decreased its greenhouse gas (GHG) emissions by 3% from the previous year, at almost the same rate as observed in 2014 (down by 3.1%) (GIO, 2016). The total GHG emissions nevertheless amounted to 1.2 Gt-CO_2e (excluding land use, land use change and forest or LULUCF), the 6th largest emitter in the world, if the European Union (EU) is seen as one entity.

In July 2015, the Japanese government announced what post-2020 climate actions Japan would intend to take, known as Intended Nationally Determined Contributions (INDCs) (GoJ, 2015). Japan pledged to reduce its GHG emissions by 26% compared to 2013 levels by 2030 (or 25.4% reductions compared to 2005 levels). Given uncertainty surrounding the re-operation of nuclear power plants after the Fukushima nuclear accident of March 2011, however, various challenges remain.

This paper will present an overview of Japan's mitigation targets and pledges as well as the historical trends of Japan's national and sectoral GHG emissions. The paper also describes a landscape of climate mitigation policy in Japan.

2. Historical Emissions Trends and Emissions Reduction Targets

2.1 Historical Trends and Targets

Figure 1 presents Japan's historical GHG emissions trends and emission reduction targets. Japan committed to reduce its GHG emissions by 6% from the base year emissions (largely 1990 levels) in the first commitment period of the Kyoto Protocol (KP-CP1 or 2008-2012). The Japanese government recently announced that Japan achieved the KP-CP1 target, taking into account the net sequestration through land-use change and forestry (LULUCF) and the purchase of Kyoto unites. In 2010, at the 16th Conference of the Parties (COP 16) to the UN Framework Convention on Climate Change, however, the Japanese government announced to not participate in the second commitment period of the Kyoto Protocol, i.e. not taking legally-binding emission reduction target.

At COP 15 of 2009 in Copenhagen, the Japanese government, led by the Democratic Party of Japan (DPJ) pledged to reduce its GHG emissions by 25% from 1990 levels by 2020, premised on the establishment of a fair and effective international framework in which all major economies participate.

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This 25% reduction target relied upon a rapid expansion of nuclear power plants, namely, 9 new power plants by 2020 in addition to the existing 54 plants. However, the Fukushima nuclear disaster in 2011 made it unrealistic to expect such an expansion of nuclear power plants. The DPJ government sought to phase out nuclear power by the end of the 2030s, and hinted indicative 2020 reduction figures of 5-9% below 1990 levels. After change of government in December 2012, however, the new government led by the Liberal Democratic Party (LDP) announced a complete revision of energy and climate policies.

In 2013, at COP 19 in Warsaw, the Japanese government announced its revised 2020 target, a reduction of 3.8% from 2005 levels (or increase by 3.1% from 1990 levels), including forest sequestration and overseas credits, and assuming zero nuclear power. This 2020 target was tentative, and would be revised after the revision of national energy policy. Nonetheless, the scale of the rollback of the revised 2020 target from the previous one was far larger than the volume of GHG emissions that nuclear power generation was expected to displace (Kuramochi, 2014). It should also be noted that this 2020 target was pledged under a voluntary framework of the Cancun Agreement, not under the Kyoto Protocol.

In July 2015, the Japanese government submitted its INDCs (26% reduction from 2013 levels, or 25.4% reduction from 2005 levels) to the UNCCC Secretariat. This amount of reduction is based upon bottom-up calculation of domestic policies and measures, excluding international carbon credits. Indicative sectoral reductions were also presented (see Figure 2 below). The amount of carbon removed by LULUCF in 2030 was also estimated to be about 37 Mt-CO_2.

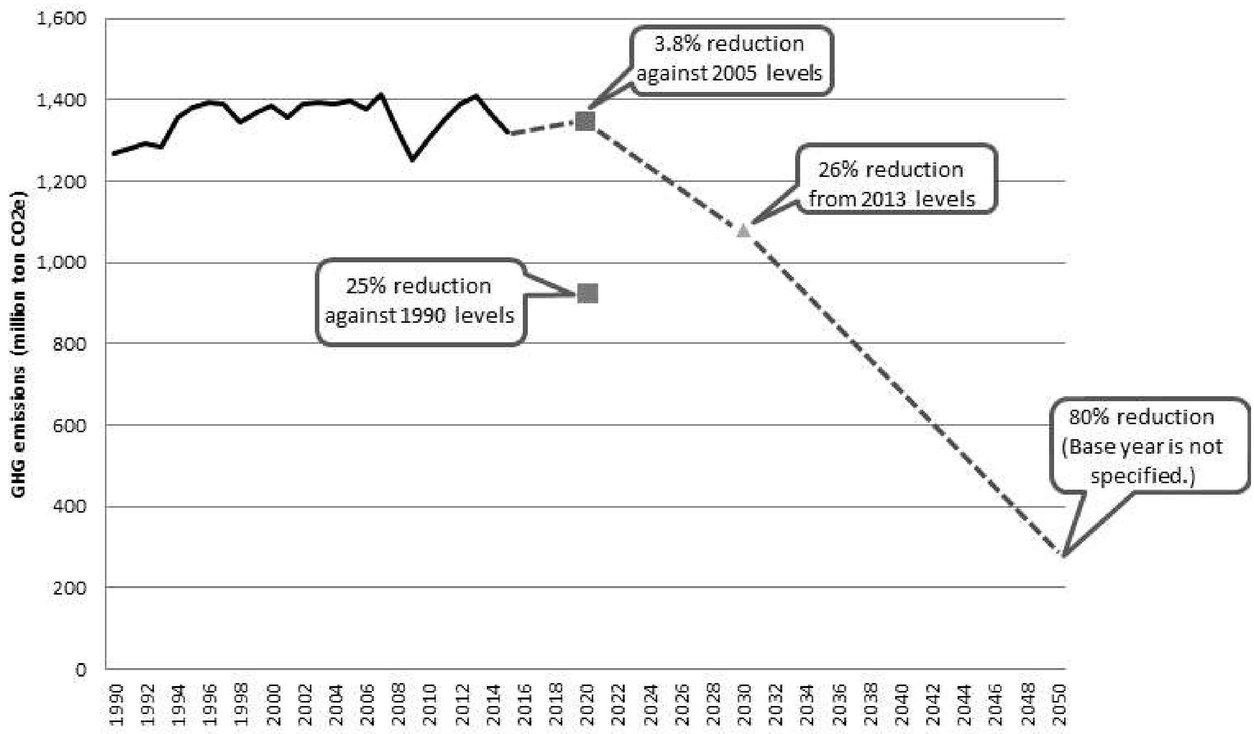
Regarding international credits, Japan's INDC mentioned the emission reduction by the Joint Crediting Mechanism (JCM). Though the use of the JCM was not included in the bottom-up calculation for the 2030 target, the INDC said that the government would prepare their budget to acquire credits ranging from 50 to 100 MtCO_2e in total by 2030 in order to account for Japan's emission target. But, it is still not clear how acquired credits will be accounted annually till 2030. This would be largely subject to the subsequent international negotiations.

Japan's INDC also referred to "international contribution other than the JCM" which will achieve emission reductions by low carbon technologies by Japanese industries' actions. This emission reduction by this approach was estimated to, at least, 1 Gt-CO_2e. However, the INDC did not mention relations between the 2030 target and these international contributions, as well as accounting and MRV methodology.

After COP 21, the Cabinet approved the Plan for Global Warming Countermeasures which increased the 2020 target to "more than" 3.8%, assuming the re-operation of some of nuclear power plants, re-affirmed the 2030 target (INDC), and set the aspirational goal of 80% reduction by 2050. The base year for the 2050 goal was not specified.

The black bold line in Figure 1 shows the historical trend of Japan's GHG emissions. In the aftermath of the global financial crisis of 2008, the GHG emissions sharply declined. However, after the Fukushima nuclear disaster in March 2011, the emissions rapidly increased because the electricity supply gap caused by the suspension of nuclear power plants was fulfilled by growing generation of thermal power plants, mainly gas-fired and oil-fired power plants. However, GHG emissions declined for consecutive two years after 2013. The emissions in 2015 has already achieved the 2020 target.

Figure 1. Japan's GHG emissions trend and reduction targets



Source: Based upon GOJ 2016 and GIO 2016.

2.2. Sectoral Breakdown

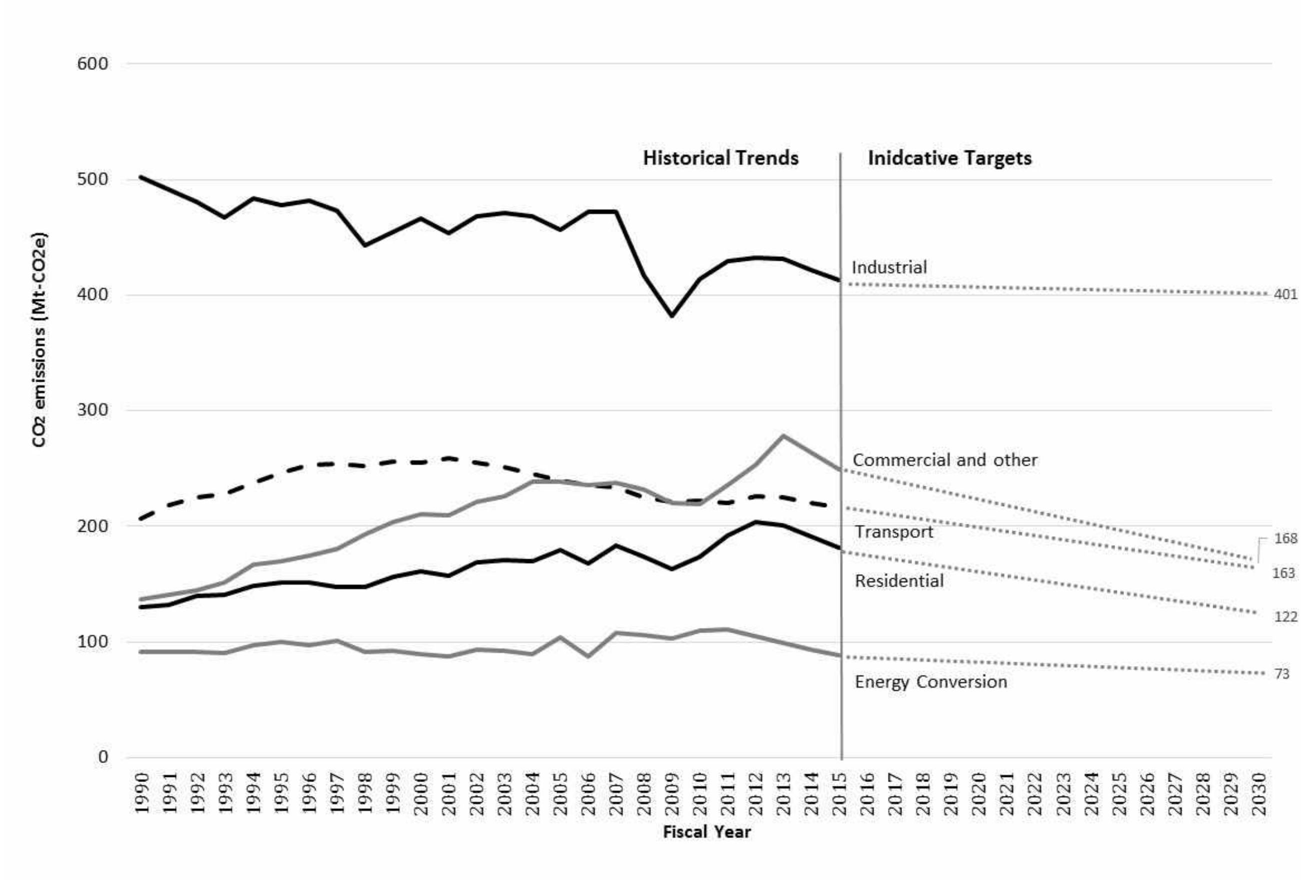
Figure 2 shows historical trends of sectoral energy-related CO_2 emissions, as well as indicative sectoral targets under Japan's INDC[2]. In FY2015, the energy-related CO_2 emissions from the industrial sector, including direct emissions and indirect emissions from electricity use, amounted to 413 Mt-CO_2e (GIO 2016). Compared to 1990, industrial emissions have decreased approximately by 18%.

Emissions from the commercial and residential sectors rather rapidly increased in last fifteen years. In particular, after the Fukushima nuclear disaster of 2011, the emissions from the two sectors jumped up because the suspension of nuclear power plants operation led to higher CO_2 emissions intensity for electricity. However, the emissions from the commercial and residential sectors started declining after their peaks in FY2013 and FY2012, respectively. These declining trends were mainly attributed to the decline in electricity demand. After rolling power outages under the tight supply-demand balance in the wake of the Fukushima nuclear disaster, electricity conservation has taken a firm hold on the Japanese life-style.

The GHG emissions from the transport sector increased in the 1990s, but they have been gradually decreasing since their peak in 2001. Improvement in fuel efficiency, in particular the diffusion of hybrid cars, contributed to this decreasing trend.

2 The emissions from the steam and electricity in the energy conversion sector are allocated to end-use sectors based on consumption.

Figure 2. Sectoral energy-related CO_2 emissions: historical trends and indicative targets for 2030



Source: Based upon GOJ 2015 and GIO 2016.

3. Policy Landscape

3.1. Overall Framework

The Act on Promotion of Global Warming Countermeasures, which was enacted in 1998 as the first climate-dedicated law, is a framework legislation for climate change policy in Japan. Based upon the Act, the Kyoto Protocol Target Achievement Plan was formulated in April 2005. The Act also provided legal foundation for the Global Warming Prevention Headquarters (GWPH), which was originally established within the Cabinet in December 1997, to achieve the KP-CP1 target and comprehensively advance concrete and effective measures for the prevention of global warming. The Prime Minster serves as the chef of the GWPH, and the ministers for the Environment (MOE) and the Economy, Trade and Industry (METI) serve as deputy chiefs.

Following the decision not to participate in the second commitment period of the Kyoto Protocol, the Act was amended to mandate both central and local governments to formulate the Plan for Global Warming Countermeasures from 2013. As previously mentioned, after the adoption of the Paris Agreement, in May 2016, the Cabinet approved the Plan for Global Warming Countermeasures which describes how Japan's INDC (2030 target) will be achieved. The Plan specified detailed actions that government entities, business sector and citizens shall take to achieve the 2030 target. The Plan emphasized the PDCA (plan-do-check-act) cycle to monitor the status of progress every year and the Plan will be revised, if necessary.

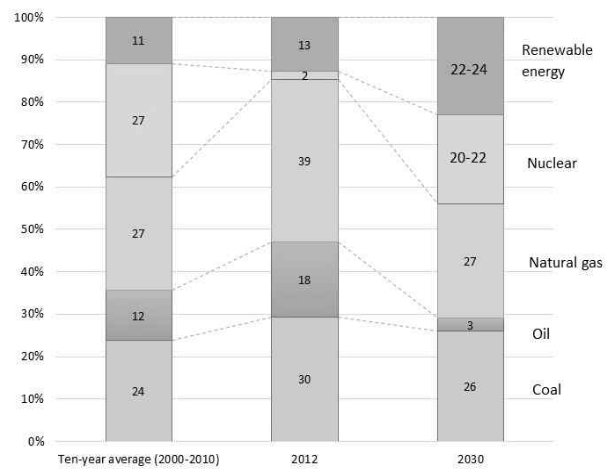
Another pillar of Japan's framework policies for tackling climate change is the Act Concerning the Rational Use of Energy (or Energy Conservation Act), which was enacted in 1979 and is the most comprehensive legislation on energy conservation. The Energy Conservation Act is significant from a climate change mitigation perspective for two reasons (Takamura, 2012). First, it covers energy-related CO_2 emissions, which account for about 90% of national GHG emissions. Second, it contains mandatory measures (for example, the requirement of energy management in industrial and commercial sectors, and energy efficiency standards for machinery and equipment including "Top Runner Standards" for electric appliances and vehicles, as well as for residential and commercial buildings), while most other energy and climate measures are not mandatory.

Regarding the long-term direction of policy, the Basic Act on Energy Policy of 2002 requires METI to develop the Basic Energy Plan. The Basic Energy Plan provides the general direction of national energy policy for the next two decades in line with three principles of "the 3Es+S": energy security, environmental protection, efficient supply and safety. The principle of "safety" was added after the Fukushima nuclear accident. The first Basic Energy Plan was developed in 2003 and revised in 2007, 2010 and 2014.

The 2014 Basic Energy Plan, which was formulated under the LDP-led government, stated that dependence on nuclear power would be reduced as much as possible in future, but called for a swift restart of existing nuclear power plants once the Nuclear Regulation Authority approves their safety. However, the 2014 Basic Energy Plan itself did not indicate the energy mix for 2030, since there was still uncertainty about the issue of nuclear power safety examinations, international climate negotiation, and the progress in the feed-in tariffs scheme. Instead, the Long-term Energy Supply and Demand Outlook of July 2015 indicated the energy mix for 2030, which in turn became the basis for bottom-up calculation of emissions reduction target for 2030 (METI, 2015).

Figure 3 presents power source mixes of ten-year average before the Fukushima nuclear accident, 2012, and 2030. The power source mix for 2030 seems well-balanced in terms of diversity of power sources. However, it would be unrealistic to expect that 20-23% of electricity could come from nuclear power, given the regulatory requirements and the current public sentiment against the re-operation of nuclear power plants (Wakiyama & Kuriyama, 2015). In addition, the validity and appropriateness for some key assumptions are debatable and may have resulted in an overestimation of baseline emission levels. One example is the assumption on future GDP growth; the compound average growth rate up to 2030 is assumed to be as high as 1.7% per year, which is consistent with the government's growth target, but most studies project lower rates, ranging at 0.3-1.6% per year (Kuramochi et al., 2015).

Figure 3. Power source ratios for 2000-2010, 2012, and 2030



Source: METI 2015

The Japanese government began to discuss its long-term low GHG emission development strategy (hereafter, long-term strategy) in Summer 2016. The Paris Agreement invites Parties to formulated and communicate their long-term strategies by 2020. In Japan, two different processes were established to discuss long-term vision under the MOE and METI, separately. While there is no official announcement as of writing, outputs from the two processes are expected to be merged and to become the basis for the Japan's long-term strategy.

3.2. Cross-sectoral Policies

The Global Warming Countermeasures Tax was introduced as a surtax on the existing upstream Petroleum and Coal Tax in October 2012. The tax rate began with JPY95/t-CO_2e in October 2012, and gradually increased to JPY 298/t-CO_2e in April 2016. While there are several exemptions such as imported coal used for the production of iron and steel, coke and cement and volatile oil feedstock for the production of petrochemical products, the Global Warming Tax covers domestic fossil fuel consumption equivalent to 80% of energy-related CO_2e emissions in FY2010 (Kuramochi, 2014).

The impact of the Global Warming Tax on CO_2 emissions reduction in 2020 is estimated to be around 6-24 Mt per year (0.5-2.2% of CO_2 emissions in 1990), of which 1.8 Mt per year results from a "price effect" (reduction in energy use through taxation) and 3.9-22 Mt per year results from a "budget effect" (reduction through the use of tax revenues for emissions reduction measures) (Kuramochi, 2014). The wide range of the expected budget effect means that it relies on how effectively the revenue is used. The tax revenue is used for promoting energy conservation, renewable energy, distributed generation, and innovative technologies, as well as promoting the JCM. Since the revenue from the Global Warming Tax is lumped together with that from the Petroleum and Coal Tax, however, it is not clear how large the budget effect is at this stage.

Regarding an economy-wide emissions trading scheme, the Japanese government has been considering it, but consensus has not yet been reached. To obtain experience and knowledge about a domestic emissions trading scheme, the MOE conducted a voluntary trial scheme, Japan Voluntary Emissions Trading Scheme (JVETS), which started in 2005 and ended in 2014. The Bill of the Basic Act on Global Warming Countermeasures, which was prepared by the DPJ-led government to realise the 25% target for 2020, stipulated the establishment of a domestic emissions trading scheme. The Bill was approved by the Cabinet for deliberation in the Diet in March 2010. The Bill passed the Lower House of the Diet, but was eventually scrapped following the dissolution of the Lower House in November 2012. Meanwhile, the Metropolitan of Tokyo introduced Japan's first mandatory cap-and-trade emissions trading scheme in April 2010, and Saitama Prefecture followed suit in April 2011. Despite these initiatives, the strong opposition from the Keidanren (Japan Business Federation) effectively hindered the introduction of the full-fledged, economy-wide emissions trading scheme. However, following the entry into force of the Paris Agreement, Minister of the Environment announced further deliberation on carbon pricing, including an emissions trading scheme, in November 2016[3].

3.3. Industrial Sector

Indirect emissions from the industrial sectors were 413 Mt-CO_2e, and accounted for 34% of total GHG emissions in FY2015 (excluding LULUCF). To achieve Japan's INDC, the industrial sector is required to reduce their emissions by 6.5% from 2013 levels by 2030. Its reduction requirement is not as large as other sectors, but the industrial sector is the biggest single sector in terms of CO_2 emissions.

3 Remarks at the Press Conference on 29 November 2016. <http://www.env.go.jp/annai/kaiken/h28/1129.html>

In 1997, just before the Kyoto Protocol was adopted, the Keidanren, the most influential industrial association in Japan, launched the Voluntary Action Plan on the Environment, which covered about 80% of energy-related CO_2 emissions from the energy conversion and industrial sectors. The Voluntary Action Plan aimed to reduce those sectors' five-year average CO_2 emissions during the period between FY2008 and FY2012 to below FY1990 levels. The Keidanren consists of several industrial associations such as the Federation of Electric Power Companies (FEPC), the Japan Iron and Steel Federation (JISF) and the Japan Cement Association, and each industrial association set its own voluntary target.

There were two main features in the Keidanren's Voluntary Action Plan. First, flexibility was given to each industrial association in choosing the form of target (either emission or energy, and either absolute or relative target). Second, despite the plan's "voluntary" nature, governmental involvement in implementation review is crucial (Rezessy & Bertoldi, 2005). Indeed, its progress was monitored under the Kyoto Protocol Achievement Plan. The Keidanren announced that the Voluntary Action Plan achieved 12.1% reduction from 1990 levels.

The Keidanren will continue this approach for the period up to 2030. In January 2013, it announced a new voluntary mitigation plan, Keidanren's Commitment to a Low Carbon Society (Phase I), which covered the period up to 2020, and in April 2015, the Commitment to a Low Carbon Society (Phase II), which will cover the period up to 2030. The Phase II Commitment is seen as a main vehicle for achieving indicative sectoral target for the industrial sector under Japan's INDC, i.e., 6.5% reduction from 2013 levels by 2030. Like the Voluntary Action Plan, each industrial association set its own voluntary target for 2020 and 2030. For example, the JSIF's voluntary reduction targets for 2020 and 2030 are 500 and 900 Mt-CO_2e from business-as-usual (BAU) emissions, respectively. The Japan Cement Association's energy intensity targets for 2020 and 2030 are to reduce 39 MJ/t-cem, and 49 MJ/t-cem from 2010 levels, respectively.

3.4. Power Sector

Direct emissions from the power sector were 480 Mt-CO_2e and accounted for 39% of total GHG emissions in FY2015 (excluding LULUCF). CO_2 emissions from the power sector increased by around 43% from 1990 levels.

Given the tight electricity supply and demand in the wake of the Fukushima nuclear accident and trends toward a liberalised electricity market, there are many plans to replace or build new coal- and gas-fired power plants (18 GW of coal-fired power plants and 29 GW of gas-fired power plants). Against this background, METI and the MOE requested electric power companies to establish a voluntary framework to reduce CO_2 emissions. In respond to this request, in July 2015, the FEPC and other power companies released the Electricity Sector's Commitment to a Low Carbon Society which contained an emission intensity target of 0.37 kgCO_2/kWh, and also launched the Voluntary Framework toward reducing CO_2 emissions. Furthermore, in February 2016, the FEPC announced the institutional arrangement of the Voluntary Framework, including the creation of the Electric Power Council for a Low Carbon Society of which mission is to monitor members' activities and promote the PDCA cycle to mitigate CO_2 emissions.

In addition, METI and the MOE also provided policy measures which support the electricity sector's voluntary framework to achieve 0.37 kgCO_2/kWh. In accordance with the Energy Conservation Act, power producers are requested to meet two kinds of benchmarks: one is the average heat efficiency (44.3%) for all power generating facilities owned; the other is fuel-type-specific heat efficiency for power generating facilities. Regarding the latter, the heat efficiency for newly constructed coal-fired power plants is set at 42% (equivalent to ultra-supercritical (USC)) and for gas-fired power plants at 50.5% (equivalent to gas turbine combined cycle (GTCC)). The heat efficiency for existing power plants is 41% for coal-fired, 48% for gas-fired and 39% for oil-fired power plants, which were determined according to a list of best available technologies.

The share of non-fossil fuel power sources, including renewable energy and nuclear power, should also be in consistent with the 2030 energy mix. For all power retailers with generating capacity of more than 500 million kWh annually, 44% of electricity should come from non-fossil fuel sources pursuant to the Law Concerning Sophisticated Methods of Energy Supply Structures.

The MOE will evaluate the status of progress on the voluntary actions by power producers, including the capacity of power plants and CO_2 emission intensity of generated electricity based upon the information delivered by METI.

Despite the voluntary framework and the supporting policies measures, there still remain challenges to meet the emission intensity target of the power sector. Although the voluntary framework sets out how power producers are to develop plans and fulfil action via PDCA, no details of how individual power producers contribute to the overall target are given. Furthermore, the supporting policy measures (the Energy Conservation Act and the Law Concerning Sophisticated Methods) require power producers and retailers to make efforts to meet the requirements, but they are not mandatory. Judging from past experience on the Energy Conservation Act's benchmarking practices, it does not necessarily follow that power producers will comply with them. As of 2015, only about half of all the benchmarks in 10 areas covering six industries including the electricity supply industry) were achieved, and none of the 11 electricity companies had achieved the benchmark for the electricity supply industry.

Assuming all thermal power plants currently planned for construction and replacement are put into operation and all thermal power plants exceeding 40-year lifespan retire, coal-fired and gas-fired power plants need to operate below 56% and 43%, respectively, of their capacity factor in order to achieve the sector-wide emission intensity target of 0.37 $kgCO_2/kWh$ (Kuriyama & Tamura, 2016). Such low capacity factors would deteriorate the profitability, in particular, of coal-fired power plants since they are commonly operated at a capacity factor of 70-80%. Otherwise, the existing power plants need to retire before 40 years of operation. Is it still not clear how the voluntary framework and the associated policy measures could ensure such earlier retirement of the existing thermal power plants.

The Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities (Renewable Energy Act), which passed the Diet in August 2011 and was enacted in July 2012, is one of the successful pieces of legislation on renewable energy promotion (Kuramochi, 2014). The Renewable Energy Act introduced a feed-in tariff system for renewable energy. The Act requires electric utilities operators to purchase all the electricity generated by renewable energy sources (solar, onshore wind, geothermal biomass and hydro smaller than 30 MW at the start of the scheme, and offshore wind from April 2014) at fixed tariff rates for 20 years. Electric power utilities collect surcharges from electricity users to the costs of purchasing renewable energy-source electricity. The FIT scheme actually boosted renewable energy installation, in particular solar PV due the high tariff rate (JPY42/kWh for 20 years at the start of the scheme), which was among the highest in the world (WWF Japan, 2012). In 2015, 10 GW of solar PV was installed.

Tariff rates were revised several times in order to control the increasing procurement cost, adjust for the declining PV module price and achieve a more balanced deployment of renewable energy sources (see Table 1).

Table 1. Changes in purchasing prices of renewable energy sourced electricity

Fiscal Year	Solar PV		Wind	Geothermal	Hydro		Biomass	
	Residential	Commercial						
2012	42	40	22	26	24		24	
2013	38	36	22	26	24		24	
2014	37	32	22	26	24		24	
2015	33	27	22	26	24		24	
2016	31	24	22	26	24		24	
2017	28	21	21	26	20	27	21	24
2018	26	Bidding	20	26	20	27	21	24
2019	24	Bidding	19	26	20	27	21	24

Unit: Japanese Yen/kWh

Source: Nikkei 14 December 2016

Notes: Residential solar PV is less than 10 kW. Commercial solar PV is less than 2,000 kW. Wind is large on-shore wind. Geothermal is also large geothermal power plants. Regarding hydro and biomass power plants, after FY2017 new categories will be introduced: large (left row) and small (right row) in terms of generation capacity.

3.5. Transportation Sector

Indirect emissions from the transport sectors were 216 Mt-CO_2e, and accounted for 18% of total GHG emissions in FY2015 (excluding LULUCF). To achieve Japan's INDC, the transport sector is required to reduce their emissions by 28% from 2013 levels by 2030.

The Plan for Global Warming Countermeasures of 2016 states that the share of highly energy-efficient next-generation vehicles (hybrid vehicles, electric vehicles, plug-in hybrids, fuel-cell vehicles, clean diesel vehicles and compressed natural gas vehicles) in the new car sales will be in a range from 50% to 70% by 2030. Tax breaks and subsidies, albeit not explicitly designed to reduce CO_2 emissions, are expected to increase the share of the next-generation vehicles. These tax breaks and subsidies were traced back to 2009, and various tax breaks and subsidies for more environmentally friendly vehicles were available and are expected to continue. Next-generation vehicles accounted for 23.3% of new car sales in 2013 as opposed to only 3% in 2008[4].

In addition, the Plan indicated that the government will support bulk purchases of the next-generation vehicles, in particular heavy duty trucks and buses. For deployment of EVs and PHVs, R&D to extend a cruising range will be supported. For further promotion of FCVs, which were in the market in 2015, hydrogen infrastructure will be expanded and supported, and the revision of related regulations is expected.

3.6. Residential and Commercial Sectors

Indirect emissions from the commercial and residential sectors were 249 Mt-CO_2e and 198 Mt-CO_2, and together accounted for 35% of total GHG emissions in FY2015 (excluding LULUCF). To achieve Japan's INDC, the residential and commercial sectors are required to reduce their

4 See Grantham Research Institute on Climate Change and the Environment, the Global Climate Legislation Study, Japan, <http://www.lse.ac.uk/GranthamInstitute/legislation/countries/japan/>

emissions by 40% from 2013 levels by 2030. Therefore, the progress in these sectors is essential for achieving the INDC.

Improvement in energy efficiency of building and houses is a key pillar of mitigation initiatives in the commercial and residential sectors. There is a roadmap to mandate compliance for new buildings with thermal insulation performance standards in a phased manner by 2020. Another example is the promotion of “Net Zero Energy Buildings and Houses (ZEB/ZEH)” which achieve a net zero or almost zero annual primary energy consumption through various energy-saving measures and by using renewable energy onsite. By 2020, the average net energy consumption of newly built public buildings plans to be zero, and the average new energy consumption of all new buildings plans to be zero by 2030. More than half of newly-built custom houses all newly built buildings are expected to ZEH by 2020.

Deployment of highly efficient equipment and products is another key pillar of mitigation initiatives in the commercial and residential sectors. By FY2015, 28 items of machinery and equipment that consume energy are subject to the Top Runner Standards. In FY2016 incandescent lamp was newly added to the Top Runner Standards in order to achieve the phase-out of incandescent lamp production by 2020 and the replacement of all the installed incandescent lamp by LED by 2030. The 2013 amendment of the Energy Conservation Act added building materials such as windows and insulation materials to the Top Runner Standards. The Japanese government also aims for introducing 1.4 million units of household fuel-cell CHP (combined heat and power) in 2020 and 5.3 million units in 2030.

The implementation of energy management is also expected to play a pivotal role in mitigation CO_2 emissions from the commercial and residential sectors. The government plans to install the Building Energy Management System (BEMS) and the Home Energy Management System (HEMS) to all commercial buildings and residential houses by 2030.

4. Conclusions

This paper presented the latest trends of Japan’s national and sectoral GHG emissions, as well as an overview of the landscape of climate mitigation policy. Following the adoption of the Paris Agreement, the Japanese government announced the Plan for Global Warming Countermeasures which provided a comprehensive package of policies and measures to achieve Japan’s INDC. The Plan also contains timelines for deployment of specific energy efficient products and equipment up to 2030. Furthermore, the Plan stipulated the 2050 target of reducing emissions by 80%. Though its base year is not specified, it is the critical step forward that the overall direction of mitigation policy was determined.

However, there is no reference to net-zero emissions or de-carbonisation of the Japanese socio-economy in the Plan for Global Warming Countermeasures. It is necessary to reduce net global CO_2 emissions to zero as soon as possible in the second half of the 21^{st} century in order to stabilise global temperatures at warming thresholds of 1.5 °C and 2 °C—the Paris Agreement’s long-term temperature goal (Rogelj et al., 2015). The 2020/2030 targets need to be regarded as stepping stones to the 80% reduction in 2050, and the 2050 goal also needs to be seen as a milestone toward net-zero emission, not as a final destination. Thus, the PDCA cycle of the Plan for Global Warming Countermeasures should not be designed only to achieve the 2030 target, but rather to achieve the 2050 goal and beyond. Perhaps, the long-term strategy, which is currently under discussion, is expected to play such a role.

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Science and Technology Trends
Greenhouse Gas Reduction and Climate Change

Greenhouse Gas Reduction and Climate Change: Indonesia's Story

Syamsidar Thamrin

1. Background

Indonesia is one of the countries that are most vulnerable to the negative impacts of climate change. Many global climate change model such as the Global Circulation Model (GCM) have predicted that Indonesia will experience an increase in temperature, intensity of rainfall that will increase the risk of floods and droughts, and extend dry seasons. As an anticipation, the Government has implemented various endeavors to adapt to climate change. This effort for adaptation has been reflected in various sectoral project implementation such as the construction of 65 new dams until 2019, improving our climate and weather monitoring system, climate insurance for farmers and fishermen. These actions are harmonised and operated based on the National Action Plan for Climate Change Adaptation (RAN-API) released in 2014. However, on the other hand, mitigation has started earlier compare to adaptation with more efforts and has received more attention especially from the global community. This paper will be focus more on the mitigation efforts both policies and programs in Indonesia.

Looking back, for Indonesia, hosting COP 13 in Bali in 2007 was a real moment to create momentum in raising awareness of climate change issue and getting people's, and especially government, attention. As it can be seen, a series of interesting experiences and policies took place in the wake of this momentum, such as creation of National Council for climate change (DNPI), Indonesia Climate Change Sectoral Roadmap (ICCSR), Indonesia Climate Change Trust Fund (ICCTF), Presidential Decree for National Mitigation Action Plan (RAN-GRK) and for GHG Inventory, REDD+ Agency and similar unit at local level. However, since the new president, Joko Widodo, took office in 2015, some of those no longer exist: DNPI and REDD+ Agency were dissolved and Ministry of Environment and Forestry (as a result of merger between Ministry of Environment and Ministry of Forestry) took back the role of DNPI and REDD+ Agency.

Since 2008, the Ministry of National Development Planning (Bappenas) started its effort to develop the Indonesia Climate Change Sectoral

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Roadmap (ICCSR) launched in 2010, which means providing inputs for the 5 year Medium-Term Development Plan (RPJM) 2010-2014, and also for the subsequent medium term development plans until 2030. The ICCSR places particular emphasis on the challenges within the forestry, energy, transportation, industry, waste, agriculture, coastal area, water and health sectors. It aims to address these challenges through effective development planning and coordination between the work of all governmental ministries, local governments, private companies and communities. To this end, the climate change sectoral roadmap established a comprehensive framework of mitigation and adaptation actions in Indonesia for the next 20 years (2010-2029).

2. National Mitigation Action Plan (RAN-GRK)

Many believe that the most important reference for current climate change policy in Indonesia is the Copenhagen pledge in the context of the UNFCCC´s pre-2020 phase. The country committed to emission reductions by 26% and up to 41% in 2020, depends on the availability of external funding support. The pledge was used as reference for ICCSR and later operationalised through the National Mitigation Action Plan (RAN-GRK) and Local Mitigation Action Plan (RAD-GRK), based on presidential decree number 61 year 2011 (RAN-GRK, 2011). Indonesia's Copenhagen pledge and the RAN/RAD-GRK set a policy-based absolute emission reduction target based on a Business as Usual (BAU) scenario. The original pledge of 26% GHG reduction needed specification, hence, the RAN/RAD-GRK operationalised the pledge in a well-defined manner. It tied the pledge to the national policy framework and translated the percentage-goal into an absolute amount of targeted GHG reduction (namely 0.767 $GtCO_2e$.). It broke down the target by sectors and regions, and established a monitoring scheme to evaluate the target.

Since Indonesia has applied a strong decentralization policy, some authority were already delegated to local governments, so for climate change policy to be successfully implemented, the involvement of the local governments became more and more important. Therefore, even though in terms of number ton CO_2 achievement so far from RAD-GRK still far below RAN-GRK (RAN-GRK, 2016), but to make RAN-GRK successful, it needs not only sectoral ministries' support but also local governments', too.

At the highest level, the government has demonstrated willingness to tackle climate change. The Government Indonesia, among the first developing countries that commit to GHG reduction, sought to play a leading role in contributing to a sustainable world economy. Indonesia has been pleased that the Bali roadmap COP 13, has finally achieved the objectives to establish a global agreement, albeit 9 years later in Paris.

During the Paris summit, COP 21, the current President, Joko Widodo committed to a reduction of 29% from Business as Usual (BAU) baseline in 2030, while aiming for 41% in cooperation with our development partners[1]. The projected reduction levels will rise to at least 2.88 billion tons of carbon dioxide in 2030[2]. From revised BAU baseline, 29 percent reduction would lower that by 835 million tons CO_2eq. Indonesia make sure that its climate change mitigation target (INDC) is aligned with its National Development Agenda and Commitment

1 In 2010, Government of Indonesia through "Jakarta Commitment" prefer to call international organization/foreign countries as "development partner" instead of "donor" to emphasize that the external support should inline with Indonesia's development's objectives.

2 RAN-GRK targets were based on the emission trend at Indonesia Second National Communication while INDC used revised BAU Baseline from RAN-GRK Review process.

of Government's Medium Term of National Development Planning (RPJMN) 2015-2019 as well the Sustainable Development Goals (SDGs) as agreed at United Nation General Assembly (UNGA) meeting in 2015.

In addition to the National Mitigation Action Plan (RAN-GRK) and RAN/RAD-GRK, the national REDD+ strategy is defined as another crucial programme and mitigation instrument for Indonesia. In 2010, Indonesia and Norway signed a Letter of Intent where Norway pledged to provide a grant for Indonesia in the amount of USD 1 billion for REDD+ program. This fund is to support Indonesia cutting emissions from deforestation and forest degradation activities, has created further stimulus for a more comprehensive legal response towards climate change in forestry sector. Soon after, Indonesia set up REDD+ agency to coordinate this effort. However, despite the country's active legislative response, enforcement and land tenure issues continue to be national main challenges when it comes to deforestation, the country's main source of emissions.

In relation to the function of RAN-GRK, there are several overlaps between the various ongoing mitigation workstreams especially REDD+ since RAN/RAD-GRK talking about landbased sector, including forestry. Therefore, a better synergy is expected to create reliable results between RAN/RAD-GRK and REDD+. After 4 years, it was dissolved, the output of REDD+ agency that is still used until now is the initiative of the one map and one data policy where finally agreed that one institution for the source of official data. For the spatial data, Geospatial Board (BIG) acts as the coordinating body, so all government institution should submit their spatial data to BIG. Then, the map published by BIG will be the official map of Indonesia for all types of land. Then, for non-spatial data, the statistic bureau will be the center and source of the official data.

In response to the need of landbased sector and an improvement to the tools for monitoring and evaluation of RAN/RAD-GRK, Bappenas has improved the PEP[3] system from RAN/RAD-GRK program for monitoring and reporting of RAN-GRK not only about statistical data but also spatial data. Therefore, the location where the activities have taken place is very important information. These data and information will be very important for Indonesia to fulfil its obligation to UNFCCC related to Biannual Update Report (BUR), global stocktakes and related to transparency issues.

The Climate Change Council (DNPI) was formed in 2008 by 17 Ministers and chaired by the President to co-ordinate climate change policies and international positions, including the creation of a cap-and-trade mechanism. The DNPI aimed to increase the effectiveness of coordination between Line-ministries due to the complexity of climate change related issues and cross-sectoral issues. However, this type of ad-hoc team has proven to be not very effective since the implementation depends so much on sectoral ministries and most of the ministers barely had time to attend DNPI meetings. As a result, this new experiment to set up a new institution to create an effective coordination was considered a failure and costly to the country because the expected outputs could not be achieved after 4 years and the country already paid for running of new offices.

While the Ministry of Environment has concentrated on GHG inventory and MRV rules and procedures, the Ministry of National Development Planning (BAPPENAS)[4] launched the Indonesia Climate Change Trust Fund (ICCTF)

3 PEP: Pemantauan Evaluasi dan Pelaporan, the jargon in Indonesian language used for monitoring and Evaluation for RAN/RAD-GRK.

4 BAPPENAS is always persistent on mainstreaming climate change into development agenda and always see climate change as co-benefit of development programs, not as separate one.

in 2009. The two ministries in the beginning seems working effectively together, but in 2016, Ministry of Environment and Forestry has started some new concept such as a new environment financing institution, a National Registry etc. which need to be seen the synergy with the existing institutions and earlier initiatives by others ministries since there are overlaps in scope and objectives.

The ICCTF aims to exercise direct access scheme from international source of funding and scale up financing by seeking to develop innovative links between international finance and domestic investment. Until today, ICCTF is the only financing institution dedicated solely for climate change in Indonesia. ICCTF continue to work on the institutional development and on the private public partnership approach. Even though, ICCTF has been working on the peatland and community forest, but until now still shy away from REDD+ projects.

3. NAMA Development in Indonesia

Nationally Appropriate Mitigation Action (NAMA) in Indonesia is relatively well accepted since it developed under RAN-GRK framework. NAMA gives clear guidance for developing policies, programmes and activities that could be accepted as mitigation actions. NAMA proposals should show the baseline on how many tons of CO_2 could be avoided, transformational impacts and potential up-scaling. There are almost 20 NAMA proposals being developed since 2009. Out of these 20 proposals, two are registered at UNFCCC secretariat and five proposals have successfully received funding. Therefore, experience of developing NAMAs has provided Indonesia a lot of technical expertise needed to improve the quality of its mitigation policy concept.

For Mitigation Action Plan, both on National and Local Levels, requires extensive capacity building, since a lot of scientific and technical calculations will be involved. Bappenas has published the technical guidelines for those calculations that could be used for line-ministries and local governments in reporting the results of national and local mitigation action plans. To support all the technical works related to RAN/RAD-GRK, Bappenas set up the RAN-GRK secretariat in 2012 which is assigned as: (1) information hub for all the stakeholders when need information related to mitigation; (2) help-desk for local governments to calculate baseline, result of implementation of mitigation activities, and liaison between stakeholders. Furthermore, Bappenas also provide special support fund for provincial governments (around $ 100K per province per year) for capacity building activities. At least twice per year, there are capacity building programs conducted for developing the local mitigation action plan and monitoring reports of the implementation. In addition, there are smaller gatherings at province level to learn the technical calculations more intensively. Almost all the provinces have also conducted capacity building for district and city governments, some province governments even put additional budget as co-financing.

Although challenges and possible improvements such as effort on tackling forest fire accident and capacity building on greenhouse gas emissions monitoring and measurement still exist, the first phase of monitoring and evaluation reports for 2010-2013 (RAN-GRK, 2016) showed that mitigation efforts are well under away as also stated at Mid-Term Development (RPJM) 2015-2019 which show Indonesia already achieve around 14% of its 2020 target and use this number as baseline for the RPJM. However, this estimate was made before the big forest fires in 2015.

4. INDC Development Process

While related to 2030 targets, it started with the reviewing process[5] of RAN-GRK based on the evaluation result of the baseline, sectoral targets and activities proposed to reduce emission, which are also the required data/information for INDC. Therefore, INDC development could go hand-in-hand with the RAN-GRK review. As a result, in INDC development part of RAN-GRK review process, Indonesia already inclusively involve all the stakeholders, especially government institutions. The process was designed in an efficient way using the same team with RAN-GRK and the existing institutional arrangement working with mostly Indonesian experts, leading to credible political decisions (RAN-GRK, 2015), by using existing material without creating an additional burden, and certainty of long-term institutional arrangements that can also be useful for a future implementation phase.

The system dynamic model that developed by the RAN-GRK team (which members coming from line ministries) and supported by modelers from Bandung Institute of Technology (ITB) for INDC (RAN-GRK, 2015) shows that even though forestry sector is still the major source of emission, after 2020 the energy sector will outpace it and become the highest source of emission in Indonesia. This shift should also change the long-term approach to tackle emission reduction in Indonesia. Therefore, Indonesia will start looking for the proper technologies to reduce GHG emission, especially in energy related sectors because the challenges are pretty huge.

In addition, the National Energy Policy (KEN) adopted in 2014 states that Indonesia should "reach" 100% electrification ratio by 2020 and 23% renewable energy in 2025. Meanwhile, the 2015-2019 Medium Term Development Plan (RPJM) puts forward a target electrification ratio of 96.6% by the end of 2019. All these targets were committed by Indonesia domestically before announcing its commitment to the Paris Agreement. In the other hand, achieving these development targets means also achieving its INDC. As a result, speed up and strengthen implementations of the development programs/activities automatically put Indonesia on ambitious track to achieve its INDC.

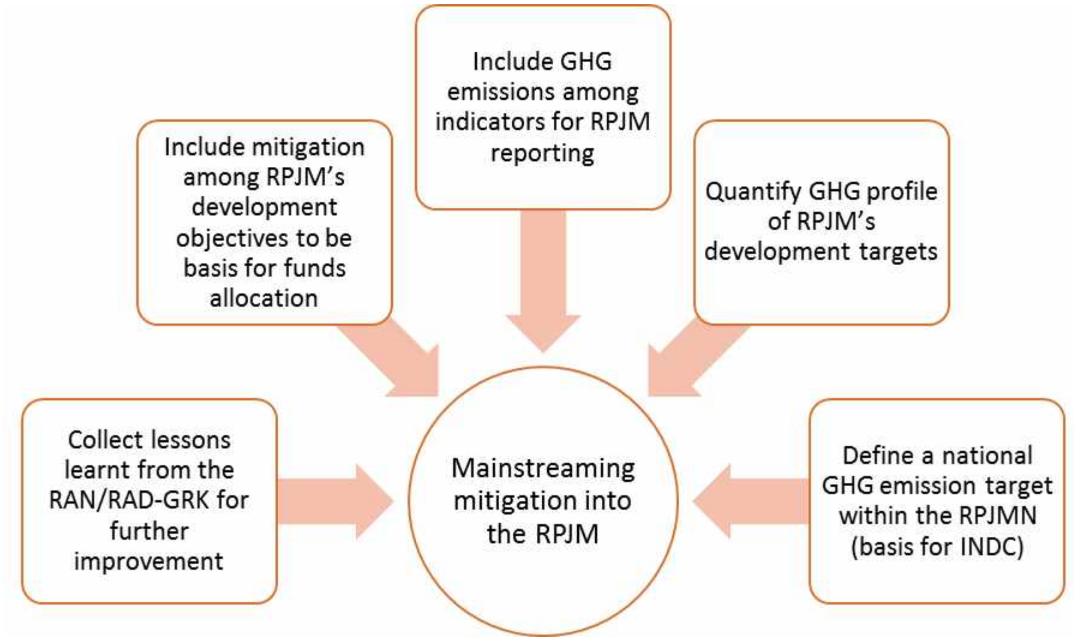
After parliament ratifying the Paris Agreement before COP 22 in Marrakesh, 2016, Indonesia submitted the long-term 2030 emission target—known as the Indonesian National Determined Contribution (NDC)—which aims to explain more details on policies, data, information and assumption used to calculate its INDC's target before. However, this NDC submission even takes times for preparation and but still needs to contain more information for people to understand how Indonesia will achieve the 2030 targets. This leads to remaining homework to accomplish the 2030's target through sound investment strategies for the implementation of mitigation action plans.

Indonesia's challenge for electrification program

Being an archipelago nation of some 17.000 islands, spanning more than 5.000 km, by the end of 2014 Indonesia has attained an 84% electrification ratio. In the last 10 years alone, the state utility has managed to connect 20 million new households, or some 78 million people. However, the approaches to electrification that have served so well in the past are increasingly ill-suited to condition Indonesia now faces to connect the remaining 16% of its population, representing some 40 million people. In addition, Indonesia needs to cope with an increasing population and hence an increasing energy demand. Given the socio-economic benefits of electrification, the Indonesian Government plans to continue along this path.

5 An approach for building on lessons learned is being developed with the imminent review in 2015 and it remains to be seen to which extent these lessons learned can be basis for prioritizing actions going forward.

Figure 1. Mainstreaming mitigation into the Medium Term Development 2015-2019 (RPJM)



5. Sustainable Development and Climate Change Policy

All these mitigation efforts are put under the umbrella policy of green economy or sustainable development by Bappenas. In the National Medium Term Development Plan for 2015-2019 (RPJMN 2015-2019), the green economy is identified as the foundation of the country's development programme, with the emphasis on "inclusive and sustainable growth, increasing value added of natural resources with the sustainable approach, increasing quality of environment, disaster mitigation and tackling climate change." Therefore, Indonesia will use the SDGs also as an umbrella policy for climate change including NDC.

6. Steps towards Mainstreaming Mitigation into the RPJMN's Development Framework

RAN-GRK already mainstream into RPJM 2015-2019 [6] (RAN-GRK, 2015). The submission process behind the establishment of the RAN/RAD GRK is made for its close alignment with the framework provided by the RPJM (RAN-GRK, 2011). The line ministries and the provinces drew on their existing planning as per the RPJM for designing actions that could be included in the RAN/RAD-GRK. Nonetheless, there is at least anecdotal evidence of how the target achievement in the RAN/RAD GRK exceeds the expectations set by the RPJM–government real spending for climate change 2010-2014 is much higher than

6 In addition, the RPJM where climate change is discussed also related to the aims to support the development of green cities; developing rural and remote areas with special attention on border areas, disadvantaged regions, transmigration areas, and small islands; eradicate illegal logging, fishing and mining; improve governance in natural resources and increase community participation in forest management; and increase community resilience to climate change impacts in 15 vulnerable areas defined in the National Adaptation Action Plan on Climate Change (RAN-API).

original plan[7]. Quantifying such achievements would make a good case for how the RAN/RAD GRK leveraged additional action. It is expected that Indonesia will consistently mainstream the (I)NDC into its mid-term development plans until the all the target achieved in 2030 and beyond.

7. What's Next for Indonesia

Donor funding for RAN/RAD-GRK is so far only at a testing phase, mostly only for capacity building activities[8]. Few actions have been developed as so-called supported NAMAs, until now only two get direct support for implementations–SUTRI NAMA and Cement NAMA. But there has not yet been a broad influx of donor funding. Continued improvement of the RAN/RAD-GRK structure might enhance transparent and effective results-based action planning and also contribute to enhancing its attractiveness for donor investments–not only in terms of its individual actions, but also in terms of the RAN/RAD-GRK itself.

The development of the RPJMN 2020-2024 is an opportunity to fully mainstream mitigation objectives related to achievement of NDC targets. From the NAMA process experiences, Indonesia has obtained a lot of technical knowledge and inclusive involvement that contributed during the "INDC readiness phase" from 2015 until 2019 and beyond. This would involve mitigation among the development key objectives, ultimately to be a criterion for funds allocation.

Related to this, indicators for RPJMN reporting would need to take on GHG emissions. This could be operationalised through using modelling approach that would quantify the RPJMN's development targets in terms of their GHG emissions. Such a quantification of GHG implications of the national development targets would also be the best basis in defining a national GHG emissions target–and, related to this, an (I)NDC for Indonesia.

Even though, domestic funding will be the main source of funding, but certainly Indonesia still need support from international sources to extend its efforts to mitigate and adapt to the negative of climate change. Therefore, still in Indonesia's agenda to pursue further to strengthen the current financing mechanism established under the UNFCCC such Green Climate Fund (GCF) and immediately realizing the committment of developed countries through climate finance schemes.

Acknowledgements

I would like to acknowledge the helpful comments from my colleagues from RAN-GRK Secretariat and from Heiner Von Luepke on earlier drafts.

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Science and Technology Trends
Greenhouse Gas Reduction and Climate Change

Greenhouse Gas Reduction Options: Towards a Climate Control Roadmap for Malaysia

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1. Introduction

It is generally acknowledged that greenhouse gas (GHGs) emissions into the atmosphere is the prime cause of climate related seasonal variations in temperature across planet (IPCC, 2007, 2011; Hansen et al., 2006; Nordhaus, 2008; Stern, 2007), which if allowed unabated shall destroy human civilization. Among the consequences of such a deleterious development is rising temperatures. Mean global atmospheric temperature rose by 14.1 °C over the period 1900-2015 (NASA, 2015). While projections on climate change have continued to grow, there is mounting evidence that climatic damage as a consequence of human activity is increasing the globe's vulnerability (Aldy, Barrett, & Stavins, 2003; Beckerman & Hepburn, 2007; Carter et al., 2006; Füssel, Toth, van Minnen, & Kaspar, 2003; JRC, 2013). Although global warming, particularly its potential speed and degree is still disputed as climatic consequences are affected by periods, country-based specificities (Keith, 2000; Kelly & Kolstad, 1999; Schimmelpfennig, 1996), that mean temperatures and sea water levels are rising is undeniable (Stern, 2007; IPCC, 2007; Bonfils et al., 2008; McKibbin & Wilcoxen, 2002; Nordhaus, 2001; Oreskes, 2004).

The direct impact of temperature rise and global warming are associated with climate change, including the deprivation of natural possessions, harm to national infrastructures and surroundings, health hazards facing humans, and devastation to the global economy (Al-Amin & Leal Filho, 2014). Current projections of climate change and global warming identify the significance of environmental eminence and sustainable economic development, which has encouraged efforts to set up an equilibrium between environmental excellence and economic expansion. Governments recognize this information and that is why 195 members of the United Nations signed the Paris Declaration in 2015 to cap temperature rise to 1.5 over the period 2010-2100 (UNFCCC, 2015). Thus, it is apparent that if existing human activity is left unregulated, temperatures would rise over the next century to between 3.0 °C and 4.0 °C, which almost certainly will elevate the earth's vulnerability to climatic catastrophes (Carter et al., 2006; IPCC, 2007; Nordhaus, 2008; Weitzman, 2007).

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However, several countries are struggling to introduce and maintain a vigorous balance between ecological order and sustainable economic development. These countries require the right instruments for economic investigation to envisage, prepare, and evaluate alternative methods taking account of their specificities, as well as the funds to execute them (Nordhaus, 2008; Stern, 2007)[1]. Indeed, developing countries are lagging behind in putting together strategies to meet sustainable climate emission thresholds, and hence, have not managed to follow the stiff milestones required to meet the goals of the Paris Declaration (UNFCCC, 2015), which include carbon cutbacks, and substitution of fossil fuels with renewable sources of energy, and introduction of backstop technologies.

Being an upper middle income country, Malaysia is no exception. While the INDC was developed through participatory process under an inter-ministerial/agencies working group, which brought 20 national policies in the remit, the stakeholder consultation group realized that there exists major barriers over their implementation, including high costs and capacity constraints. Malaysia developed “A Roadmap of Emissions Intensity Reduction in Malaysia in 2014,” which outlined opportunities across various sectors to meet the reduction target of 45% emissions intensity reduction of GDP as contained in the 11th Malaysia Plan. The major challenges facing the country are: unclear technology cost, fragmented institutional framework, LULUCF legacy status related to peat-land management, and the weak national adaptation plan. The country is under pressure to incorporate climate mitigation strategies into development, viz., in energy, industrial processes, water, waste management and agriculture (INDC, 2015).

Nevertheless, it is important to recognise that effective governance of climate mitigation is critical to meet the government’s ambition to meet its INDC targets. Moreover, Malaysia is considered a leader among the developing countries in meeting development targets. Malaysia’s total GHG emissions represent about 0.6% of global emissions in 2011. The emission intensity per GDP was 0.41 tCO_2eq/RM1000 for that year, which requires a reduction of about 23% from 2005 values (INDC, 2015). The total GHG emissions, including removals by LULUCF sinks is about 0.05% of global emissions. Through public and private sector initiatives, the country prioritising allocation of financial resources for the implementation of climate change programmes as since the Ninth Malaysia Plan (2006-2010), Malaysia has started initiatives to increase the share of use of non-fossil fuel energy. The climate-related policies are nationally implemented along with national priorities such as poverty eradication, improving quality of life and development.

While there is concern over climate change, including the surfacing of limits to growth arguments that claim that the world cannot absorb too much of economic expansion (which was originally advanced by Meadows et al. (1972)), Stern (2007) and Nordhaus (2008) have given us hope by providing convincing evidence that the solution lies with switching its propellants from environment unfriendly to environment-friendly energy. We analyze the greenhouse gas reduction target and abatement costs in this study under two scenarios compared to the no intervention scenario for Malaysia. The purpose is to offer alternatives that can assist Malaysia meet the objectives of the Paris Declaration, which is to cap temperature rise over the next century to 1.5 °C and follow-up with Marrakech initiatives to meet the emission reduction common strategies by the INDCs.

1 Two major economics of climate change projections are available, both of which are based on global options (Nordhaus, 2008; Stern, 2007).

2. Methodology

This study uses a multidisciplinary top-down dynamic model with a detailed description of the 'Climate and the Ecology' notions combining economic theory and earth science concepts, which is arguably the best method available to model emission changes in an economy at the aggregate level. The modelling starts with a detailed description of climatic variables that are deemed responsible for climate change and environmental damage with a focus on abatement costs, backstop technology, carbon concentration (e.g. ppm[2] under 900) over the next 100 years and temperature cap below 1.5 °C to analyse the long-run climate damage effects[3]. The study model considers three scenarios. The first is the business as usual scenario. The second uses Malaysia's INDC submitted to COP 21 with an update of COP 22 until 2030, and subsequent developments if no additional interventions are made to reduce carbon emissions further. The third scenario focuses on initiatives necessary to cap temperature rise to 1.5 °C over the century. Thus, fundamental variables, such as the rate of social time preference, initial growth rate of backstop technology, level of total factor productivity, marginal atmospheric retention rate, emissions-output ratio, and discount rate are used in order to visualize long-run effects. The model also considers population growth rate, capital stock, fossil fuel stock, and cumulative improvement of energy efficiency.

There are two major 'decision variables' in the 'Climate and the Economy' model that are considered, which represent: (a) rate for physical capital (*K(t)*) accumulation (e.g. equation 1) as a function of investment (*I(t)*) with depreciation rate (δ_k) to substitute with green growth in future, and (b) rate of emissions control in the production function, *Q(t)* (e.g. equation 2) with factor productivity, *A(t)* for GHGs over time with a damage, $\Omega(t)$ and abatement cost, $\Lambda(t)$ functions.

$$K(t) = I(t) + (1 - \delta_k)K(t-1) \qquad (1)$$

$$Q(t) = \Omega(t)[1 - \Lambda(t)]A(t)K(t)^{\gamma} L(t)^{1-\gamma} \qquad (2)$$

The two decision variables are closely linked with temperature limit over time (e.g. equations 3 and 4), carbon-saving and capital accumulation for green financing. Capital accumulation is endogenously determined by optimizing the flow of vulnerability over time and carbon-saving is endogenously linked with the abatement or alternative green technology adoption, and is modelled as reducing the ratio of carbon emission to the production process. Production is determined using CES and CET productivity functions, which takes the form of either carbon-based or non-carbon-based energy in output production ratio over the long run. However, technology substitution and abatement costs will fall over time as a consequence of the switch from carbon-based to non-carbon-based technologies as the conventional energy option would become expensive due to rigorous climatic policies.

$$T_{AT} = T_{AT}(t-1) + \zeta_1\{F(t) - \zeta_2 T_{AT}(t-1) - \zeta_3 T_{AT}(t-1) T_{LO}(t-1)\} \qquad (3)$$

$$T_{LO}(t) = T_{LO}(t-1) + \zeta_4\{T_{AT}(t-1) - T_{LO}(t-1)\} \qquad (4)$$

The model projects economic growth for Malaysia by considering national growth, investment in capital, marginal damage of climate change, marginal cost of controlling damage, and backstop technologies and abatement costs against related climatic effects and vulnerabilities based on three scenarios, viz., (a) climate change with no abatement (b) climate change under Malaysia's INDC committed to cop until 2030 but no further reduction in carbon emissions, and (c)

2 PPM refers to parts particulate matters.

3 This model runs using mathematical optimization with geometric algebraic modelling system (GAMS) programming.

concentrations below doubling rate over next 100 years targeted at meeting 1.5 °C temperature rise cap over the next century[4].

2.1. Study Area and Adoption of Empirical Downscaling

Malaysia is the study area with climate data obtained from the four locations of Kuching (Sarawak) and Kota Kinabalu (Sabah) in East Malaysia, and Kuantan (Pahang) and Petaling Jaya (Selangor) in West Malaysia (MMD, 2009), which are located at 1°25'0"N and 110°20'0"E, 5°58'50″N and 116°4'37″E, 3°48'0"N and 103°20'0"E and 3°5'0"N and 101°39'0"E respectively. The data used in this study abstracts from the global level to the local level through empirical downscaling exercise and applied using a national observational data set to predict the annual cycle of observed (a) temperatures and climate effects, (b) GHGs warming parameters, and (b) large-scale unforeseen climate shocks. The predicted annual cycle is downscaled and adjusted by considering (i) national emission, (ii) net damage, (iii) climate vulnerability, (iv) abatement cost, and (v) emission control[5]. The annual cycle of observed parameters of predicted variables (e.g. climate vulnerabilities with their likely impacts) and predictor variables (e.g. yearly average circulation parameters) are closely followed by the probability of unforeseen climate shocks in future.

2.2. Damage Considerations

The damage estimation in the 'Climate and the Economy' model assumes that climate changes are proportional to the output or national economic production process and polynomial functions of mean temperature fluctuation (e.g. equation 5). Aggregate climate change is a function of damages over time, and hence, it is a function ($\Omega(t)$) of climatic effects and fraction of output, climatic vulnerability parameters ($\psi 1$, $\psi 2$) and fluctuation of mean atmospheric temperatures (°C), TAT(t) from 1990. The climate change is estimated with tangible and intangible losses based on monetary value and the utility function with the GHG emission effects. Thus, moving intangible losses of climate change from the production function to the utility function shall enhance the prospects for sustainable economic growth. Lastly, climate change estimation is evaluated in this study after factoring in the emission reduction schedules contained in Malaysia's INDC for UNFCCC (2015)[6].

$$\Omega(t) = 1/[1+\psi_1 T_{AT}(t)+\psi_2 T_{AT}(t)^2] \qquad (5)$$

2.3. The Discount Rate and Social Preference

The 'Climate and the Economy' model uses the neoclassical economic growth theory assumptions where sustainable economic growth is optimized under the constraint of a discount rate (ρ) of 1.5% to translate future costs into present values. The discount rate over time (R(t)) is assessed in the present and future as goods and takes a monetary value (e.g. ringgit Malaysia (MYR)) with a net inflation rate of 3-4 per cent per annum (e.g. equation 6). The model is assumed to have a social preference of sustainable economic growth as defined by a social welfare function that ranks different paths of future growth that are constrained by both climate and economic relationships.

$$R(t) = (1+\rho)^{-t} \qquad (6)$$

4 The full details of the modeling equations and procedures are presented in Appendix 1.

5 The scenario assumed that neighbouring countries follow the recommendations on reducing carbon emissions made in COP agendas. Otherwise, the projections will be affected as the environment－being a global common－is permeable, and hence, emissions from the neighbours can diffuse into Malaysia.

6 A separate scenario using existing patterns of production to project climate damage over the period 2010–2105 can be found in Al-Amin et al. (2015).

2.4. Data

Two types of data are used in this study, viz., (a) macroeconomic data, and (b) climate and meteorological data. The macroeconomic data is derived from Malaysia's national accounts, including the Department of Statistics (DOS), and Economic Planning Unit (EPU) (DOS, 2010, 2013a, 2013b; Unit, 2010), while the climate and meteorological data are derived from Malaysia's Metrological Department (MMD) (MMD, 2009; 2015). Macroeconomic data from 2010 to 2015 is used to derive the macro baseline estimation in 2015, while meteorological data is based on two monsoons and four seasons from 1969 to 2007. National temperature fluctuations are derived from historical records from 1969 to 2015 to project changes in GHGs (280–927 parts per million (ppm)) concentrations to derive the climatic baseline 2015 [7].

The study also used for calibration:

(i) temperature fluctuations ranges between 0.8 °C and 1.5 °C

(ii) carbon concentration (CO_2) with a maximum limit of 650 ppm level of variations until 2050

(iii) maximum carbon concentration in upper and lower strata of 950 ppm

(iv) equilibrium temperature impact in the national level of 26 °C

(v) initial lower stratum temperature change of 0.8 °C

(vi) final atmospheric temperature change from 1900

(vii) optimal abatement costs from guidelines defined in IPCC (2007; 2011), Nordhaus (2008) and Stern (2007).

However, some modifications have been made to the data from MMD (2019, 2015), IPCC (2007; 2011), Nordhaus (2008) and Stern Review (2007) to meet the present scope of the study.

3. Results and Findings

This study examined three scenarios on climate change mitigation for Malaysia, namely, (a) baseline case with no climate control interventions (Scenario 1), (b) Malaysian INDC pledged to UNFCCC (2015) until 2030 (Scenario 2)[8], and (c) planned climate control intervention to cap global temperature rise to 1.5°C over the next century and carbon concentration to a maximum of 650 ppm from the 1990 level (Scenario 3). Figure 1 presents carbon emissions projections by the three scenarios over the years from 2010 to 2100. Scenario 1 indicates a rapid increase in carbon emissions from 188 million toe in 2010 to 248 million toe in 2050 and 419 million toe in 2100 with existing environmental practices (Scenario 1). Carbon emissions would decline from 188 million toe in 2010 to 112 million toe in 2050 and to 83 million toe in 2100 once Malaysia implements its climate change commitments to UNFCCC (2015) (Scenario 2).

The study finds that carbon emissions would fall from 188 million toe in 2010 to 163 million toe in 2050 and to 77 million toe in 2100 under the planned climate control framework (Scenario 3). However, the pace of emission reduction of the second and third scenarios are dissimilar, though the pace of the fall is almost similar. The findings indicate that the final outcomes in carbon emission reduction of scenarios second and third are close,

7 Details of the southwest monsoon and northeast monsoon that influences Malaysia's climate from May to September, and from November to February can be found in Al-Amin and Leal Filho (2014).

8 Malaysia planned to reduce greenhouse gas emissions intensity by 45% by 2030, 35% on an unconditional basis and a further 10% upon receipt of climate finance, technology transfer and capacity building from the developed countries (UNFCCC, 2015). Malaysia contributed 0.62% of global emissions with an average of 6.7 metric tons/person of carbon emission, which raised mean surface temperature by 0.14 to 0.25 °C every 10 years.

Figure 1. Carbon emissions, three scenarios

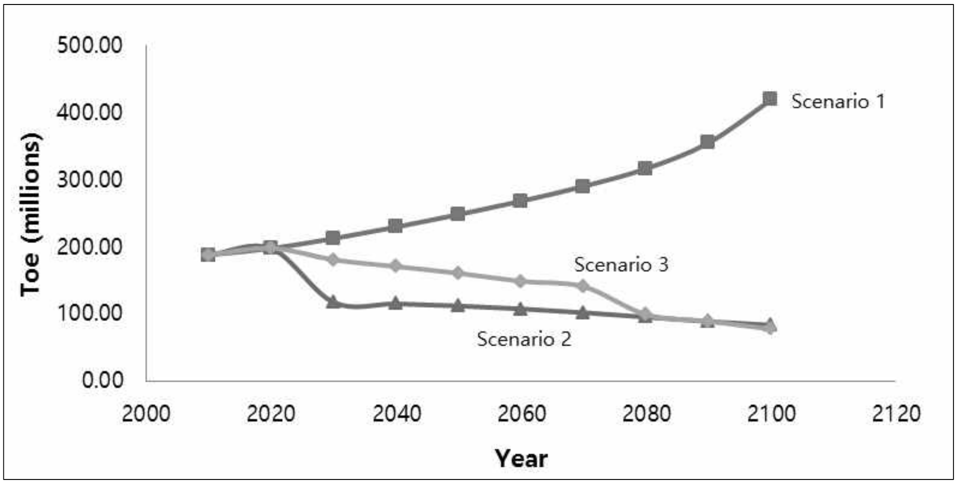
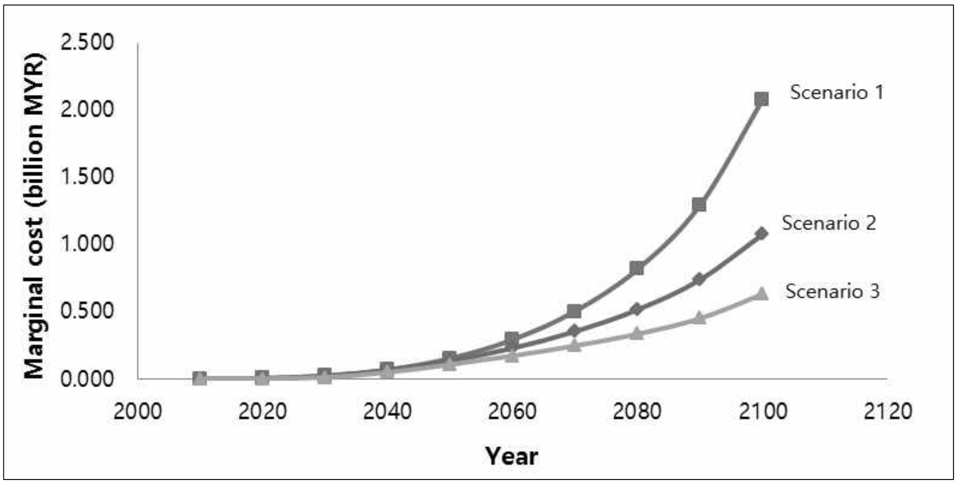


Figure 2. Marginal climate damage cost, three scenarios



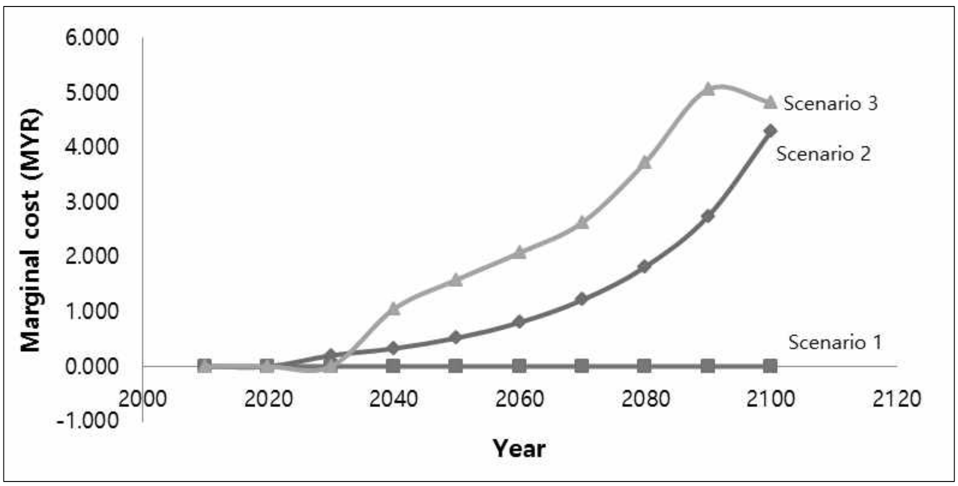
but the nature and emission fluctuations from 2020 to 2035 are quite dissimilar. The second scenario shows better emission reduction outcomes over the period 2030 to 2080, while the third scenario shows better outcomes over the period 2090 to 2100.

To understand better the second and third scenarios, the important sub-components of carbon emission reduction actions under various marginality conditions require evaluation. Figures 2, 3 and 4 present the sub-components of carbon emission reduction actions by marginal damage cost, marginal abatement cost and marginal control rate for the three scenarios over the period 2010-2100. The elasticity of the marginal utility of consumption with a pure rate of social time preference, discount factor, capital stock and investment projections are estimated to capture the relevant and real long-term projections. The marginality findings indicate differences in relative costs trends over the period 2010-2100.

Figure 2 shows marginal climate damage cost of the three scenarios from 2010 to 2100, which is estimated using temperature and carbon concentration cap. The marginal climate damage costs show that at each level of climate action higher additional costs are generated in the second scenario due to additional costs that will have to be borne to reduce of climate damage from 2020 to 2100. The costs in Scenario 2 increase faster than Scenario 3 after 2050 to almost double by 2100. Marginal climate damage cost is the highest in Scenario 1 followed by Scenario 2 and Scenario 3 over the period 2010-2100. The actual climatic damage cost will amount to MYR 14,257 million in Scenario 1, which will fall to MYR 3,789 million in Scenario 2 and MYR 1,407 million in Scenario 3. Thus, the marginal damage cost estimations indicate that the third scenario is more economic than the second scenario, particularly after 2050 onwards.

Figure 3 presents the marginal abatement cost under the three scenarios. The projections in Scenario 2 is based on emissions intensity falling by 45% by 2030 with the assumption that Malaysia will apply the latest greening technology with suitable preferences targeted at emission control with adequate climate change financing for the first 35% reduction in emissions, and capacity building support from the developed countries for the remaining 10% (UNFCCC, 2015). The findings indicate marginal abatement costs and relative outcomes for Scenarios 2 and 3 over the period 2010 to 2100. The marginal abatement cost from 2020 to 2025 and 2100 under Scenarios 2 and 3 are similar. However, the results are quite dissimilar from 2035 to 2090. Importantly, it shows that the abatement cost in Scenario 2 is relatively modest and there is relatively less increase in trend terms compared to Scenario 3. Thus, the marginal abatement costs of Scenario 2 shows the best outcome. The marginal abatement cost for Scenarios 1, 2 and 3 will be nil, MYR 12 million and MYR 21 million respectively. The total abatement costs[9] for Scenarios 1, 2 and 3 will then be nil, MYR 14,350 million, and MYR 14,645 million.

Figure 3. Marginal abatement costs, three scenarios



9 Total abatement cost is derived by multiplying the marginal abatement cost with cumulative damage measured in toes.

Figure 4. Marginal control rates, three scenarios

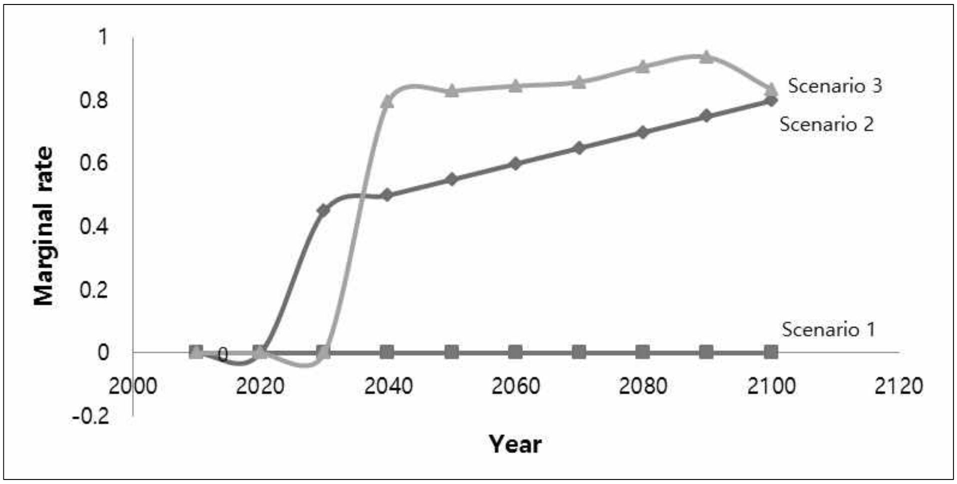


Figure 4 presents the marginal control rate from 2010 to 2100 under the three scenarios. The findings indicate similar marginal control rates in both Scenarios 2 and 3 over the period 2010 and 2100. However, the marginal control rates diverge over time, particularly from 2025 to 2095. Thus, the control rates in scenario is increasing faster than the control rates in Scenario 3 2020 to 2035. However, the control rates in Scenario 3 increase faster than in Scenario 2 from 2035 to 2095. Notably, under the COP 21 proposal carbon emissions would fall gradually and at a faster pace from 2035 to reach the commitment made to UNFCCC by the middle of century. However, the emission scenarios cannot alone indicate the best options, and hence, we examine emission intensities and marginal cost contractions in the next sections.

Figures 5, 6 and 7 present emission intensities under Scenarios 1, 2 and 3, respectively, estimated on the basis of per-capita and per-output estimations over the period 2010 to 2100. The carbon intensity per-output is higher than per-capita. The findings indicate a declining rate over time both for per-capita and per-output basis scenarios in the second scenario. Also, emission intensities per-output shows a more rapid decline compared to emission intensities per-capita scenarios, particularly from 2030 after Malaysia finishes with the implementation of its INDC commitment to UNFCCC. Under Scenario 3, emission intensity for per-output declines faster than emission intensity per-capita. These findings call into question Malaysia's INDC commitment to the UNFCCC given that the measurements used ere on a per-capita basis rather than per-output basis.

This study also considered climate control options by using emission intensities in the economy and limiting the concentration of GHGs by COP emission reduction strategies targeted at averting climate damage over the long run with planned climate control measured as optimal condition. The findings using the emission intensity option and limiting the concentration of GHGs are shown in Figures 8 and 9. The outcomes from the simulations show that emission concentration is expected to rise to a maximum of 899 ppm in scenario 1,850 ppm in Scenario 2, and 851 ppm in Scenario 3. However, carbon concentration is expected to rise to a maximum level of 390 ppm in 2020, 677 ppm in 2050 and 1087 ppm in 2100, 390 ppm in 2020, 677 ppm in 2050 and 881 ppm in 2100 in Scenario 2. The findings indicate similarities in controlling emissions by the end of 2100. However, yearly controlling rates yearly in the period from 2035 to 2080 are more intense in Scenario 3 compared to Scenario 2.

Figure 5. Emission intensity, Scenario 1

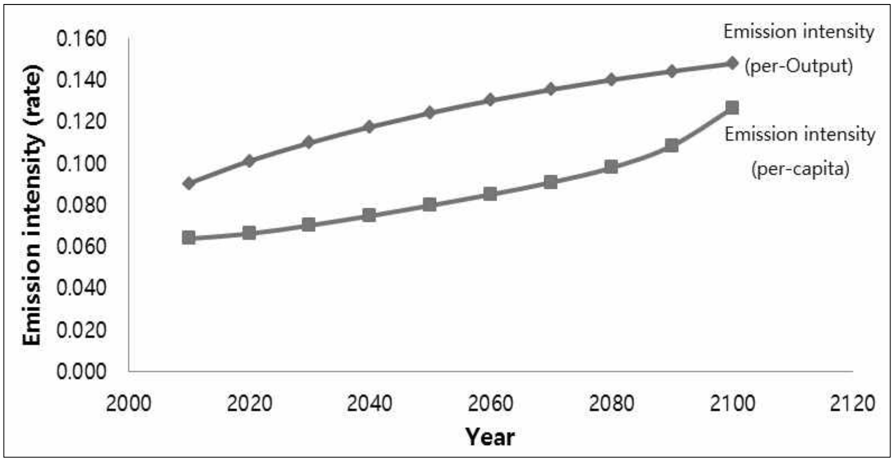


Figure 6. Emission intensity, Scenario 2

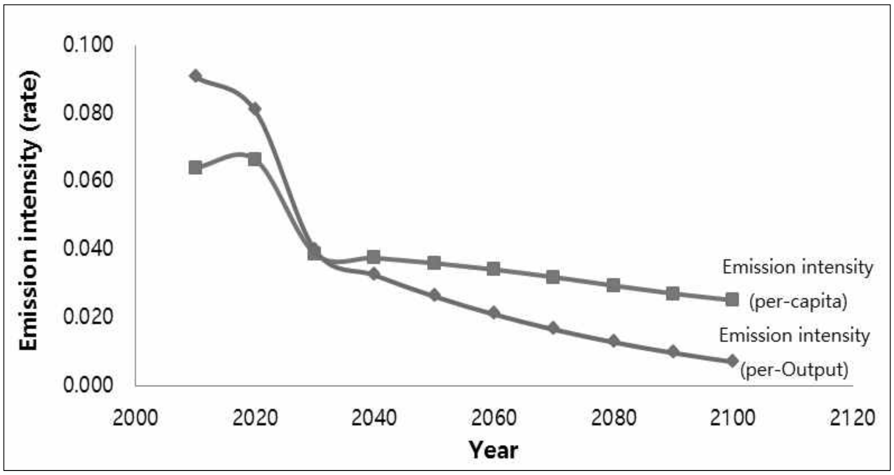


Figure 7. Emission intensity, Scenario 3

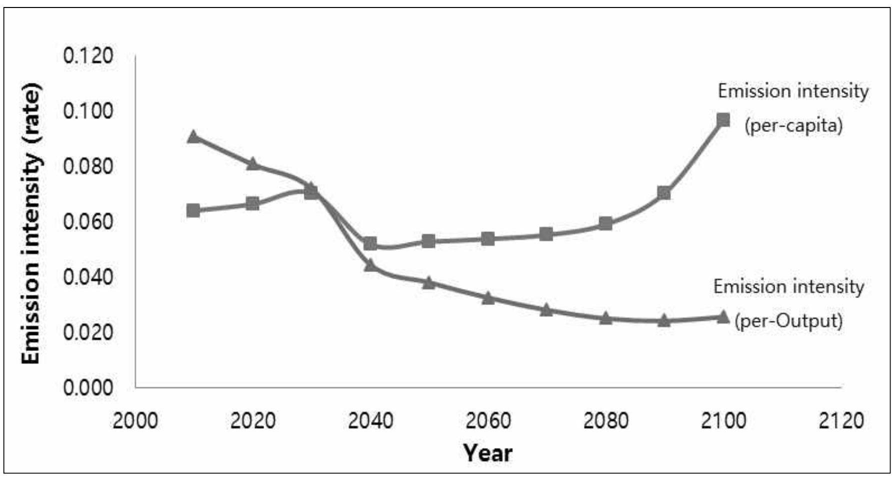


Figure 8. Emission control intensity, three scenarios

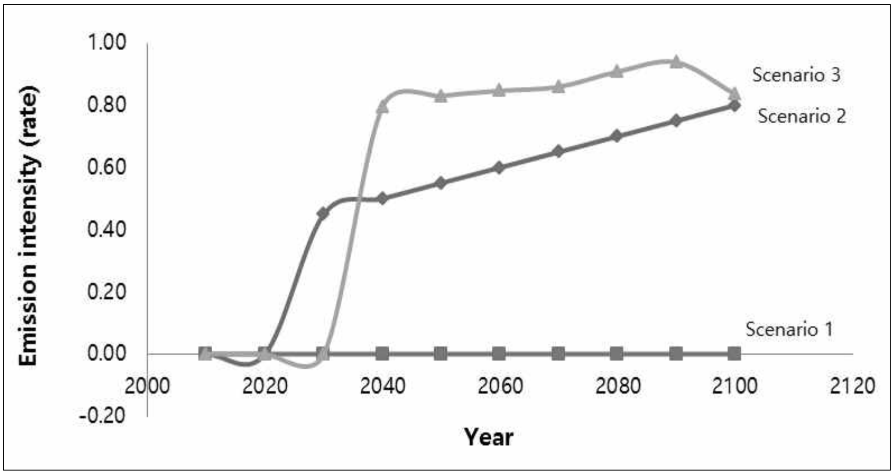
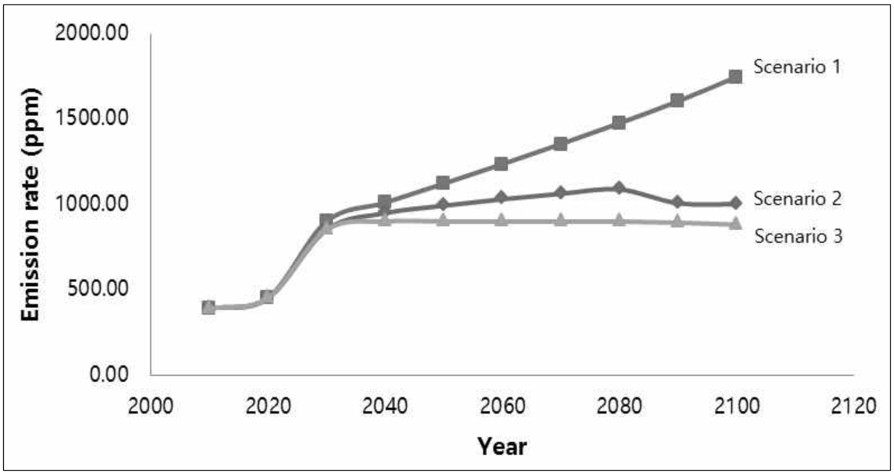


Figure 9. Emission control rates (ppm), three scenarios



Overall, both Scenarios 2 and 3 provide a declining projection trend of emissions over time. However, there are differences in the intensity and pace of emission fluctuations, and abatement costs between the two scenarios. Scenario 3 is the best alternative when the emphasis is on reducing emission intensity, but Scenario 2 shows lower abatement costs. Since the objective is to lower emission intensity efforts must be taken to stimulate the development of backstop technologies, which would inevitably raise the unavoidable abatement costs.

4. Conclusions

This study sought to examine Malaysia's climate mitigation scenarios over the period from 2010 to 2100 based on the existing no intervention scenario and two proposals that have been presented in recent climate policy dialogues, namely, Malaysia's INDC submitted to UNFCCC, planned climate control intervention proposal to cap global temperature rise to 1.5 °C and carbon concentration to a maximum of 650ppm from the 1990 level. On the one hand, the cumulative damage of climatic change over the period 2010-2100 will amount to 2,722 mtoe under the present climate regime (Scenario 1); 1,203 mtoe under Scenario 2, and 699 mtoe under Scenario 3. On the other hand, cumulative carbon concentration over the period 2010-2100 will amount to 11,912 ppm under the present climatic regime, which will fall to 9,714 ppm and 8,592 ppm respectively under Scenarios 2 and 3 respectively. Since the total abatement costs for Scenario 2 of MYR 14,351 million, is close to that of Scenario 3 of MYR 14,645 million, the third proposal is clearly the best. The results are not only important to define Malaysia's climate change mitigation roadmap, but they also offer lessons for other countries seeking to do the same. The findings enhance current knowledge on: (a) setting up long-term national climate change mitigation policies, and (b) plugging gaps in our understanding of impact, (including costs) of the different climate control options.

Acknowledgements

The corresponding author would like to thank to Dr. Ferdous Ahmed, Dr. Santha Chenayah and Mr. Anwar H. Chowdhury for excellent editorial support. Special thanks goes to Prof. Dr.Walter Leal Filho to provide some necessary inputs for the modelling exercise.

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APPENDIX I

Mathematical statement of the study model:

$$W = \sum_{t=1}^{T\max} u\left[c(t), l(t)\right]R(t) \tag{1}$$

$$R(t) = (1+\rho)^{-t} \tag{2}$$

$$U\left[c(t), L(t)\right] = l(t)[c(t)^{1-\alpha} / (1-\alpha) \tag{3}$$

$$Q(t) = \Omega(t)[1-\Lambda(t)]A(t)K(t)^{\gamma} L(t)^{1-\gamma} \tag{4}$$

$$\Omega(t) = 1/[1+\Pi_1 T_{AT}(t) + \Pi_2 T_{AT}(t)^2] \tag{5}$$

$$\Lambda(t) = \pi(t)\theta_1(t)\mu(t)^{\theta_2} \tag{6}$$

$$Q(t) = C(t) + I(t) \tag{7}$$

$$C(t) = C(t) / L(t) \tag{8}$$

$$K(t) = I(t) + (1-\delta_k)K(t-1) \tag{9}$$

$$E_{Ind}(t) = \sigma(t)[1-\mu(t)]K(t)^{\lambda} L(t)^{1-\lambda} \tag{10}$$

$$CCum \leq \sum_{t=0}^{T\max} E_{Ind(t)} \tag{11}$$

$$E(t) = E_{Ind}(t) + E_{Land}(t) \tag{12}$$

$$M_{AT}(t) = E(t) + \phi_7 M_{AT}(t-1) + \phi_{11} M_{UP}(t-1) \tag{13}$$

$$M_{UP}(t) = \phi_{11} M_{AT}(t-1) + \phi_{11} M_{UP}(t-1) + \phi_{11} M_{LO}(t-1) \tag{14}$$

$$M_{LO}(t) = \phi_{12} M_{UP}(t-1) + \phi_{12} M_{LO}(t-1) \tag{15}$$

$$F(t) = \eta\left\{\log_2[M_{AT} / M_{AT}(1900]\right\} + F_{EX}(t) \tag{16}$$

$$T_{AT} = T_{AT}(t-1) + \zeta_1\{F(t) - \zeta_2 T_{AT}(t-1) - \zeta_3 T_{AT}(t-1) T_{LO}(t-1)\} \tag{17}$$

$$T_{LO}(t) = T_{LO}(t-1) + \zeta_4\{T_{AT}(t-1) - T_{LO}(t-1)\} \tag{18}$$

$$\Pi(t) = \varphi(t)^{1-\theta_2} \tag{19}$$

Variable Definitions and Units (endogenous variables marked as asterisks):

A(t) = total factor productivity (TFP) in units)

*$c(t)$ = capita consumption of goods and services (RM per person)

*$C(t)$ = consumption of goods and services (RM)

$E_{Land}(t)$ = emissions of carbon from land use (carbon per period)

*$E_{Ind}(t)$ = industrial carbon emissions (carbon per period)

*$E(t)$ = total carbon emissions (carbon per period)

*$F(t)$, $FEX(t)$ = total and exogenous radiative forcing

*$I(t)$ = investment (RM)

*$K(t)$ = capital stock (RM)

$L(t)$ = population and labor inputs (number)

*$M_{AT}(t)$, $M_{UP}(t)$, $M_{LO}(t)$ = mass of carbon in reservoir for atmosphere, upper oceans, and lower oceans (carbon, beginning of period)

*$Q(t)$ = net output of goods and services, net abatement and damages (RM)

T = time (decades from 2010–2020, 2021–2030, ...)

*$T_{AT}(t)$, $T_{LO}(t)$ = global mean surface temperature and temperature of lower oceans (°C increase from 1900)

*$U[c(t), L(t)]$ = instantaneous utility function (utility per period)

*W = objective function in present value of utility (utility units)

*$\Lambda(t)$ = abatement-cost function (abatement costs as fraction of world output)

*$\mu(t)$ = emissions-control rate (fraction of uncontrolled emissions)

*$\Omega(t)$ = damage function (climate damages as fraction of world output)

*$\varphi(t)$ = participation rate (fraction of emissions included in policy)

*$\prod(t)$ = participation cost markup (abatement cost with incomplete participation as fraction of abatement cost with complete participation)

*$\sigma(t)$ = ratio of uncontrolled industrial emissions to output

$CCum$ = maximum consumption of fossil fuels (tons of carbon)

γ = elasticity of output with respect to capita (pure number)

δ_k = rate of depreciation of capital (per period)

$R(t)$ = social time preference discount factor (per time period)

T_{max} = length of estimate period for model

η = temperature-forcing parameter (°C per watts per meter squared)

ϕ = parameters of the carbon cycle (flows per period)

σ = pure rate of social time preference (per year)

$\theta_{1....2}$ = parameters of the abatement-cost function

ζ = parameters of climate equations (flows per period)

Science and Technology Trends
Greenhouse Gas Reduction and Climate Change

Localization of Global Target in Paris Agreement Efforts from a Developing Country: National Policies and Sub-National Pioneers

Nguyen Thi Dieu Trinh

1. Introduction

Vietnam is one of the first countries ratifying the Paris Agreement in April 2016, following her strong commitment by the Prime Minister at COP 21 Paris of GHG emission intensity reduction, and also contributes to the Green Climate Fund. To implement the commitment, Vietnam has been proactive in nationalizing the global will. Remarkably, more have been done at the sub-national and sectoral levels. This review will overview how Vietnam localizes those global targets in terms of institutional setup, initial achievements in sectors and sub-regions/ provinces as well as boosting climate finance resources for climate and low carbon/green growth investment. Being active in international cooperation for peer to peer learning, sharing experiences in policy making process, and practices is expected to facilitate Vietnam to successfully localize global objectives at national and sub-national levels. This reflects connection between practical demands and challenges at grassroots levels to central policy making process as well as trends for donors' support and scientific works. The active involvement also help maximize two approaches of top-down and bottom-up to ensure the close collaboration between practitioners and policy-makers, investors and researchers.

2. Paris Agreement–A New Era for Development and Implications for Vietnam

Vietnam is one of the first countries certifying the Paris Agreement (PA) at UN Headquarter in April 2016, following her strong commitment by the Prime Minister at COP 21 Paris of GHG emission intensity reduction target at 8-10% by 2020 and also contributes honorably 1 million USD to the Green Climate Fund. The Paris Agreement has been widely hailed as "historic" regarding its aim of "well below" 2 °C and "pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels," as well as the new element relating to support for obligations and commitments that other parties, in addition to developed countries, are encouraged to also provide (or continue to provide) support.

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Therefore, Vietnam, from her position as a low-middle-income developing country is proud to continue her efforts to join the globe's common but differentiated responsibilities against climate change.

The main massage from Paris Agreement to Vietnam is the first legal binding framework for all parties through INDC (Intended National Determined Contributions). This is a sign to show serious view of parties in solving GHG emission globally. This Agreement is seen to have great impacts on Vietnam's development, expectedly to reduce climate change's adverse consequences. To actively implement Prime Minister's statement for the GHG emission intensity reduction target at 8-10% by 2020 in comparison to BAU scenario, and increase to 25% with additional support from development partners, localizing Paris Agreement and activities under her INDC is expected to facilitate Vietnam to gain long term socio-economic development goals for sustainable development where green growth strategy serves as a vehicle to remain achievements and continue to promote activities for a new international environment of post-COP 21. The overall objective of Vietnam to implement PA is to identify and implement appropriate activities and solutions until 2020 and 2030 to gradually carry out all the provisions in the Paris Agreement that are applicable to Vietnam in the following manner:

(i) Suitable to Vietnam's development circumstances and the level of international support received;

(ii) Following direction from Parties, Government; Inherit viewpoints, undertakings and activities for climate change response and green growth (GG) which have been and are being implemented, and take advantage of opportunities presented by the PA

(iii) Adaptation continues to be the focus with main resources comes from the public budget, including international supports. Mitigation is important with resources come from private investments, with state resources playing a leveraging role.

However, the implementation in Vietnam for Paris Agreement would face the following challenges in governance (identifying responsibilities for ministries and provinces and other related key stakeholders; coordination capacity and enforcing legal framework) and resources (human resources: skills and knowledge; technology and finance).

To cope with those barriers, Vietnam has been proactive in finding her own ways in pursuing green growth vision, developing policy framework based on best practices, and promoting international cooperation for knowledge transfer and diversifying financial resources.

3. Vietnam's Policy Development in Climate Change and Green Growth —Pathway Towards to Implementing Paris Agreement in Vietnam

According to the 2014 Climate Change Vulnerability Index (CCVI) of Maplecroft[1], Vietnam is one of the "extreme risk" countries that are highly exposed to extreme climate-related events, the sensitivity of populations, and the adaptive capacity of countries. Recognizing the risks with support from the international community, Vietnam has been active in preparing institutional setup for better adaptive to changing situation since the late 1990s. Policies responding to climate change have been built comprehensively to help the country implement her will. Those policies include: Vietnam's Initial Communication to the UNFCCC (2003) (the 2nd National Communication submitted in 2010); the National

1 Maplecroft (2014). Climate Change and Environmental Risk Atlas 2014. <http://maplecroft.com/portfolio/new-analysis/2013/10/30/31-global-economic-output-forecast-face-high-or-extreme-climate-change-risks-2025-maplecroft-risk-atlas/>

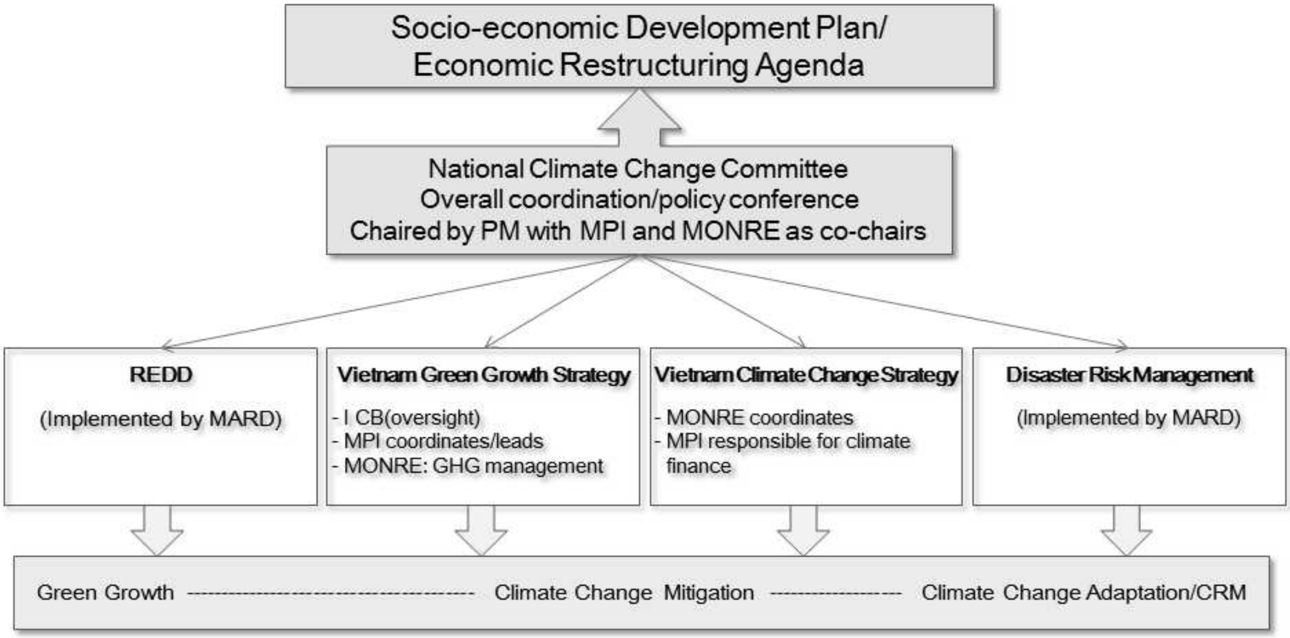
Target Program to Respond to Climate Change (NTP-RCC: Decision 158/2008/QĐ-TTg, 2008; and 1183/QĐ-TTg, 2012 for the period 2012-2015), followed by the National Climate Change Strategy (NCCS: Decision 2139/QĐ-TTg, 2011) and the Vietnam Green Growth Strategy (VGGS: Decision 1393/QĐ-TTg, 2012). These two strategies form the overarching policy frame and have been prioritized and made concrete in the National Action Plan on Climate Change (NAPCC) and the Green Growth Action Plan (GGAP), both for the period up to 2020, whereas sector and provincial CC-response and green growth (GG) action plans have either been completed or will be formulated. In addition, the National Action Program on REDD+ 2011-2020 was issued in 2012 (Decision 799/QĐ-TTg, 2012). There are also a number of other related policies, including the National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020 (2007); the Law on Natural Disaster Prevention and Control (2013); the National Forestry Development Plan 2011-2020 (2012); and the National Target Program for Energy Efficiency and Conservation (NTP-EE).

In June 2013, the Central Executive Committee of the Party further committed to a more active response to CC. Resolution 24-NQ/TW on "Active response to climate change, improvement of natural resource management and environmental protection" stated that the response to climate change to date was "passive and confusing" and that the CC-response was "one of the most important tasks of the entire political system." The resolution provided a strong political direction with clear and specific objectives by 2020 in adaptation, natural resource management and environmental protection, as well as general objectives by 2050. It also reaffirms the CC-response priority from the highest level and calls for renewed efforts from all relevant entities. To translate these policies, key CC-response programs have been implemented: (i) the National Target Program to Respond to CC (NTP-RCC); (ii) the Support Program to Respond to Climate Change (SP-RCC); (iii) the National Scientific and Technological Program on Climate Change aiming to support the NTP-RCC; and (iv) the National Target Program on Economical and Efficient Use of Energy (NTP-EE). These ongoing programs have helped establish a CC-response policy capacity, but they need to be fully integrated into the GoV institutional structure.

The NCCS and VGGS complement each other to help Vietnam respond to climate change effectively. While VGGS low-carbon development focus mainly on mitigation aspect with objectives linked to green production, efficient use of natural resources and green lifestyle including sustainable consumption and "new rural model with lifestyles in harmony with the environment" linking to adaptation. The ten priorities of NCCC are highlighted in the National Action Plan on Climate Change 2012-2020 (NAPCC, 2012), which lists 65 specific programs and projects, many of which focus on strengthening observation systems and adaptation activities.

The VGGS proposes more efficient use of natural capital, reduction of GHG emissions and an improvement in environmental quality. The Green Growth Action Plan (GGAP, 2014) presents 66 activities, which are grouped under four themes: (1) Institutional improvement and formulation of green growth action plans at the local level; (2) Reducing GHG emissions intensity and promoting the use of clean and renewable sources of energy; (3) Greening production; and (4) Greening lifestyle and promoting sustainable consumption. The priority activities for 2013-2015 include completing the institutional framework to enhance the economic restructuring process in accordance with the VGGS, and formulating the green growth financial policy framework.

Figure 1. Green growth and climate change institutional setup in Vietnam



MPI: Ministry of Planning and Investment
MONRE: Ministry of National Resources and Environment
REDD: Reducing Emissions from Deforestration and Forest Degradation
MARD: Ministry of Agriculture and Rural Development

Source: Mai and Trinh (2016)

The VGGS establishes renewable energy and energy efficiency as important parts of sustainable development and shifts the economy towards a low-carbon green trajectory. This will help Vietnam to avoid the "middle income trap" a shift away from labor- and resource-intensive economic activities is needed, as has been demonstrated by South Korea[2]. As consulted with business community during the formulation process, technology and financial resources are crucial for nearly 70% of enterprises in Vietnam at the size of small and medium, especially when pursuing development of new, technological- and knowledge-intensive industries.

Vietnam's Green Growth Strategy has set targets for reducing greenhouse gases (GHG) intensity and promoting the use of clean and renewable energy in accordance with following main criteria:

- In the period 2011-2020: Reduce the intensity of GHG emissions by 8-10% as compared with 2010 and reduce energy consumption per GDP by 1 to 1.5% per year. Reduce greenhouse gas emissions from energy activities from 10% to 20% as compared with normal development plan. Particularly, the voluntary reduction is 10% while the remaining 10% might be achieved with international support.
- Vision to 2030: Reduce annual GHG emissions by at least 1.5% to 2%; reduce greenhouse gas emissions from energy activities from 20% to 30% as compared with normal development plan. Particularly, the voluntary reduction is 20% while

2 Tran, Van Tho (2013). The Middle-Income Trap: Issues for Members of the Association of Southeast Asian Nations. ADBI Working Paper 421. Tokyo: Asian Development Bank Institute. <http://www.adbi.org/working-paper/2013/05/16/5667.middle.income.trap.issues.asean/>

the remaining 10% might be achieved with international support.

- Vision to 2050: Reduce annual GHG emissions by 1.5% to 2%.

The strategy also stipulates that “the People's Committees of provinces and cities under central government shall be responsible for formulating programs and action plans; guiding the implementation of green growth strategies; specifying tasks; integrating into annual and 5-year economic-social development plans and ensuring funds for implementation at local levels.”

Recently on 28th October 2016, Vietnam’s Prime Minister approved the Vietnam’s action plan towards 2030 in implementing Paris Agreement via Decision 2053/QĐ-TTg with 5 pillars:

(i) Fulfill commitments in the INDC on GHG emissions mitigation and GG;

(ii) Fulfill commitments in the INDC on climate change adaptation;

(iii) Prepare human, technological and financial resources to fulfill commitments in the INDC and contribute to the transition to a low-carbon, highly resilient economy;

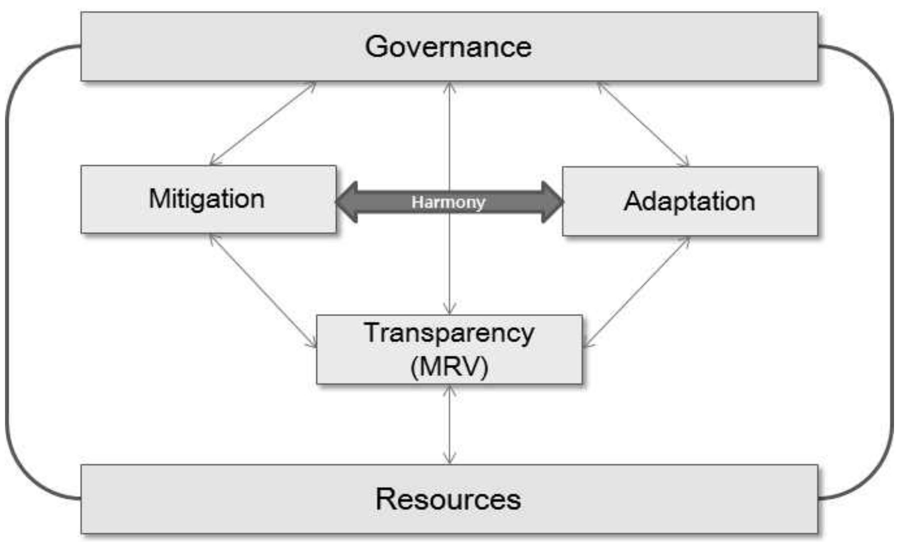
(iv) Establish and operate a Transparency System (MRV) to monitor and assess the implementation of adaptation, mitigation, and resource preparation;

(v) Revise institutions and policies to establish a favorable environment and focus national efforts to respond to CC

Reviewing targets in VGGS and Prime Minister’s commitments at COP 21 as well as INDC, there is a consistency in term of mitigation goals. VGGS and its (green growth) action plan cover 55% activities of Vietnam’s (I)NDC.

Therefore, from both top-down and bottom up perspective, to save resources, inheriting efforts nationwide and especially avoiding overloading in complying with too many central government’s new policies (as required by the global changing context) at provincial/sub-national and sectoral level, it has been recommended to identify VGGS and VPGGAP as the main channel to implement mitigation targets in Paris Agreement in Vietnam as well as (I)NDC.

Figure 2. Five components of the Action Plan



Source: Pham Van Tan, DHMCC, MONRE, Vietnam

Figure 3. Relation between National Determined Contributions (NDC) and Marginal Abatement Cost Curve (MACC) OPTIONS/VGGS target

NDC OF VIETNAM

Sector	Modality	Reduction target by 2030 (%)	Expenditure (mil. US$)
Energy	self-executing	-4.4	1,894.3
	international support required	-9.8	5,317.4
Agriculture	self-executing	5.8	885.43
	international support required	41.8	12,093.54
Waste	self-executing	-8.6	311.7
	international support required	-42.1	2,596.2
LULUCF*	self-executing	+50.05	131.98
	international support required	+145.7	1,127.98
Total self-executing expenditure			3,223.41
Total required international support expenditure (mil. US$)			17,911.71
Total (mil. US$)			21,135.12

Unconditional reduction in GHG emissions of 8% by 2030 and would increase the emissions reductions to 25% with international support

MACC OPTIONS/VGGS TARGET

CO2 emission reduction potential of sub-sectors/options by cost 2020

Sub-sector	Cost of CO_2 emission reduction (US$/ton CO_2)							
	<=0		<=5		<=10		<=20	
	No. of option	Amount of emission reduction ($MtCO_2$)	No. of option	Amount of emission reduction ($MtCO_2$)	No. of option	Amount of emission reduction ($MtCO_2$)	No. of option	Amount of emission reduction ($MtCO_2$)
Building	3	0.17	3	0.17	3	0.17	3	0.17
Construction material	1	0.49	1	0.49	1	0.49	1	0.49
Cement	3	2.61	3	2.61	3	2.61	3	2.61
Textile	2	0.08	2	0.08	2	0.08	2	0.08
Household	8	14.80	9	16.22	9	16.22	9	16.22
Pulp and paper	2	0.19	2	0.19	2	0.19	2	0.19
Electricity generation	0	0	1	15.49	3	17.96	9	61.23
Iron and steel	2	0.09	3	0.22	3	0.22	3	0.22
Road transportation	1	3.45	1	3.45	1	3.45	1	3.45
Total:	22	21.88	25	38.92	27	41.38	33	84.65

Emmision intensity to be reduced by 8-10% annually by 2020 and could be doubled with international support

Source: Mai and Trinh (2016)

4. Vietnam's Green Growth Strategy: from Strategy to Actions

Under the globalization trend, every economy and business needs to improve their competitiveness by service quality and environmentally-friendly products through the efficient use of resources and resource savings, environment protection and apply modern, innovative and low emission technology. Green grow th model towards sustainable development has been recognized by the international community and is being implemented in areas, which are in different conditions and at different economic development levels. During the process of international integration, Vietnam is not an exception to this trend and agreeme nt, the selection of pursuing green growth model is widely implemented at national and local levels, in various sectors and fields. This is an opportunity for Vietnam to improve its competitiveness in the economic development, attract external resources to support the economic development and response to climate change.

4.1. From Strategy....

The Prime Minister has approved the Vietnam Green Growth Strategy (VGGS) in the Decision No. 1393/QD-TTg dated 25/9/2012, showing Vietnam's effort and commitment towards sustainable development and response to climate change.

VGGS is expected to promote restructure process and improve economic institutions towards more-efficient use of natural resources, and improve economic competitiveness through increased investments in innovative technology, natural capital, and economic tools. Thus VGGS contributes to the response to climate change, reduction of poverty, and the guarantee for sustainable economic development. This is the different connotation of Vietnam green growth compared to other countries.

With its features, the aim of implementing VGGS is restructuring and completing economic institutions towards greening existing sectors, and promoting development in economic sectors using resources and energies efficiently with high added values. The purpose of research and increasingly widespread application of innovative technology are to use energies and resources more efficiently, reduce greenhouse gas emissions, contributes to effective responses to climate change; simultaneously, improve people's lives, create environmental-friendly lifestyle by creating more jobs in industrial and agricultural sectors, green service, natural capital investment, and green infrastructure development.

Funding for activities are mobilised from resources, including state budget for Support Program to Respond to Climate Change (SP-RCC), private and public resources, and international aid. The government prioritizes and spends adequate funds from state and local budgets on implementing Green Growth Action Plan (GGAP), especially, improving efficiency in using energies and developing renewable energies. The Government creates legal basis to encourage financial institutions, and businesses to invest in the implementation of GGAP activities. Furthermore, international funds for climate change and green growth are also the objects that government and local agencies need to study and prepare to approach by proactively cooperating with Ministry of Planning and Investment (MPI), and Ministry of Finance (MoF).

4.2. To Actions....

The National Action Plan, which was approved by the Prime Minister by Decision 403/QĐ-TTg dated 20.03.2014, also specify the requirements for activities related to:

- Institutional and green growth plan preparation at local levels: 8 activities under 2 groups (institutional development (5); and green growth plan at local levels (3))
- Reducing GHG emissions intensity and promoting the use of clean and renewable energy: 20 activities under 4 groups (energy saving and efficiency and reducing greenhouse gas emissions intensity in industrial sectors that heavily rely on energy (8); energy saving and efficiency and reducing greenhouse gas emissions intensity in transportation sector (3); innovating cultivation techniques and management to reduce GHG emissions intensity in agriculture, forestry and fisheries sectors (6); and developing clean and renewable energy sources (3))

In addition, some specific activities are as follows:

- Develop, implement, and expand green growth plans/programs in some provinces.
- Capacity building in energy management in industrial and construction sectors.
- Develop and implement policies that prioritize the development of clean energy sources.
- Improve institutions on clean air; inventory and monitor GHG emissions and manage activities to minimize GHG emissions.

4.3. Initial Implementation

In recent years, MPI has been cooperating with line ministries and provinces to implement GGAP at national level. Following that, ministries, sectors, and provinces will develop action plans, create project list, pilot projects, issue guidelines for green investment, framework guideline for provincial GGAP and propose mechanism for mobilization of capital for green growth with participation from private sector.

Specifically, ministries and provinces will implement an assessment of current emission status in provinces and sector. Sectors consuming the most energies and resources will be identified, based on which, provincial GGAP for provinces and sectors can be developed. Besides, provinces, cities, ministries, and sectors have been developing their GGAP with at least 2 targets in reduction of energy use and intensity of GHG emissions per unit of GDP; and 23 activities prioritizing green growth. Moreover, MPI is proceeding to propose the Government to establish the National Coordination Committee on Green Growth as required in the Government Decision No. 1393/QD-TTg and 403/QD-TTg. Many ministries, provinces have been implementing activities having connotations that fit this action.

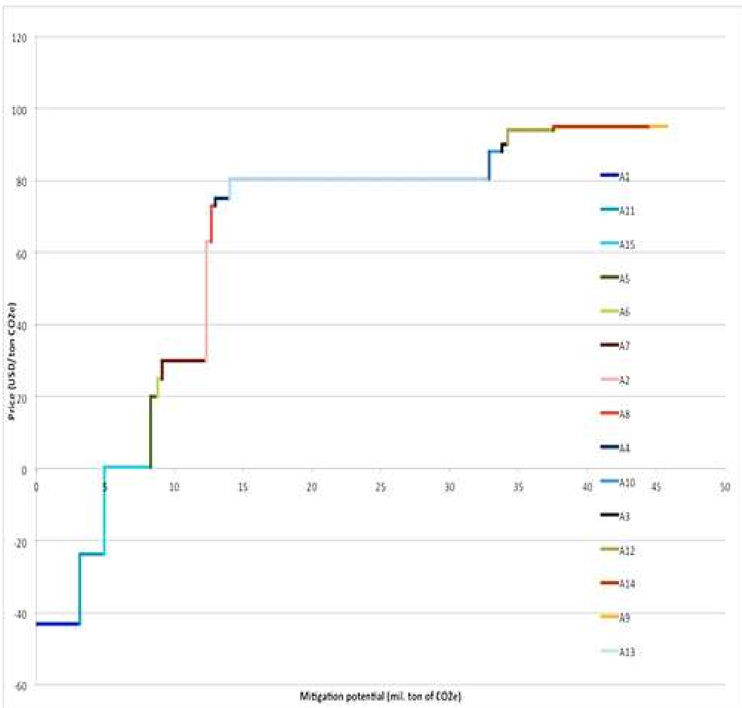
Simultaneously, MPI issued a guideline to integrate GGAP into socio-economic development plans for ministries, sectors and provinces for the period from 2016-2020.

Ministries such as Ministry of industry and Trade (MOIT), MARD, Ministry of Construction (MOC), Ministry of Transport (MOT), MOF, MONRE, etc. have been cooperating with MPI to develop their action plan.

More than 30 provinces[3] have started to develop provincial action plans, which shows the provinces' effort in implementing GGAP in Ministries, and provinces. Regarding resources, the Government has reviewed resources which have been mobilized for green growth, climate change, as well as expected resources in coming time. In addition, three types of resources need to be clearly identified: planned to allocate to green growth, possible allocation plan, or no resource yet.

Figure 4. NDC and MACC options in the agricultural sector

Option	Potential for emission mitigation by 2030 (Million metric ton of CO2 equivalent)	Cost for emission mitigation* ($/t.$CO_2$)
A1. Increased use of biogas	-3.17	-43.00
A2. Reusing of agricultural residues	-0.36	63.02
A3. Alternate wetting and drying, and improved rice cultivation	-0.94	88.00
A4. Introduction of biochar	-1.07	75.00
A5. Integrated Crop Management (ICM) for rice	-0.50	20.00
A6. Integrated Crop management (ICM) for upland annual crops	-0.32	25.00
A7. Substitute of Urea fertilizer by Sulfate amon-(NH4)2SO4	-3.2	30.00
A8. Reusing of agricultural residues	-0.29	73.02
A9. Alternate wetting and drying, and improved rice cultivation	-7.02	94.90
A10. Introduction of biochar	-18.80	80.45
A11. Improving diets for cattle	-1.75	-23.63
A12. Improve quality and services of variety, food and input material for aquaculture	-0.41*	90.00
A13. Revise technologies for aquaculture and waste treatment of aquaculture	-1.21*	95.00
A14. Revise technologies of food processing and waste treatment for crop, forestry, livestock and aquaculture	-3.36**	94.00
A15. Optimal irrigation for coffee	-3.39	0.46

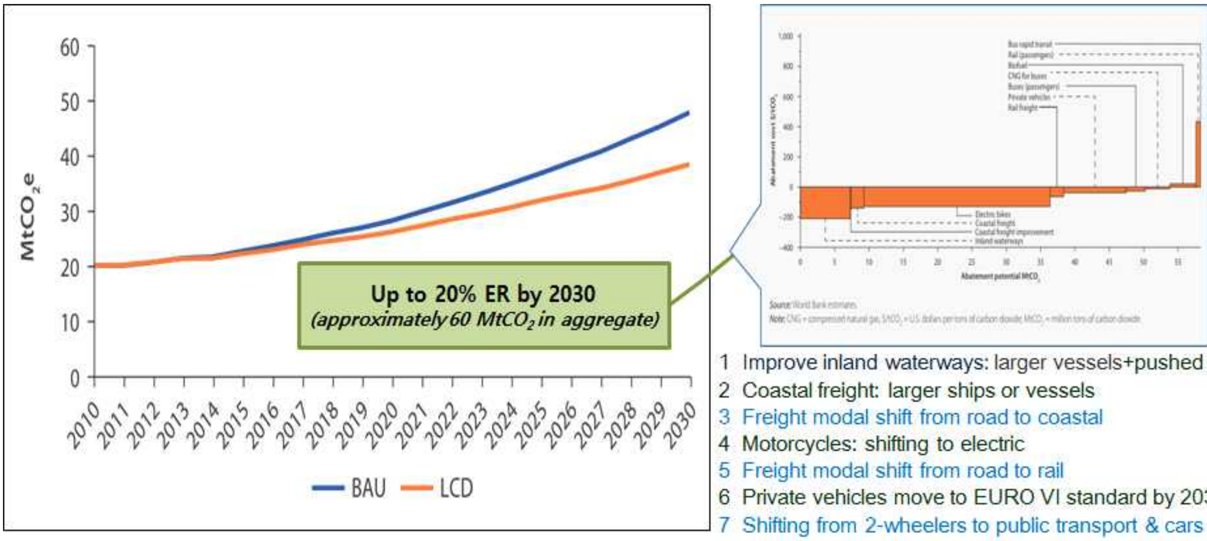


Reduce 6.63 million tonnes of CO_2 by 6 options

Continue to reduce 39.422 million tonnes of CO_2 by 9 extended options with international support

3 Quang Ninh, Bac Ninh, Quang Nam, Thanh Hoa, Ben Tre, Da Lat city, Vinh Phuc, Ha Giang, Thanh Hoa, Ha Tinh, Hue, Ninh Thuan, Binh Thuan, etc.

Figure 5. Low carbon development in transport



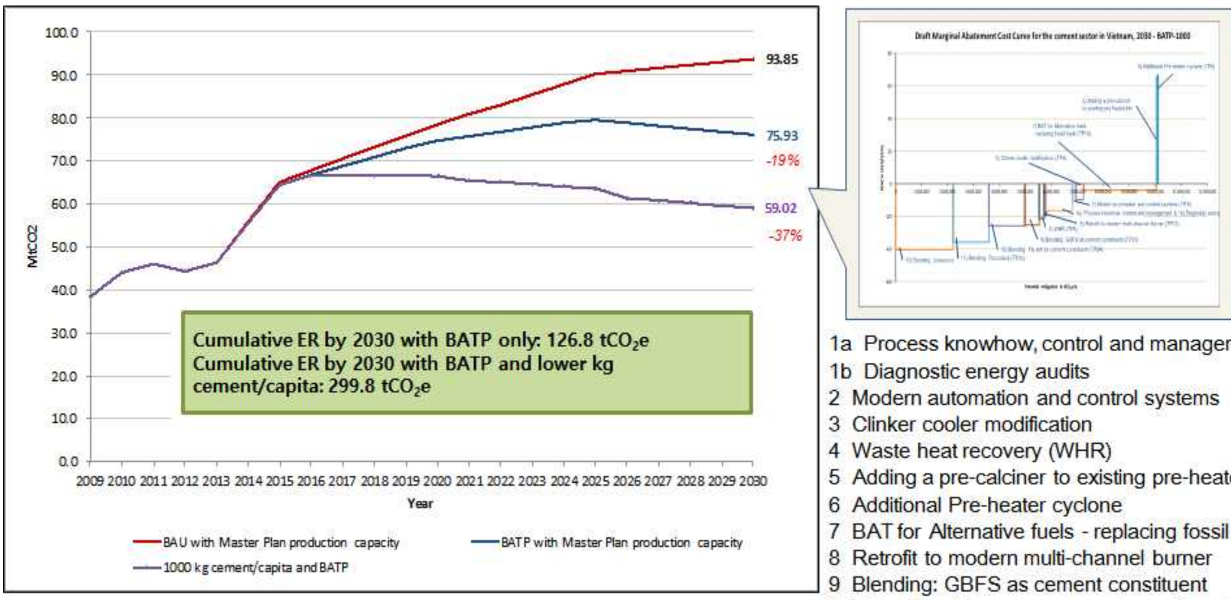
1 Improve inland waterways: larger vessels+pushed barges
2 Coastal freight: larger ships or vessels
3 Freight modal shift from road to coastal
4 Motorcycles: shifting to electric
5 Freight modal shift from road to rail
6 Private vehicles move to EURO VI standard by 2030
7 Shifting from 2-wheelers to public transport & cars to buses
8 Switch bus fuel to CNG
9 Increase the use of biofuel
10 Passenger modal shift from road to rail
11 Add BRT in Hanoi (1 line) and HCMC (2 lines)

BAU: Business-as-Usual

LCD: Low Carbon Development

Source: WB (2016), Exploring a Low-Carbon Development Path for Vietnam

Figure 6. Low carbon development in cement sector



1a Process knowhow, control and management
1b Diagnostic energy audits
2 Modern automation and control systems
3 Clinker cooler modification
4 Waste heat recovery (WHR)
5 Adding a pre-calciner to existing pre-heater kiln
6 Additional Pre-heater cyclone
7 BAT for Alternative fuels - replacing fossil fuels
8 Retrofit to modern multi-channel burner
9 Blending: GBFS as cement constituent
10 Blending: Fly ash as cement constituent
11 Blending: Pozzolana
12 Blending: Limestone

BATP: Best Available Technology and Practice

Source: NDF's Pilot Program for Supporting Up-scaled Climate Change Mitigation Action in Vietnam's Cement Sector (2016)

Total funding to implement VGGS is estimated to be $30 billion, in which, 70% is expected from private sector. In order to support pilot projects about green growth, the Government of Belgium funded 5,000,000 EUR, Vietnamese Government contributed 500,000 EUR to establish green growth support fund. Many provinces have proactively mobilized resources, especially foreign resources. To support this activity, and MPI is developing guidelines for green investments, and guidelines to categorize green investment projects in order to prioritize resource allocation. Simultaneously, the ministry is reviewing legal documents, sectoral, local, and territorial planning; adjusting sectoral planning for sectors, which are energy and resource consuming, towards sectors using energies and resources efficiently.

Besides, MPI, as the National Designated Authority (NDA) to approach Green Climate Fund and study the mobilising mechanism for financial resources for green growth and climate change, is proactively coordinating with donors to evaluate capacity, create conditions about institutions, human resource and structure to strengthen the readiness to directly and indirectly approach international resources for green growth and climate change.

Green growth is a new paradigm. Vietnam's experience in green growth is limited, and policies to mobilize financial resources are short. Vietnam is facing difficulties in mobilizing domestic and international investors.

5. Initial Achievements in Implementing Vietnam's Green Growth Strategy and Action Plan

Institutional Arrangement and Communication:

- Enhance dialogues on formulation and implementation of green growth strategy and action plan at all levels, among provinces, and with development partners;
- Review the existing legal framework under green growth lights (initially focusing on energy, environment, planning and investment);
- Review resources for climate change and green growth (completed the Climate Public Expenditure and Investment Review (CPEIR)) as well as potentials to access to climate finance and the Green Climate Fund (GCF);
- Enable environment for green investment and formulating the Green Investment Guidelines.
- Establishing the Climate Finance Task Force (CFTF) and Climate Finance Options database/ website (CFO);
- Designing template for formulating provincial green growth action plan (PGGAP);
- Issuing the Adaptation Prioritization Investment Framework (APRF);
- Promote private sector engagement in green growth via assessing their potential investment for green growth (CPrEIR);
- Formulating special mechanism to access to climate finance resources.
- Inter-ministerial Coordinating Board (ICB) for green growth: GG ICB will belong to the National Council for Climate Change, and chaired by Deputy Prime Minister with the supporting unit based in MPI.

Up to present, most of ministries are completing their draft sectoral green growth action plans, including: industries and trade; agriculture and rural development; construction, transportation, finance, natural resources and environment.

Many provinces, including provinces in main regions of mountainous areas in the north, the south as well as 2 biggest deltas of Mekong River and Red River have been active in formulating and approving their provincial green growth action plans. Around 15 provinces are on the way to completing their PGGAP for approval, and 5 provinces have obtained approval to put into practice. Among them, some provinces already mainstream green growth into their socio-economic development master plans towards 2020[4].

4 Quảng Ninh, Quảng Nam, Bến Tre, Bắc Ninh, Tp. Đà Lạt, Hà Nam, Vĩnh Phúc, Đà Nẵng, Hòa Bình, Thanh Hóa, Lào Cai, Hà Giang,

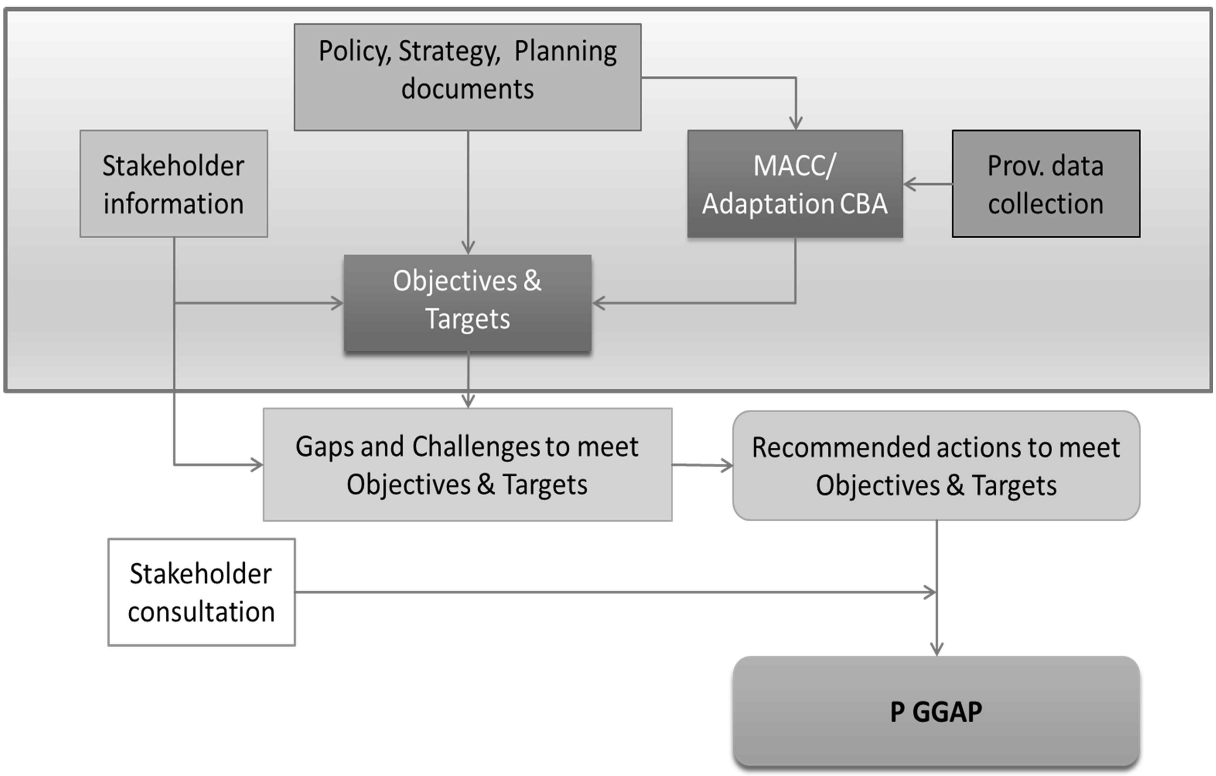
6. Boosting Pioneers and Transparency: Lessons Learnt from the Implementation of Green Growth Action Plan at Provincial/Sub-national Levels

Each province, especially provinces which were selected as pilots to implement GGAP with support from development partners with close guidance by central government, needs to do research and develop appropriate plans for reducing GHG emission, that are consistent with the national and ministerial overall development strategy on the basis of sustainable development, practical context and characteristics of each province.

According to incomplete statistics, there are around 30 provinces/cities out of 63 provinces in Vietnam that have developed provincial green growth action plan. Of these, about 10 provinces are in the process of approving the draft action plans, which are developed based on scientific research methodology and calculation to set out specific goals as well as determine the list of prioritized targets.

Overall, in order to develop Green growth action plan at provincial levels, each province needs to conduct research and develop appropriate plans for reducing greenhouse gas emission, that are consistent with the national and ministerial development strategies on the basis of sustainable development, practical context and characteristics of each province.

Figure 7. Methodology for Green Growth Action Plan



Source: Trinh et al.

Hà Tĩnh, Huế, Ninh Thuận, and Bình Thuận.

To unify calculation methods and develop objectives of national green growth action plan and strategy, each province needs to identify GHG emission potentials in relevant sectors and develop its own Green growth action plan. A number of specific tasks are as follows:

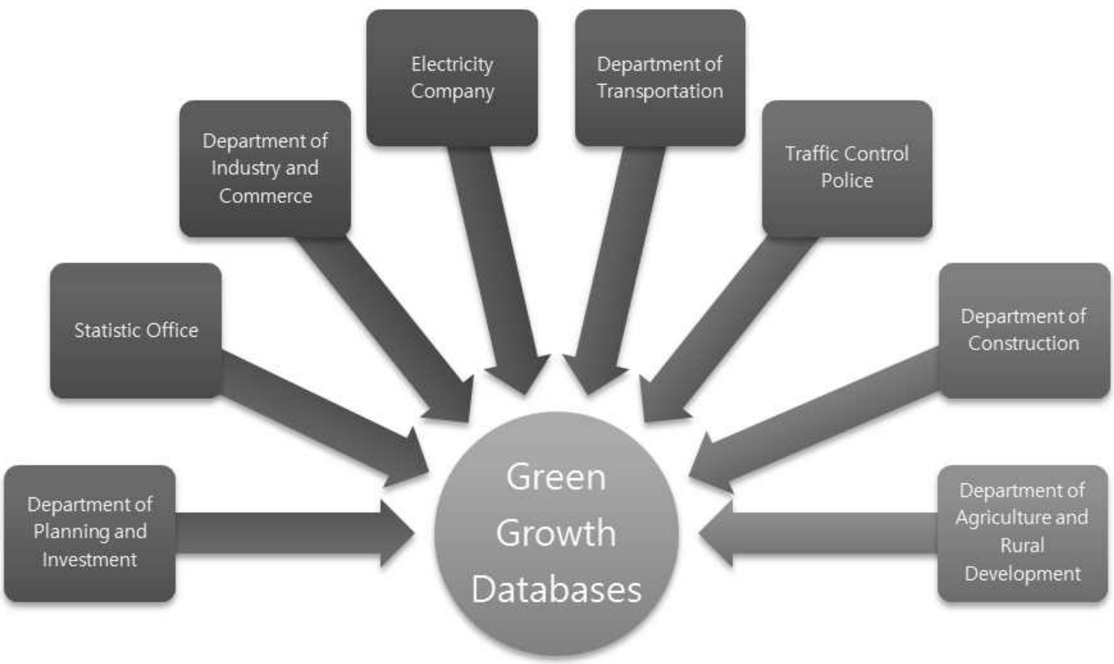
(i) Quantitative analyze the amount of GHG emissions reduction as compared with local baseline scenario;

(ii) Review potential plans of GHG emissions reduction in selected areas in accordance with economic, finance and environment indicators;

(iii) Provide recommendations to local leaders regarding future prioritized GHG reduction investment plan, in order to achieve goals outlined in green growth strategy.

To achieve goals mentioned above, strong support and commitment of local authorities in human resources (e.g. develop green growth task team with the participation of major departments) are needed. Additionally, to align with Vietnam's planning system, province should allocate appropriate resources and link activities with socio-economic development process, as well as development priorities. Hence, the coordinating role of department of planning and investment is very important. This will assure synergy between the PGGAP (as crucial input data) with the Socio-economic Development Plan (SEDP) in terms of planning, budgeting and allocating investment annually and 5-year basis. The preparation of provincial green growth action plan and development options to reduce emission would be useful inputs to consider appropriate development plans, and ensure economic development, green growth goals, energy and resources savings, as well as climate change resilience.

Figure 8. Green growth databases



As Marginal Abatement Cost Curve (MACC) is applied for identifying targets in and options in VGGS formulation process as well as other sectoral GGAP at the central level, the mentioned provinces and others have been recommended to use MACC as the main tool to calculate and provide recommendations.

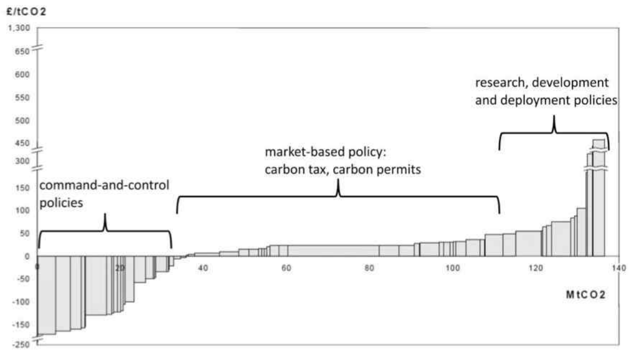
The MACC analysis results help to understand the scope of lower carbon growth that is driven by following factors:

- Electricity, coal and less use of fossil fuels, efficient use of natural resources, or avoid using outdated devices, the use of traditional production methods and lower fossil fuel inputs and relative electricity prices.
- Limit the use of the modern technology, partly because it is not effective. Small companies in Vietnam continue to be based on outdated technology. Especially in existing power plants, retrofitting will provide significant potential to improve energy efficiency.
- In the last decade, the use and management of forest land has been improved and Vietnam is currently a net carbon sink forests. However, an assessment of the land use plan shows potential to further enhance and improve forest management, through which potential carbon sink can be significantly increased.
- The improvements in the agricultural sector, particularly sustainability and efficiency have shown that win-win situations (e.g. GHG emissions reduction and net benefits increased) have potential development. New technology can further enhance this potential.

Different approaches have been developed through MACC analysis to provide information to policy makers regarding the most feasible solution in developing development scenarios.

Overall, through standardized methodology, tools and scientific basis, together with strong commitment and adequate resources, provinces would develop

Figure 9. Marginal Abatement Cost Curve (MACC)



their own GGAP in a reliable way in order to mobilize domestic and international resources, and ensure rapid and sustainable socio-economic development. A green growth action plan, which includes an overall approach that focuses on increasing the economic resources efficiency, reducing GHG and restore natural resources, would consist four components as follows:

(i) Institutional: Develop conditions for organizations and human resource to do research, develop policies, implement and monitor the implementation of GGAP.

(ii) Technology: Green growth action plan prioritizes the development and dissemination of appropriate green technology because it will allow provinces to select and speed up development processes. Green technology provides a combination of benefits, including enhancing energy security and communication, reducing CO_2 emissions, and lowering energy costs.

(iii) Capacity Building: GGAP significantly encourages capacity building activities that allow provinces to independently develop and implement plans.

(iv) Finance: Financial issue is very important for the implementation of green growth action plan. These activities will include climate finance choices and capacity building activities for directly access to green climate fund and other funds for climate change in the world.

7. Being Ready for Climate Finance Resources

According to ADB estimation, it costs Vietnam around 2-6% of GDP to recover from climate change damages. Additionally, to implement VGGS, about $30 billion will be needed by 2020, of which 70% targeted from non-public sources as shown below in Table 1.

Green finance can be considered as a tool to implement transitional process towards the economy using resources efficiently, low-carbon and adaptive to climate change. Green finance includes green finance policies, green investments, and agriculture and weather insurances[5]. Green finance policies support policy-makers, central banks, and law-makers in developing banking policies to promote environmentally-friendly investments. Banking and market management activities are implemented under social and environmental risk management standards. Green investments will support manufacturing and green business initiatives, develop carbon trading market, and green value chain.

Table 1. List of GHG emission options and the result of MACC, 2020 (discount rate = 12%)

Sub-sector	No. of options	Total capital cost (million USD)	Total annual CO_2 emission saved ($MtCO_2$)	Average MACC (USD/ton CO_2)
Building	3	3.33	0.17	-69.46
Construction materials	1	17.54	0.49	-14.39
Cement	3	725.00	2.61	-45.27
Textile	2	0.00	0.08	-60.28
Household	10	2,279.19	16.54	-32.32
Pulp and paper	2	0.00	0.19	-93.46
Electricity generation	10	27,625.00	61.37	16.11
Iron and steel	3	79.50	0.22	-44.60
Road transportation	1	0.00	3.45	0.00
Total	35	30,729.56	85.12	

Sources: Working papers for VGGS formulation (MPI, 2011)

Reality in Vietnam shows that many policies and plans are unsuccessfully implemented due to the lack of funding as a main cause. This reflects not only the capacity in developing strategies and plans but also the unreadiness/incapability in mobilizing diversified financial sources. Therefore, in order to succeed in implementing Vietnam Green Growth Strategy (VGGS), Vietnam needs to be more proactive to understand, mobilize, and widen potential resources, especially based on updates from negotiations under the United Nations Framework Convention on Climate Change (UNFCCC). Following that, developed countries are committed to providing "additional" financial resources for climate change and green growth[6].

So far, Vietnamese government has carried out many efforts to mobilize resources and realize her will, these include both legal framework establishment and institutional arrangement

- Establishment of the Climate Finance Task Force (Decision 505/QD-BKHDT, 25 Apr 2013);
- In collaboration with the World Bank and UNDP to conduct the Climate Public Expenditure and Investment Review (CPEIR - recently launch in May 2015);
- In cooperation with UNDP and GGGI to elaborate green investment guidelines;
- In collaboration with the WB to issue CC Adaption Priotization Framework for SEDP.
- Vietnam has responded strongly by pursuing development of a CC-response strategy and programs;
- Some progress made to mainstream the sector and provincial CC-Response but gaps remain;
- Adaptation and mitigation responses raise different technical and policy challenges;
- The mandate of NCCC is clear defined, but NCCC still needs further support to perform its tasks;

5 Green Finance: An Innovative Approach to Fostering Sustainable Economic Development and Adaptation to Climate Change, GiZ.
6 Copenhagen Accord in COP 16.

The government of Vietnam has exploited various channels/forms to finance identified activities, including:

From Public sources:

- Government investment for Climate Change projects and programs including Green Growth (around $1 billion annually): National Targeted Programs (NTP-RCC, Energy Efficiency, Reforestation); Projects and programs directly link to Climate Change and Green Growth.
- Current expenditure for research, capacity building projects
- ODA: from 1993 of about $11 billion under the forms of CC related projects & programs and budget support;
- Others: REDD+, Vietnam Environment Protection Fund, CDM.

From non-public: private investment comes under the forms of FDI, equity, local Investment etc.

According to the CPEIR report, the government budget has contributed much to the total resources for responding to climate change in Vietnam with the total share up to 69%.

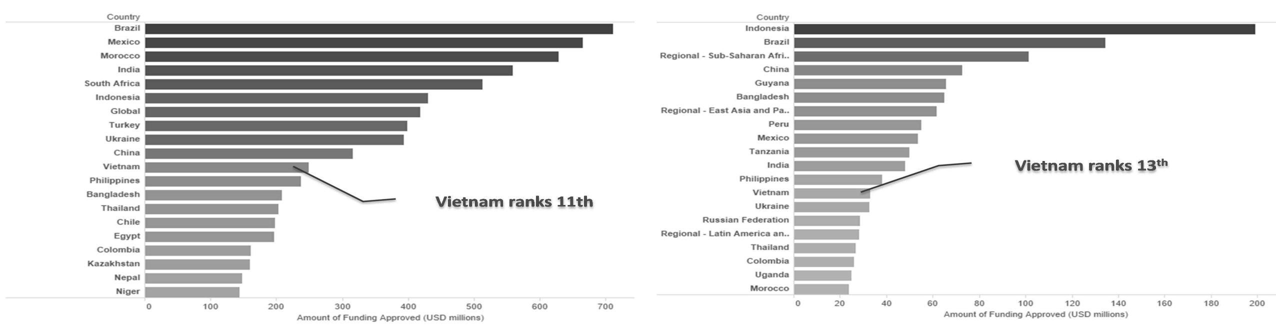
However, there is still a big gap between the need and the supply when we compare 66 activities under the National Green Growth action Plan (VGGAP) together with on-going projects and programs funded by development partners working in Vietnam, there are currently 177 programs, projects related to 36 actions of VGGS, among which:

- 48 programs, projects related to 10 priority actions of VGGS
- 129 programs, projects related to 26 actions of VGGS
- Other 64/241 programs, projects related to VGGS

That means, there are still 30 actions of VGGAPS not yet receive ODA supports. Therefore, efforts to access to climate finance sources bilaterally and multilaterally are very important.

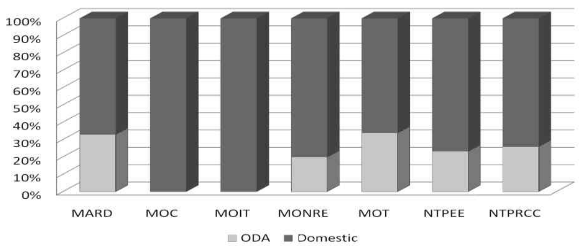
To fill in the gap, there are challenges that Vietnam has to overcome. Globally, it is estimated that there is nearly 200-364 billion USD from existing public and private funds spent for climate finance annually (Frankfurt School, 2012). However this amounts to only 20-30% of around 1 trillion USD needed for implementing the transition to low carbon/green growth annually over the next decade (Robins, 2012). Up to present, donor countries have pledged 35 trillion USD for climate related-activities globally and a total of 26 billion USD has been deposited into 25 public sector climate funds (Climate Funds Update and Nexant research). A total of 9 billion USD has been approved for projects and programs. Notably, annual approval amounts during fast-start finance period (2010-2012) were estimated approximately more than six times that of 2008-2009 levels.

Figure 10. Recipients of multilateral (left) and bilateral (right) climate finance



Source: Pham Van Tan, DHMCC, MoNRE, (data from www.climatefundsupdate.org/data)

Figure 11. Climate change resources dominated by government budget



Fact also shows that the private sector increasingly emerges as the dominant investor in comparison to the public sector in climate finance. The private climate finance resource has reached three-quarters of overall total public and private sector climate finance globally in 2011 and 2012 (Climate Policy Initiative, 2012). However, these potential resources could only be mobilized further if there would be innovative and successful partnership mechanism between public and private sectors.

The UNFCCC conferences in 2009 (Copenhagen) and 2010 (Cancun) prevailed the agreement to set aside 100 billion of USD annually by 2020 but fact shows that this agreement has not reached. There are many reasons for this unsuccessful agreement, however, one lies on the fact that there is not clear about the mechanism to mobilize such amount of money, either contributing from donor community or carbon market, or public and private funds. An effort is reflected in the establishment of the Green Climate Fund (GCF) however, it takes time to be really operated. Therefore, developing countries seems to be invited to a "spaghetti of climate finance flows" party without any transparent procedures and conditions to access to complicated climate finance sources.

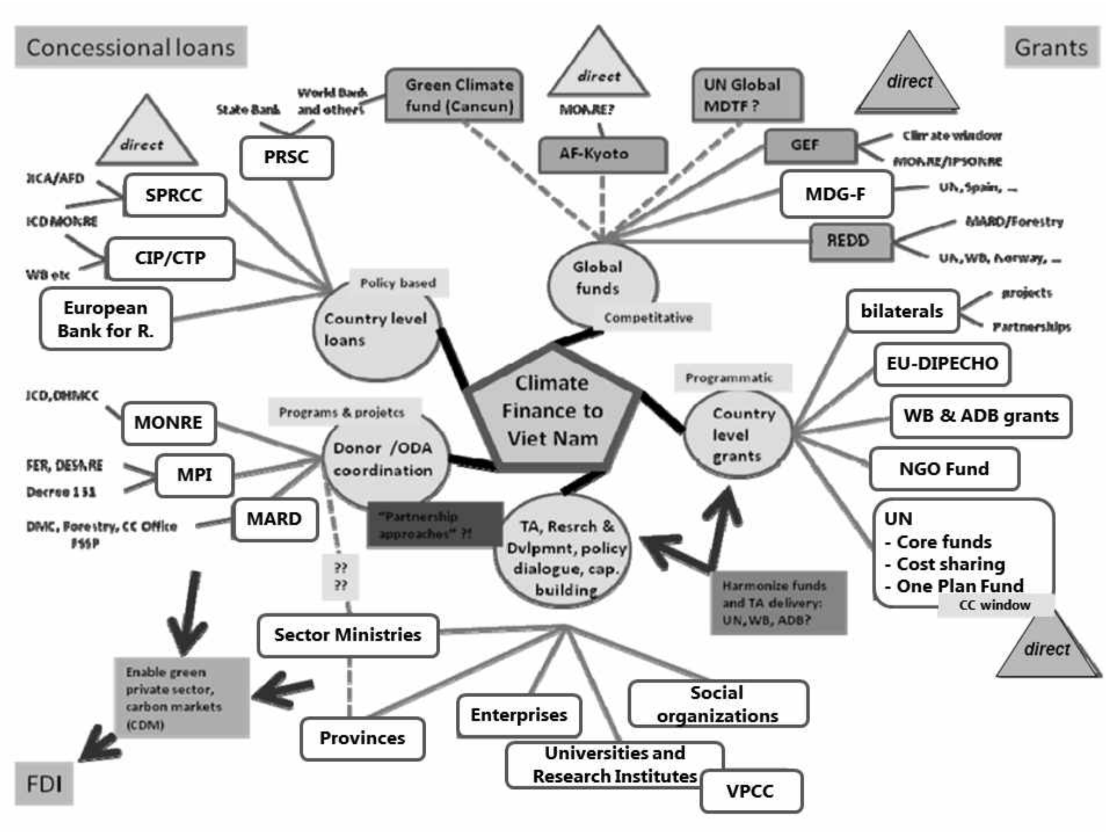
Strategically, in the long term, Vietnam should arrange adequate institutional structure for climate finance management and coordination. This assures for an effective mechanism as well as building trust and transparency in successful channeling climate finance resources. These both serve the expectation for enhanced climate finance resources and request from the donor communities in tracking and creating good records and profiles to access to those sources. In the short term, Vietnam should identify existing mechanisms which are most promising for accessibility. GCF is a hope for Vietnam as well as other developing countries to fulfill their dream for a greener and more resilient future.

After some years of operation, it is observed that once there is capacity to go through GCF's approval process—or eligible to receive GCF's support, a country/organizations can be confident to prepare strong proposals for other resources in terms of strict and/or complicated procedures (due to the fact that GCF is still on development of their procedures).

Vietnam should fully capture international financial and technical support to address climate change and help sustainable development efforts. It is important for Vietnam to develop appropriate structures and mechanisms to receive and strategically allocate climate change financing. This requires putting greater priority on capacity building, priority setting and ensuring transparent regulatory processes because these are stringent requirements of the GCF as well as other international financing mechanisms. It also requires stronger co-ordination among key ministries including the Ministry of Natural Resources and Environment, the Ministry of Planning and Investment, and the Ministry of Finance to ensure the climate change fund flows to areas where it is needed most.

The GCF requires some new mechanisms, including: involvement of private sector (both domestically and internationally in using capital, providing technologies, etc.); in parallel, it is needed to exploit financial resources from domestic private sector for counterpart funds, either via the public-private partnership (PPP) or commercial banks;

Figure 12. "Spaghetti of climate finance flows"



Therefore, to be eligible for accessing GCF, Vietnam needs to mainstream its GCF-related policies into its legal framework reform agenda, including state management on ODA and PPP as well as policies on small and medium enterprises (SMEs).

Lessons learnt from and information exchange with development partners and other successful developing nations (the Word Bank, UNDP, UNEP, GiZ, KfW, Indonesia, etc.), NDA should be a synthesizing agency in charge of planning and coordinating development resources including those for climate change issues. Those requirements that are expected to be handled by the NDA can be detailed as following:

- Capable to combine GCF resources with other sources like domestic budget, ODA, FDI and resources from private sector for development, including climate change. This is an essential requirement to assure for long term and sustainable financial sources for development in all countries.
- Meet all requirements of transparence in using all financial resources for development.
- Criteria to select eligible projects that are in line with the national development strategies and priorities as well as avoiding all overlapping.

In Vietnam's system and context, Ministry of Planning and Investment, as assigned by the Prime Minister to take lead in the mentioned-above policies including state management on ODA, PPP, SMEs development and private sector engagement.

Therefore, in 2014, Government of Vietnam officially appointed Ministry of Planning and Investment, the NDA to GCF.

Within the international context, Vietnam is already well positioned to access international climate finance. For any support, political commitment play vital role and Government of Vietnam has shown their strong commitments through intensive works on legal framework and policies related to climate change and green growth. Especially for GCF, Vietnam has prepared soft infrastructure and capacity to both indirect access (in the short run) and strong interest in the direct access modality of the GCF (in the long run). With regard to strategic planning, Vietnam has submitted its First and Second National Communication to the UNFCCC and has a comprehensive set of national strategies in place such as a National Climate Change Strategy, the National Green Growth Strategy, the National Action Plan on Climate Change, National Action Plan on Green Growth, etc. The strategies have been made operational by a set of legal documents (Laws/Decrees/Decisions/Circulars); some are now at the implementation level. Particularly, National Action Plan on Green Growth has identified prioritized sectors and actions as well as projects to be financed from government budget, ODA and private sectors. Forms of mobilizing financial sources are also addressed.

With regard to tracking climate-related expenditures in the national budget, Vietnam has no overall system in place; however Vietnam is tracking the funds for climate through climate public expenditure and investment review. The Government recognizes the importance of domestic finances responding to climate change and international support as importantly additional sources. Therefore, it is important to develop a financing mechanism to engage and mobilize resources from businesses. The GCF has a private sector facility to help mobilize private sector contributions, and it may also include a mechanism to allow business to get access to the funds of the fund. Vietnam should actively contribute to the design of such an approach and needs to define a suitable approach in its own context. Government is taking the initiatives in coming up with policies that engage the participation of private sector. MPI is working to produce list of CC/GG projects that can be used under PPP mechanism. Green bond and green stock market are also under studied for further potential mobilization of more resources for a greener Vietnam. Issues relating to carbon emission including carbon tax, carbon prices, CDM in the new context after COP 21 and emission trading system are also under investigation for application. Initiatives have been promoted in reality via the Circular by State Bank of Vietnam for green credit line to guide commercial banks to fund low emission projects. The Bank is also studying the Green Catalogue based on the Green Investment Guidelines for the banking system.

In case of Vietnam, it is essential to enhance the role of domestic resources (state budget and PPP) and external resources (ODA and FDI) through innovative policies triggering capital resources and focus on improving capacity to access to resources and technology transfer for government agencies and private companies. In the process shifting towards green economy, the following policies should be considered:

- Fiscal and tax policies (environment tax, green procurement, analysis on subsidies)
- Policies on innovation and industries (selecting and implementing policy tools, policy mix effectively)
- Policies facilitating restructuring (development of appropriate system and strategic reform)
- Policies supporting private sector’s adaptive process (identifying and solving risks and opportunities)
- Policies promoting sustainable consumption;
- Policies for high quality human resource development (vocational training)

8. Sharing Experiences among Countries at Global Forum–an Example from LEDS Forum

Low Emission Development Strategies (LEDS) are country-led and country-specific national strategic plans to promote economic growth while simultaneously reducing GHG emissions (in absolute or relative terms) over the long term without causing trade-offs with other environmental pressures. LEDS provide a framework for broader green growth strategies. LEDS are key element for short, medium and long term national economic development plans, contributing to green growth and climate resilience. At regional and global level, LEDS are used to support the objectives of the Millennium Development Goals, prioritizing the four "pros" of pro-growth, pro-job, pro-poor, and pro-environment. The five stages of LEDS process include organizing the process (e.g. identifying the institutional structure, selecting mechanisms for stakeholders involvement), collecting data and assessing the current situation, using analytical decision-making to identify and assess pathways, prioritizing and planning a portfolio of actions, and implementing and monitoring actions.

Many countries around the world are designing and implementing LEDS. These seek to achieve social, economic and environmental development goals while reducing greenhouse gas emissions and increasing resilience to climate change impacts in the long term. The LEDS Global Partnership (LEDS GP) (established in 2011) harnesses the collective knowledge and resources of more than 160 countries, as well as international donor and technical organizations, to strengthen climate-resilient, low-emission development efforts around the world.

The LEDS GP delivers support through three vibrant regional platforms: the Africa LEDS Partnership (AfLP), the Asia LEDS Partnership (ALP) and the LEDS Latin America and Caribbean Regional Platform (LEDS LAC). Each platform identifies its members' common priorities to focus the Global Partnership's efforts and achieve the greatest possible results. Technical working groups and affiliated programs provide technical support for implementation, through four global work streams: planning; finance; analysis and tools; and sectors. The Latimer House Principles provide a guiding structure for activities of the LEDS GP.

Asia LEDS is one of the three regional platforms of the LEDS GP, a network of more than 120 countries and international programs that enhances coordination, information exchange, and cooperation to advance climate-resilient, low emission growth. The Asia LEDS is a voluntary regional network that promotes and enables low-emission, climate-resilient development across the Asia and Pacific region through peer-to-peer learning, knowledge sharing, and improved coordination and cooperation among governmental and non-governmental partners. Members include organizations and individuals from the public, private and non-governmental sectors active in designing, promoting, and/or implementing LEDS and broader green growth initiatives.

Active implementation of National Green Growth Strategy and Action Plan at central and provincial levels in Vietnam is considered as country-led approach to localize global objectives on green growth and low-emission development. This has been seen as an innovatively best practice in the Low-Emission Development Strategies Global and Asian Partnership Forums (LEDS GP and Asia LEDS). This is a good connection between country leadership and global development agenda in pursuing green growth, low-emission development for a sustainable future. This enables linkages from on-ground demands to macro policy making process, setting systematic and well-addressed development policy directions for all sectors and regions within a country up to global level, where local people's voices would be heard and global development trends is truly for communities and future of member nations.

Ministry of Planning and Investment, focal point in formulating and leading the coordination of implementing Vietnam's green growth strategy and action plan, has been actively involved in all activities of LEDS GP and Asia LEDS from the early stage. Objectives set by MPI to join the forum are to:

(i) Highlight Vietnam's efforts to the world in pursuing sustainable development through the innovative implementation of Vietnam's green growth strategy and action plan;

(ii) Improve country competitiveness in mobilizing resources from development partners in implementing green growth and climate response activities.

(ii) Expanding opportunities to access to knowledge and experiences in implementing green growth.

(iv) More access to climate finances.

Currently, Vietnam is among a few countries in the Asia pioneering in realization of green growth and low emission development. To achieve set goals, Vietnam has been actively and voluntarily to engage in all types of activities in the forums. Vietnam serves as the Co-chair of the Global Finance Working group and Co-chair of the Steering Committee of Asia LEDS.

Vietnam is proudly organized and hosted three regional events in March 2014, October 2015 and recently June 2016 within Asia LEDS and LEDS GP framework, focusing on leveraging resources and catalyzing private participation in green growth and LEDS activities with more than 500 participants from 30 countries in the world.

With these efforts, Vietnam has successfully localized global objectives at national and sub-national levels. This reflects connection between practical demands and challenges to central policy making process as well as trends for donors' support and scientific works. The active involvement also help maximize two approaches of top-down and bottom-up to ensure the close collaboration between practitioners and policy-makers, investors and researchers.

9. The Way Forward

To enhance implementing Paris Agreement via continuing efforts from on-going activities in VGGS, there are some strategic tasks to be carried out:

Firstly, there is a need to formulate sectoral/sub-sectoral and provincial/sub-national green growth action plans with prioritized project lists according to their own needs and conditions.

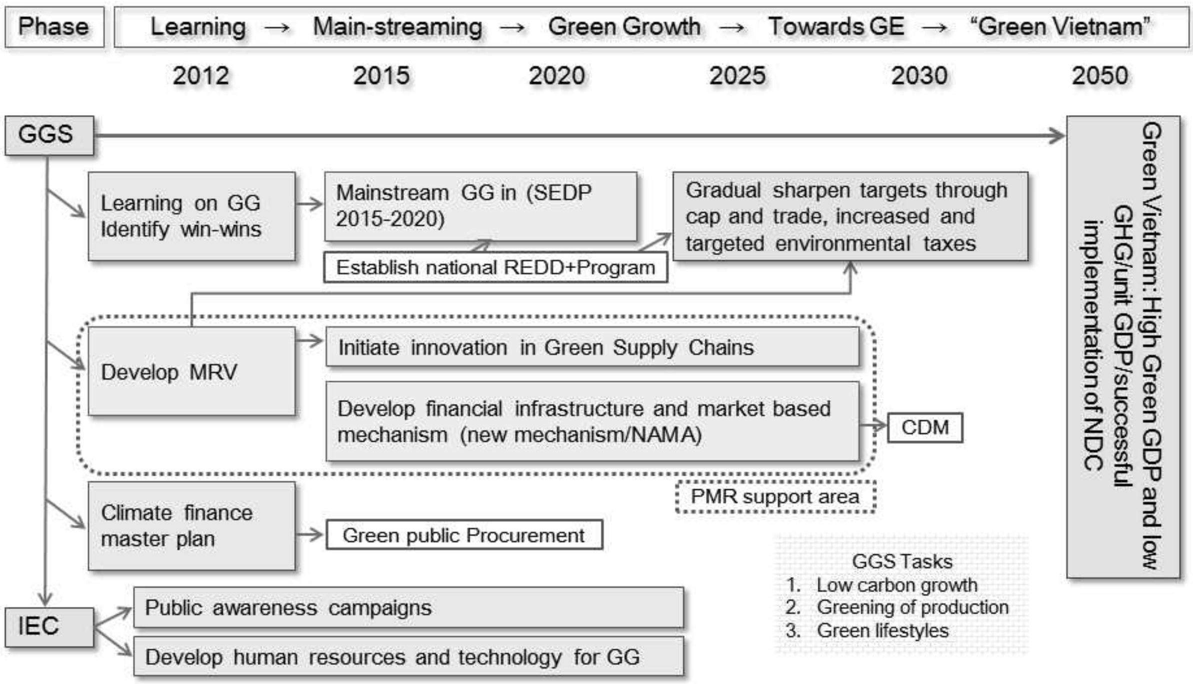
Secondly, enhancement of capacity and institutional setup are essential element to assure for effective coordination during implementing process. Improvement in finance and banking services as well as monetary market will help diversifying resources; Embedding results from green investment mapping exercise to call for investment.

Thirdly, finalizing the guideline for green public investment based on lessons gained from international organizations and other countries in the region.

Fourthly, engaging participation from private sector while ODA will catalyze the favorable environment for attracting private investment in climate change and green growth (under forms of technology transfer/pilot projects/case studies); Identify and apply public-private partnership in infrastructure and power generation areas. There is also need for a set of criteria for M&E to track progress and contributions from enterprises who accompanying the government in the implementation process via honorable recognition, prioritizing accessibility to incentives/funds,… in a transparent, accountable and fairplay manner.

Fifthly, promoting communication activities; improving energy efficiency; reducing energy consumption in production, transportation, trade; gradually improving energy mix in industrial production and transportation through increasing the use of clean, new and renewable energy; developing sustainable organic agriculture by changing structures of crop and husbandry production as well as reuse agriculture waste.

Figure 13. Proposed roadmap of Green Vietnam



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