THE COSTS AND BENEFITS OF TRANSITION TO A GREEN ECONOMY IN THE CONTEXT OF ENERGY AND CLIMATE CHANGE

by

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Abstract

This paper evaluates the costs and benefits of a green economy transition in the context of energy and climate change. Green economy has become one of the main topics that the world community deliberated in the RIO+20 United Nations Conference on Sustainable Development in 2012. The concept of green economy appeared first in the UNEP report in 2008 as a vehicle for a new engine for growth, employment and poverty eradication. OECD in 2011 released a similar report which highlights the role of green growth as instrument of opening up new sources of growth and reducing risks of shocks from imbalances of natural systems. Notwithstanding these assertions, developing countries are concerned that transition to a green economy will require additional costs to them and consequently they demand measures to reduce such risks. The Rio+20 provided quantitative targets for energy sector transformation for green economy: it called for doubling of energy efficiency improvement rate by 2030 and also doubling of the share of renewable energy in the global energy mix by 2030. By using an integrated assessment model of climate and the economy, the costs and benefits of achieving this transition are estimated. The present value of total abatement costs are lower than that of total benefits measured as a value of avoided climate damages. The incremental costs of abatement are estimated to be lower than the incremental benefits of carbon reduction. These configurations of costs and benefits indicate that a more ambitious action is justified. The financing availability will determine how much of the potential net benefits will be realizable. The Rio+20 green energy targets are insufficient to achieve climate stabilization. With climate problems remaining unresolved, the green economy would lose its rationale.

1. Introduction : The scope of analysis

Green economy has become one of the main topics that the world community deliberated in the Rio+20 United Nations Conference on Sustainable Development. The concept of green economy appeared first in the UNEP report in 2008 as a tool for operationalizing sustainable development which has been in existence more than two decades. It was presented as a vehicle for a new engine for growth, employment and poverty eradication. OECD in 2011 released a similar report which highlights the role of green growth as instrument of opening up new sources of growth and reducing risks of shocks from imbalances of natural systems. UNEP identified further positive aspects of green economy as a means of safeguarding natural capital and social equity and improving opportunities for jobs, energy and mobility.

Notwithstanding these assertions, developing countries are concerned that transition to a green economy will require additional costs to them and consequently they demand measures to reduce such risks. There is no reason to expect that transition costs would be limited to developing countries.

This paper examines the global costs and benefits of transition to a green economy. The agenda document of the Rio+20 UNCSD provides quantitative targets for energy sector transformation for green economy. Energy is the only natural capital for which the Rio+20 sets quantitative goals. This may imply that energy transformation is prerequisite to moving toward a green economy. The agenda document calls for specifically doubling of energy efficiency improvement rate by 2030 and also doubling of the share of renewable energy in the global energy mix by 2030. These actions will entail abatement costs and in return reduce climate damages.

The abatement costs depend upon three factors: reference emissions, mitigation targets, and technology. The reference emission is the base to which abatement activities will apply. It depends upon assumptions of future socio-economic parameters – such as population, productivity, industrial structure, and urbanization – and technology. A business-as-usual (BAU) scenario which is an emission scenario under the assumption of no climate policy is one class of reference scenarios. Depending on the assumptions of the future path of key drivers, there can be as many reference scenarios as modellers imagine. IPCC SRES(2000) is a notable example. If the reference scenario assumes a climate-resilient future so that low-carbon technologies become dominant, the abatement cost and the benefits of carbon reduction would be less than those expected under a carbon-intensive future. Thus, reference scenario is as much important as mitigation scenario in assessing abatement costs and the benefits of carbon reduction which would be the value of climate damages that would be avoided due to abatement actions.

The Rio+20 agenda documents, however, do not provide any quantitative indication of future CO_2 emissions to which the two measures of mitigation options will apply. In the absence of a Rio+20 reference CO_2 emissions scenario, I used the DICE's Base Case scenario as reference scenario.[1] This particular choice of reference scenario affects the feature of benefits analysis among others. The benefits of a green economy will be more than avoided climate damages, according to UNEP and OECD which presented the green economy vision as a new paradigm of world development. UNEP(2011) asserts that the green economy would bring forth "improved human well-being and social equity, while significantly reducing the environmental risks and ecological scarcities." UNEP argues that these outcomes would be the consequence of a green economy strategy which pursues efficiency improvement in the use of energy and other natural resources, and enhancement of the integrity of ecosystem and the earth system. The Rio+20 agenda documents clearly showed that the transition to green economy would be more than response to climate changes as they identified 15 sectors in need of transformation: food security, water, energy, sustainable cities, green-jobs-social inclusion, oceans and seas, natural disaster, climate change, forest and biodiversity, land degradation and desertification, mountains, chemicals and waste, sustainable consumption and production, education, and gender equality.

This paper does not attempt to analyze whether the green economy would be a viable alternative strategy of world development under which the flow of services from natural and traditional capital are optimized. The proponents of the green economy do not provide parameters defining green economy, amenable to quantitative analysis of transition path that would differentiate from the traditional growth path.

The scope of analysis in this paper is limited to the assessment of climate related costs and benefits under the green economy goals. The costs and benefits of achieving these goals are estimated using integrated assessment model of climate change. This paper consists of five sections. The following section provides an overview of the DICE. Section 3 presents the results of the key climate related variables under the reference and the green economy goals and Section 4 discusses the costs and benefits of green economy measures, followed by conclusions in Section 5.

2. Model

The DICE shows economic perspective of climate change based on the economic growth theory. The DICE consists of two sectors. The economic sector of the DICE provides a framework of analysis of the economy under the constraints of global warming. The atmospheric concentration of CO_2, which leads to climate change, is considered a negative capital in the aggregate production function.

The endogenous variables are GDP, carbon emissions, concentration of carbon in the atmosphere, temperature increases, climate damages, and abatement costs. The exogenous variables consist of population, social rate of

[1] The DICE (Dynamic Integrated model of Climate and the Economy) one of the integrated assessment models, was developed by William Nordhaus (2008). *A question of balance: Weighing the options on global warming policies*. New Haven: Yale University Press.

time preference, and productivity factors. Climate damages are estimated by a damage equation which is a function of the global mean surface temperature and GDP. The abatement cost is a function of the backstop technology costs, emission reduction, and participation rates.

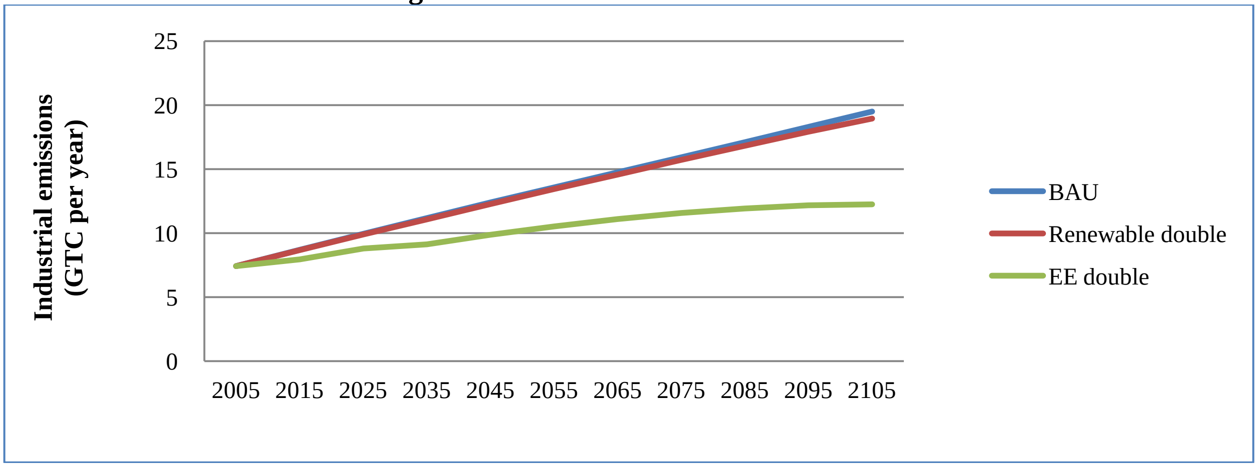
The geophysical sectors capture the anthropogenic dimensions of the carbon cycle: anthropogenic emissions, atmospheric concentrations of carbon, radiative forcing, the global mean surface temperatures and sea level rises are major variables of analysis.

For model analysis of green economy goals as specified in terms of energy efficiency and renewable energy targets, I controlled the model parameter related to emission reduction rates to accommodate these two policy targets.

3. Results

This section examines the major variables related to climate change under the green economy goal scenario. Figure 1 shows industrial emissions under the green economy reflecting the results of energy efficiency improvement and renewable energy expansion and BAU[2]. The UNEP green economy goals do not extend beyond 2035. For purpose of model simulation, I assumed for the remaining future years a doubling of the renewable energy share and energy efficiency improvement rates in every 30 years.

Figure 1. Industrial Emissions



The two-fold increase in the proportion of renewable energy in total primary energy consumption, one of the green economy goals, does not lead to much reduction in emissions. This reflects the very low base from which the renewable energy would have to grow to meet the target. The energy efficiency improvement leads to much larger reduction in emissions.

Under green economy, the industrial emissions in 2035will be 19.6% below BAU, and by 2105 the emissions will be 40% below BAU as shown in Table 1.

[2] Industrial emissions in the DICE model include emissions from all sectors-- such as industry, energy supply, transport, buildings, and waste management—except emissions resulting from land use changes.

Table 1. Industrial Emissions, under BAU and Green Economy (GtC per year)

	2005	2035	2105
BAU	7.4	11.2	19.5
Green Economy	7.4	9.0	11.7

Under the green economy scenario, the cumulative emissions for the period 2005-2055 will be 1953.9 Gt CO_2. The cumulative emissions -the key parameter for climate stabilization- are shown in the Figure 2. The upper limit for cumulative emissions for a 2℃ temperature stabilization is 1,000 Gt CO_2 at which the probability of exceeding 2℃ is 25%.[3] The green economy goals do not contribute to limiting emissions sufficiently to achieve 2℃ target.

Figure 2. Cumulative Emissions

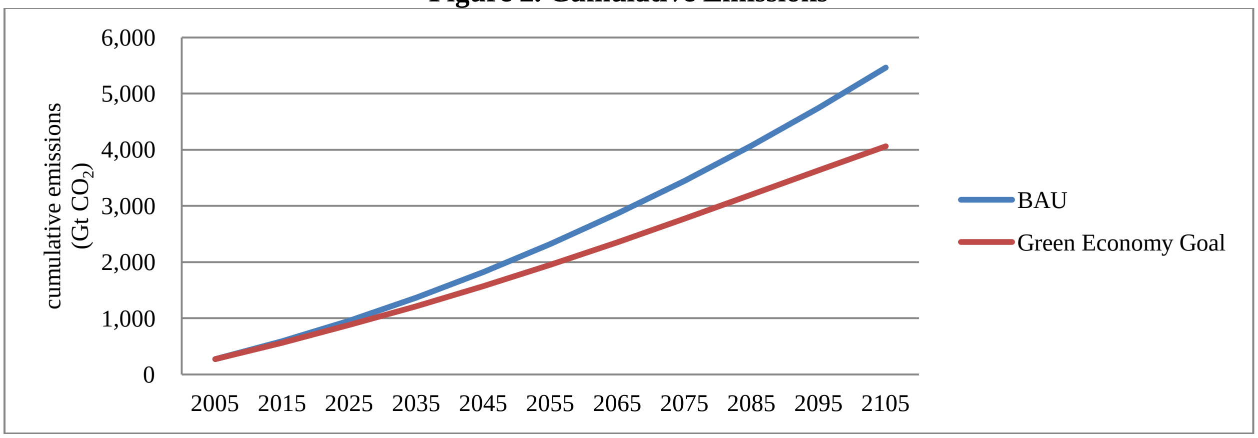
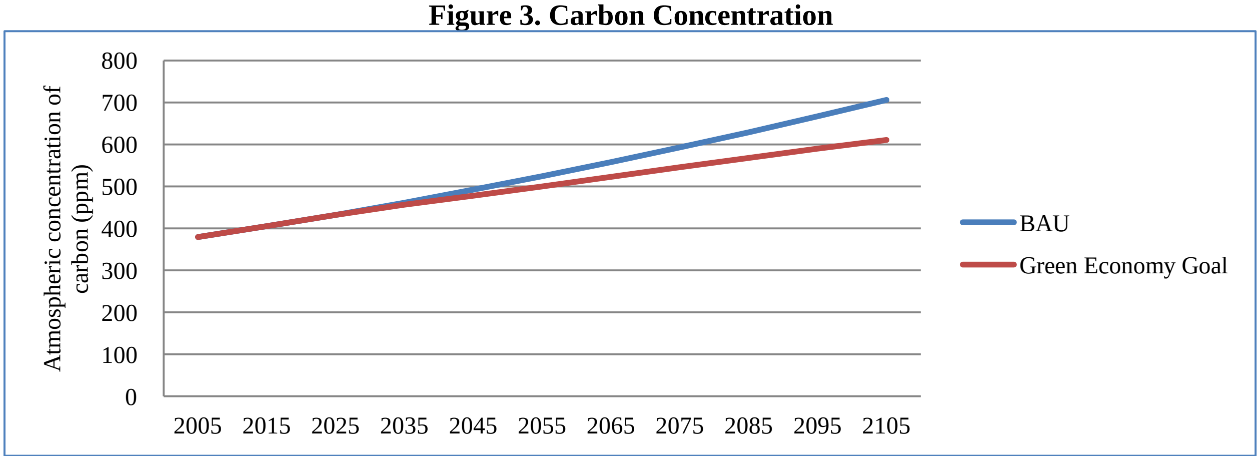


Figure 3 shows carbon concentration in the atmosphere under the two scenarios. The carbon concentration under BAU increases sharply compared to the green economy: 706 ppm vs. 609 pm by 2105. The atmospheric CO_2 concentration under the green economy is lower than the BAU, but fails to achieve stabilization of atmospheric stock of CO_2.

Figure 3. Carbon Concentration

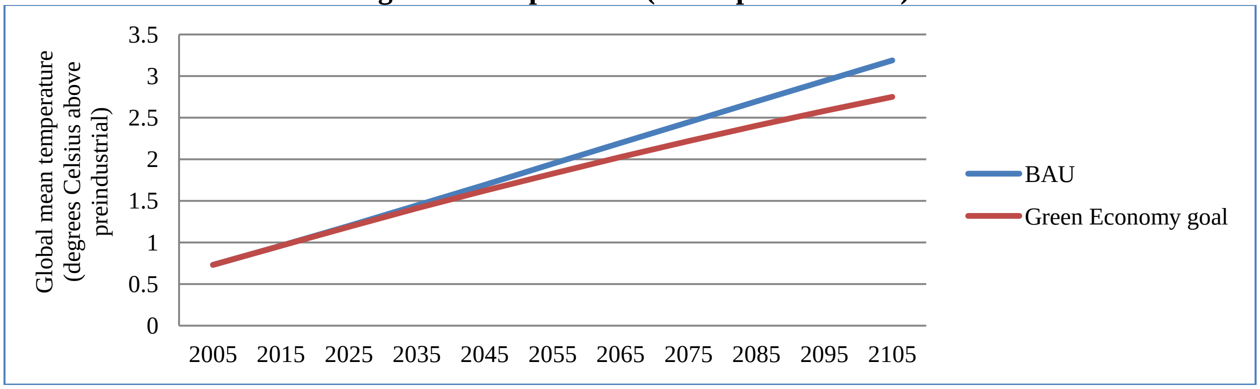


The global mean temperature under the two scenarios shows similar trajectories to those of the atmospheric carbon concentration. As shown in Figure 4, when no action is implemented, the temperature will be 3.19 degrees Celsius above preindustrial level by the end of this century. Under the green economy, the increase in global

[3] Malte Meinshausen, et al., "Greenhouse-gas emission targets for limiting global warming to 2℃, *Nature* Vol 458, 2009

mean temperature is less than 3 degree Celsius, but the warming continues. The green economy fails to stop the warming.

Figure 4. Temperature (above preindustrial)



4. The Costs and Benefits of a Green Economy

4.1 Costs of a Green Economy

The abatement cost is dependent upon emission reduction rates which are specified by the green economy goals in terms of target energy efficiency improvement and renewable energy penetration. The back-stop technology is an important element in determining abatement costs in the DICE model. But for the 100-year time horizon considered in this paper, the cost of back-stop technology would not affect the abatement costs because the DICE model sets it at $1000 per ton of carbon dioxide removal and the carbon value would not rise to that level within 100 years under green economy, as will be explained later.

Figure 5. Abatement Cost

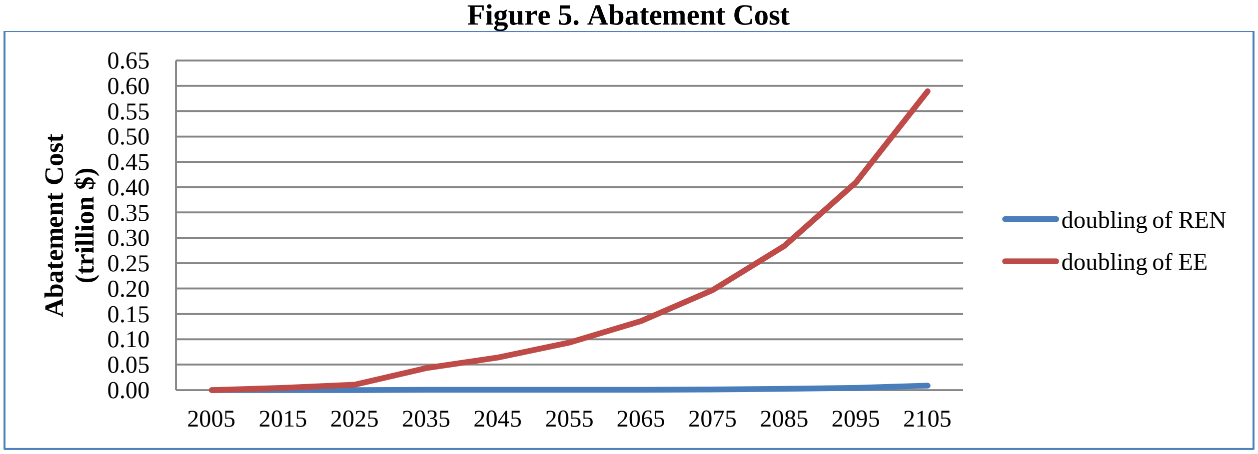


Figure 5 shows the abatement costs of two reduction options. The cost required for the doubling of energy efficiency improvement is much higher than the one for doubling the share of renewable energy in total primary energy consumption. Most bottom-up studies show the occurrence of negative costs from adoption of energy efficiency improvement options.[4] The DICE is not a bottom-up model and thus the abatement cost of energy efficiency improvement may not be lower than other options. The higher abatement costs for efficiency improvement are consistent with the much larger reductions in carbon emissions expected from this option than from renewable energy expansion.

[4] IPCC Fourth Assessment Report: Mitigation 2007

Figure 6. The Relation Between Abatement Costs and Emissions Reductions

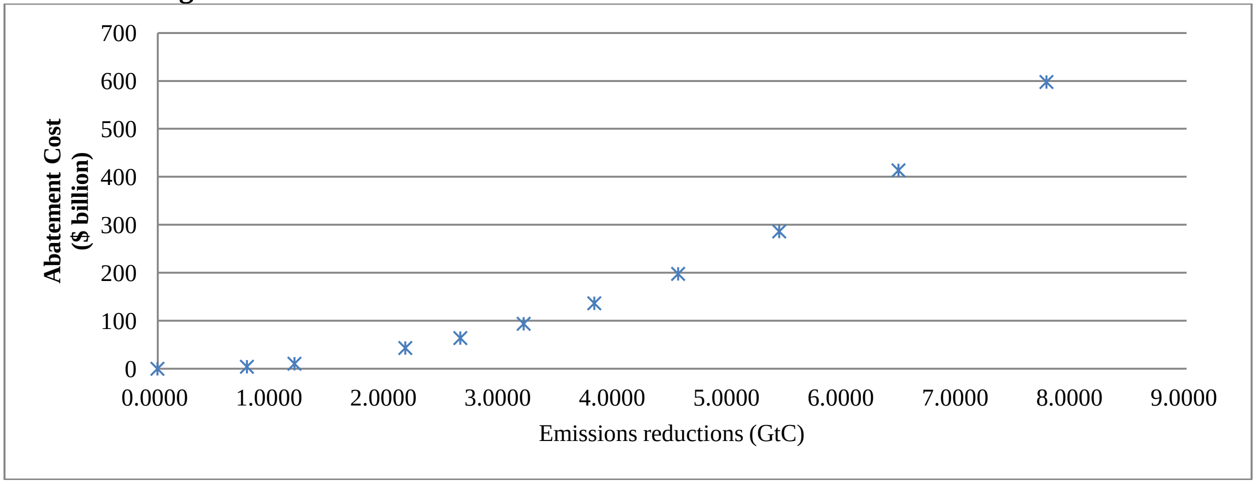


Table 2. Incremental Abatement Cost ($/tC)

	2005-2015	2015-2025	2025-2035	2035-2045	2045-2055	2055-2065	2065-2075	2075-2085	2085-2095	2095-2105
Incremental Abatement Cost	5.4	15.2	33.8	43.0	53.7	69.2	83.8	100	122.2	142.3

Figure 6 shows the relation between abatement costs and emissions reductions for the 2005-2105 time horizon. The average abatement cost is rising at an increasing rate over time. The incremental abatement cost for the period 2015-2025 is $15 per ton of carbon reduced and this rises to $54 for the period 2045-2055, and $122 for the period 2085-2095 as shown in Table 2. For the entire 100-year period, the present value of total abatement cost is $0.62 trillion as shown in Table 3.

Table 3. Present Value Abatement Cost

	Present value Abatement Cost (Trillion of 2005 U.S. dollar)	Cumulative emissions (GtC)	Global temperature (2100)
BAU	0.0014	1487	3.19
Green Economy	0.6109	1107	2.74

4.2 Benefits of Green Economy

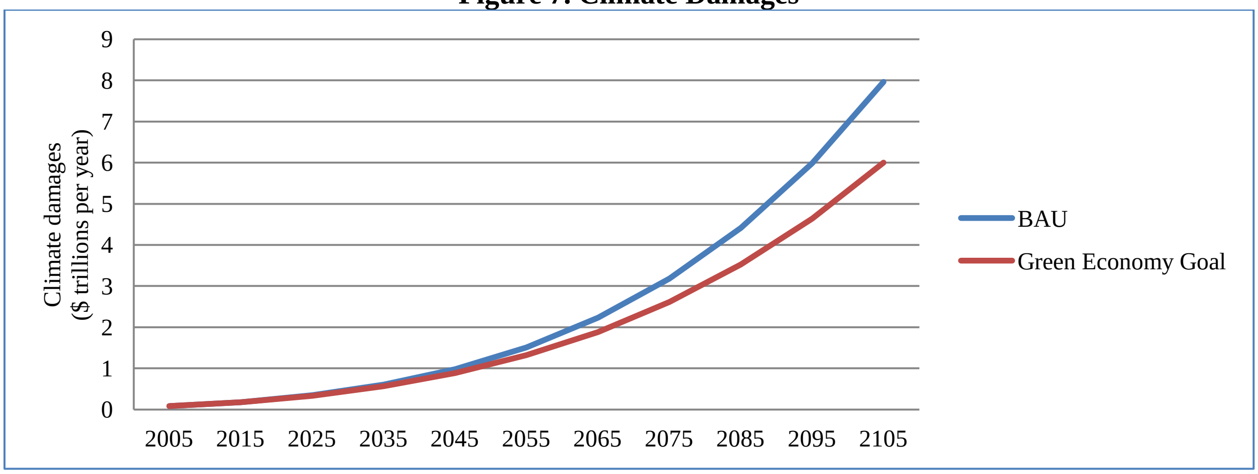
Benefits are the amount of damages reduced due to green economy actions. In this paper, the damages are assumed to reflect negative impacts of climate changes. There would be other damages that the pursuit of green economy may contribute to their reductions. But this paper focuses on only the climate-related damages because the green economy vision as presented by OECD and UNEP would be incompatible with a carbon-intensive economy.

Table 4. Climate Damages under the Green Economy

	Present value Climate Damages (Trillion of 2005 U.S.)	Cumulative emissions (GtC)	Global temperature (2100)
BAU	13.5	1487	3.19
Green Economy	11.7	1107	2.74

The climate damages are a function of global mean temperature increase and the scale of the world economy. The increase in global mean temperature would be limited to 2.74℃ under the green economy as opposed to 3.19℃ under BAU. This reduced warming is due to 25% decrease in cumulative emissions under the green economy to 1107 billion tons of carbon over years up to 2105. In terms of present value, the estimate of climate damages under the green economy would be 13% less than the damage estimate under BAU, leading to a present value benefit of $1.8 trillion as shown in Table 4.

Figure 7. Climate Damages



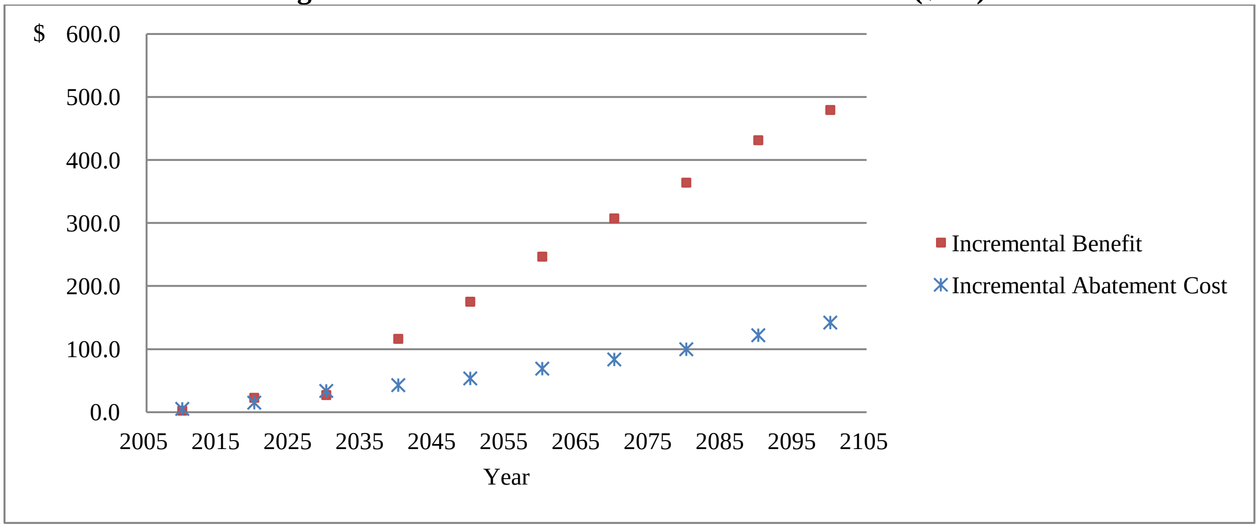
In the BAU, climate damages rise from $0.084 trillion in 2005 to $ 7.56 trillion in 2105. The green economy reduces the climate damages 13% relative to BAU in 2055 and 25% relative to BAU in 2105 as shown in Figure 7. The area between the two damage curves is the total amount of reduced damages resulting from green economy and equal to the total benefits of pursing the green economy.

Climate damage reduction will not begin appreciably until 2065. Figure 7 clearly demonstrates that the benefits of emissions reductions belong to future generations living in the second half of this century. The costs of the decision to adopt the green economy, however, begin to impose immediately on the current generation. The incremental benefit of carbon reduction is very low in early period but rises very rapidly. For the period 2015-2025, the incremental benefit per ton of carbon reduction is $23 and it rises to $175 in 2045-2055, and $432 in 2085-2095. Note that the incremental benefits exceed the incremental abatement costs as shown in Figure 8.

Table 5. Incremental Benefit

	2005-2015	2015-2025	2025-2035	2035-2045	2045-2055	2055-2065	2065-2075	2075-2085	2085-2095	2095-2105
Incremental Benefit	2.6	22.9	27.3	116.4	175.3	246.8	307.5	364.2	431.5	479.5

Figure 8. Incremental Abatement Cost and Benefit ($/tC)



4.3 Comparison of Costs and Benefit under the Green Economy

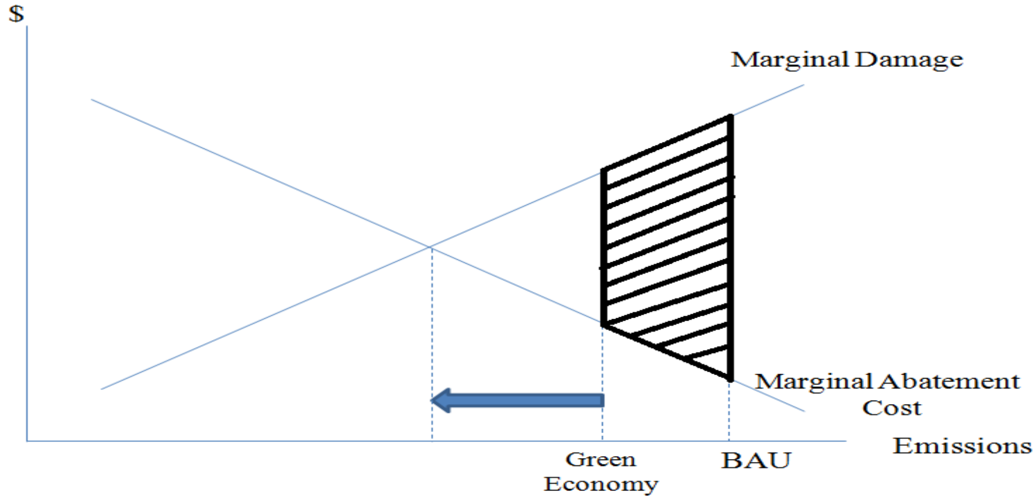
The total costs of a transition to the green economy would be present value $0.6 trillion; and the total benefits of a transition would be present value $1.8 trillion. This outcome of costs and benefits reflect the combined effects of adopting two green economy goals; doubling of energy efficiency improvement and doubling of renewable energy shares by 2035 and continuation of these trends at slightly reduced rates afterward.

Table 6. Summary of the Main Results

	Present value Climate Damages (Trillion of 2005 U.S.)	Present value Abatement Cost (Trillion of 2005 U.S. dollar)	Cumulative emissions (GtC)	Global temperature (2100)
BAU	13.5	0.0014	1487	3.19
Green Economy	11.7	0.6109	1107	2.74

The positive net benefit implies that a more ambitious action is warranted. Such a move would increase net benefit as evidenced by the higher estimate of incremental benefits than incremental abatement cost. Figure 9 shows the evaluation of cost and benefit at the margin. A trapezoid with deviant crease lines in the figure shows the reduction of climate damages net of increased abatement costs when the green economy pushes CO_2 emissions to the left of BAU. A further push to the left would increase the size of the net benefit. The green economy targets as expressed in doubling of energy efficiency and the renewable energy shares are insufficient to achieve climate stabilization, and operate at sub-optimal scales.

Figure 9. Cost and Benefit at the Margin



5. Conclusions

The cost of pursuing the doubling of energy efficiency and renewable energy penetration would be much less than the benefits that those options would yield in terms of avoided climate damages. A more ambitious goal than the current targets would thus be warranted. The current targets would yield slightly less climate damages compared to BAU, but fail to contribute to stabilization of atmospheric CO_2 concentration. The cumulative emissions will continue increase, exacerbating climate changes and attendant impacts and vulnerabilities. If climate changes continued worsen under the green economy, what would be rationale for pursuing green economy? Would the grand vision of the green economy survive when it fails to respond to climate change challenges?

A more ambitious action is justified based upon cost-benefit comparison. Whether such actions will indeed be taken up depends upon the availability of financing. The front-end costs of efficiency improvement and renewable energy use are high and financing of investment is key to realizing potential benefits. With a benefit side subject to larger uncertainty than the uncertainty facing the cost side, the prospect of financing a transition to green economy may not be good. The concerns raised by developing countries are thus rational and apply as well to developed countries. The poor countries are, however, more exposed to the risks than the rich ones due to differences in the financing capacity. The developing country's demand for financing and technology support to get on board the green economy is justified not only by equity consideration but also by efficiency criteria which call for global participation in emissions reduction.

The positive net benefit reported in this paper applies only to the analysis of climate related activities. What's not covered in the analysis is an assessment of net benefits between climate investment and non-climate investment. Would technological progress and productivity increase differ between these two types of investment? Would this difference, if exists, reflect opportunity costs of green economy? The green economy goal competes against many other global challenges. Each individual, each country has different perspectives and priorities toward competing global problems. Should the cost and benefit assessment of green economy consider the balance of the competing goals? Further research is needed.

Reference

Azar, C. and K.Lindgren(2003): "Catastrophic Events and Stochastic Cost-Benefit Analysis of Climate Change," *Climatic Change* 56: 245-255

Bréchet, T., F. Gerard. And H. Tulkens (2011): "*Effieicnty vs. Stability in Coimate Coalitions: A Conceptual and Computational Appraisal*," The Energy Journal 32. no. 1: 49-74

IPCC, *Emissions Scenarios*, Cambridge University Press, 2000

Malte Meinshausen, et al., "Greenhouse-gas emission targets for limiting global warming to 2℃", Nature Vol 458, 2009

Metz, B., Intergovernmental Panel on Climate Change., & Intergovernmental Panel on Climate Change. (2007). *Climate change 2007: Mitigation of climate change : contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Nordhaus, W. D. (May 01, 1993). "Optimal Greenhouse-Gas Reductions and Tax Policy in the "DICE" Model," *The American Economic Review, 83,* 2, 313-317.

Nordhaus, W. D. (2008): *A question of balance: Weighing the options on global warming policies*. New Haven: Yale University Press.

OECD (2011): *Towards Green Growth*

Rio+20 United Nations Conference on Sustainable Development (2012): *The Future We Want—Zero draft of outcome document*

United Nations (2012): *Report of the United Nations Conference on Sustainable Development*

UNEP: http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=548&ArticleID=5957&l=en

United Nations Environment Program (2011): *Towards a Green Economy: Pathways to Sustainable Devleopment and Poverty Eradication*