WHAT DEVELOPMENT FOR BIOENERGY IN ASIA: A LONG-TERM ANALYSIS OF THE EFFECTS OF POLICY INSTRUMENTS USING TIAM-FR MODEL

Seungwoo Kang*, Sandrine Selosse*, Nadia Maïzi*
*MINES ParisTech, PSL Research University, CMA - Centre for applied mathematics,
CS 10207 rue Claude Daunesse 06904 Sophia Antipolis Cedex, France

ABSTRACT: Asian countries have sharply increased their energy consumption with economic growth, inducing an extremely high dependency on energy fossil due to a low level of energy resources. In 2011, Asia's share in global energy consumption reached 40%, of which China, India, Japan and South Korea represented 70%. Furthermore, these countries are ranked among the world's largest CO_2 emitters. Hence, bioenergy is currently being highlighted to diversify the energy mix and to mitigate climate change in these countries. Along with the direct bioenergy promotion policies, a variety of economic policy instruments are introduced as emission trading scheme, carbon and energy taxes. In this study, we estimated the evolution of bioenergy deployment from current energy and climate policies through scenarios analysis using bottom-up energy system optimization model, TIAM-FR, a TIMES family model from ETSAP/IEA. Different scenarios were developed with basis on political instruments in these countries: (1) BAU, (2) Global climate change (50% of world GHG emissions reduction), (3) National GHG mitigation targets from INDCs, (4) National GHG mitigation targets + Bioenergy policy, (5) Carbon tax system. According to the results, the higher is climate constraints, the higher is bioenergy development. Hence, carbon tax system derived the most bioenergy consumption by 2030 followed by global climate change scenario. Current INDCs target is evaluated as not sufficient to promote bioenergy development without renewable energy targets and biofuel blending mandates.
Keywords: bioenergy, climate change, action plan, strategy, policies

1 INTRODUCTION

During the last decades, Asia countries have drastically increased their energy consumption due to fast economic developments and growing population. Currently, Asia is highly dependent on fossil energy and it led this region to be ranked at top Greenhouse gas (GHG) emitter in the world. Then, growing concerns about climate change, bioenergy attracts more and more attention as one of the best alternative sources of energy to fossil energy, as currently shown in the number of ambitious bioenergy promotion policies implemented in Asia. However, the relation between bioenergy deployment and several political instruments in harmonized energy system still needs to be addressed. Therefore, this study aims to observe how the different political tools encourage or discourage bioenergy development and especially for the largest contributors to GHG emissions in Asia, i.e. China, India, Japan and South Korea.

2 METHODOLOGY

The evaluation of bioenergy's future is performed through scenario analysis. Several different scenarios have been analyzed and compared to current bioenergy policies of four Asian countries, China, India, Japan and South Korea, for the period 2005-2050. This long-term analysis is performed with a bottom-up energy system optimization model, TIAM-FR, developed by the MINES ParisTech's Centre for Applied Mathematics[1].

2.1 Presentation of TIAM-FR

TIAM-FR is the French version of ETSAP-TIAM, the world TIMES model developed under IEA's ETSAP (Energy Technology Systems Analysis Program). This model is based on a bottom-up approach and a technology-rich representation of the energy system to estimate its changes and evolutions for the long-term.

The model covers the entire world in 15 regions, of which China, India, Japan and South Korea are separately represented. And the model has 5 energy service sectors (agriculture, industry, commercial, residential, transport) whose demands are based on socio-economic assumptions (GDP, household, population, sectorial growth, etc.). Technico-economic characteristics are integrated into the model to describe several technologies in all sectors of each stage of the energy chain (extraction, conversion, processing, transmission, and end-uses) in each region (see figure 1).

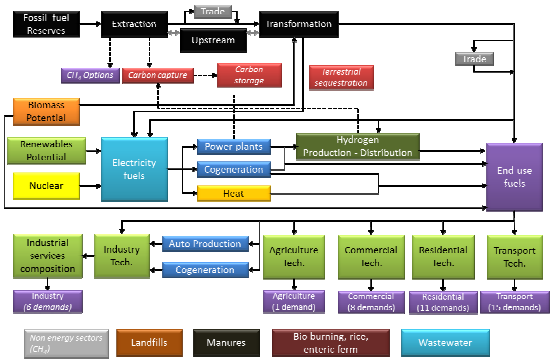


Figure 1: Energy system structure in TIAM-FR

This model is based on the optimization theory, which aims to minimize the discounted global energy system cost over the entire model horizon until 2050. The model calculates the net present values of total cost for each region with the objective function as follows:

$$NPV = \sum_{r=1}^{R} \sum_{y \in YEARS} \left(1 + d_{r,y}\right)^{REFYR-y} * ANNCOST(r,y)$$

Where NPV is the net present value of the total cost for all regions over the projected period; ANNCOST (r,y) is

the total annual cost in region r and year y; dr,y is the discount rate; REFYR is the reference year for discounting; YEARS is the set of years and R is the set of regions (15 regions).

Results of the optimization are the structure of the energy system for each region, i.e. type and capacity of the energy technologies, energy consumption by fuel, development of emissions, energy trade flows between the regions as well as the therefore required transport capacities, and detailed energy system costs plus information on the marginal costs of environmental measures, etc.

2.2 Energy-climate Scenarios

In this study, several different climate scenarios were explored on four countries (China, India, Japan and South Korea). A business as usual (BAU) scenario is firstly developed and calculated. This baseline scenario without any emission constraint outlines some key patterns in the evolution of the energy system, and serves as the starting point for comparing other different avenues of carbon mitigation over the period 2005-2050.

Secondly, Global_Factor2_GHG scenario, which consists in reducing 50% of GHG emissions by the year 2050 compared to the year 2005.

From the recent decision at COP 20 (Conference of Parties) in Lima, Peru, each country is invited to communicate its GHG mitigation action plan by reporting Intended Nationally Determined Contributions (INDCs) in advanced of the COP 21 in Paris. Currently, China, India, Japan and South Korea have submitted their INDCs report to the UNFCCC secretariat [2]. According to these reports, it comprises national GHG emission reduction target until 2030 and action plans as renewable energy and biofuel supply targets. Based on INDCs reports [3–6], two scenarios are developed in this study.

First of them, called "INDC", applies only the GHG emission reduction targets until 2030 to investigate the bioenergy evolution without other mandates. Second scenario, called "INDC+RNW+BIOFUEL", combines GHG emission targets with renewable and bioenergy supply targets. The table 1 presents the different GHG emission targets applied to this scenario:

Table I: GHG emission reduction targest applied to scenario (recalculated INDCs target by author)

Country	Target
China	Reduce CO_2 emissions per unit of GDP by 60-65% in 2030 compared to 2005 level
India	Reduce GHG emissions per unit of GDP by 33-35% in 2030 compared to 2005 level
Japan	Reduce GHG emissions level 16-20% in 2030 compared to 2005 level
S. Korea	Reduce BAU GHG emissions level by 25.7 in 2030

In case of Japan, announced GHG emission reduction target is a reduction of 26% by 2030 compared to 2005 level. However, the Japanese government plans to use 50 -100 million tCO2eq of JCM (Japanese Crediting Mechanism), which achieves 4-8% of their target. In addition, we applied the target of GHG emission related to energy consumption, which is published as 24% of reduction by 2030 in INDCs. Hence, we applied recalculated target of 16-20% of reduction by 2030 compared to 2005 level to our scenario.

South Korea announced their target to reduce 36% of BAU GHG emissions by 2030. However, the ministry of environment of South Korea communicates in official press that 11.3% emission reduction will be achieved by international carbon crediting system. Hence, we applied only domestic GHG emission targets of 25.7% reduction to our scenario.[7]

Different renewable energy targets and biofuel blending rates are explained in table 2. Particularly, in case of Japan, maximum blending rates of bioethanol and biodiesel are implemented for avoiding possible degradation of vehicle performance.

Table II: Renewable energy targets and biofuel blending mandates

Country	Target
China	15% of non-fossil in TPES by 2020 and 20% by 2030 10% minimum blending rate of bioethanol in gasoline by 2015
India	40% of power supply capacity from renewables in 2030 20% minimum blending rate of biofuel
Japan	Solar 7%, Wind 1.7%, Geo 1.1%, Hydro 9.2%, Biomass 4.6% by 2030 [3] maximum blending rate (3% bioethanol, 5% biodiesel) [8]
S. Korea	4.6% renewables by 2029 [9] 3% minimum blending rate of biodiesel by 2020; 5% by 2030 [10]

In addition to these direct GHG emission constraints, economic instrument to reduce GHG emission, a carbon tax system, was analyzed in this study. We developed two different levels of carbon tax scenarios described in table 3. For low level of carbon tax, 80$/tCO2 was applied by 2020 and 100$/tCO2 by 2030. Then the carbon tax level progresses to 270$/tCO2 until 2050. On the other hand, under high level of carbon tax scenario, tax rate is doubled by 2030 as 200$/tCO2 compared to low level scenario.

Table III: Carbon tax levels

Unit : $/tCO2eq	2020	2030	2050
Low Tax	80	100	270
High Tax	150	200	530

In our study, carbon tax scenarios are independently represented, which are not combined with other scenarios. The stand-alone carbon tax scenarios are calculated to estimate the effectiveness on GHG emission reduction and bioenergy development.

3 RESULTS

3.1 Final energy consumption: bioenergy

In this study, we calculated each scenarios until 2030 for each countries (China, India, Japan and South Korea).

The first option to response to theses climate constraints in these countries was transition from coal to gas and other less GHG emitting energies. Furthermore, the results state that stricterclimate constraints derive more bioenergy consumption share in final energy consumption. In all four studied countries, high level of CO2 tax system, which is the most restrictive climate scenario, promotes more bioenergy consumption than other scenarios.

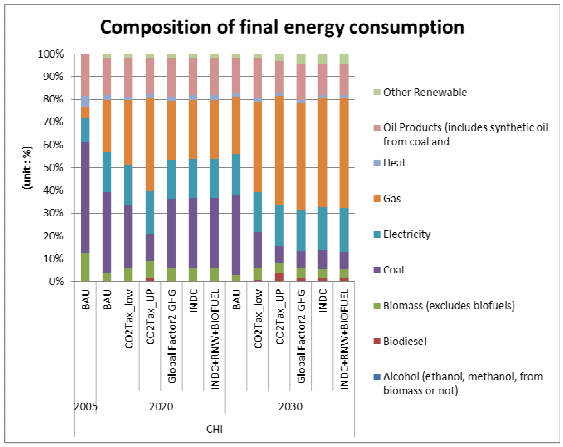


Figure 2: Finale energy consumption until 2030 : China

In China, bioenergy consumption share increases up to 22.9% by 2030 with high level of carbon tax scenario although it remains at 11.4% with BAU scenario. On the contrary, coal consumption disappears in the first reaction to climate-energy constraints by being replaced with gas (see figure 2).

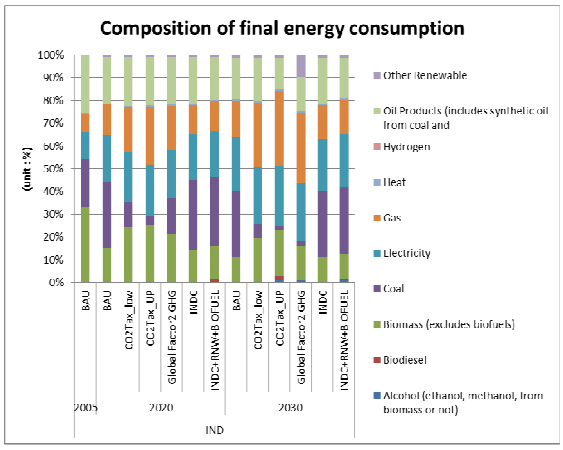


Figure 3: Finale energy consumption until 2030 : India

In case of India, biofuel consumption start to appear since 2020 under INDCs scenario combined with 20% of biofuel blending mandate. However, India's voluntary GHG target can not enoughly drive bioenergy consumption than BAU scenario. For example, INDCs scenario derives between 14% ~ 15% by 2020 while 15% of bioenergy consumption shows up under BAU scenario by 2020. By strengthening climate constraiants by 2030, bioenergy consumption becomes more sigfinifcant under climate scenarios than BAU scenario. While BAU scenario shows 11% of bioenergy consumption, intensified climate scenarios promote it up to 22% from 12%. In case of fossil energy consumption, India's INDCs pledges allow still significant quantity of coal consumption, about 30% of total final consumption, due to the low restriction of GHG emissions (see figure 3).

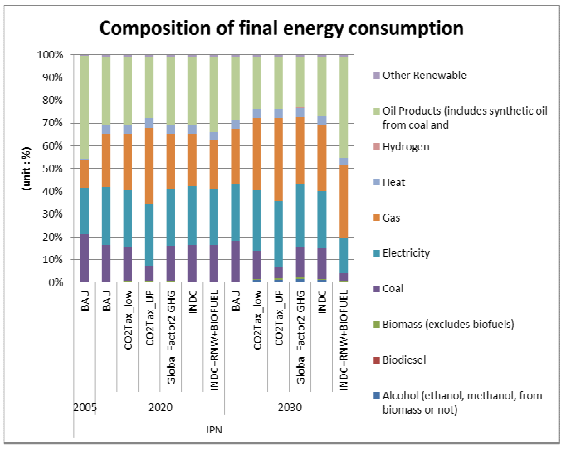


Figure 4: Finale energy consumption until 2030 : Japan

In Japan, the share of bioenergy in final energy consumption is insignificant during all projected years, which represents only between 0.4%~2.5% (see figure 4). In fact, Japan is the only country, who set a maximum blending rate of biofuels for the reason of vehicle performance and security issues. Hence, this regulation limits promotion of biofuels in transport sector.

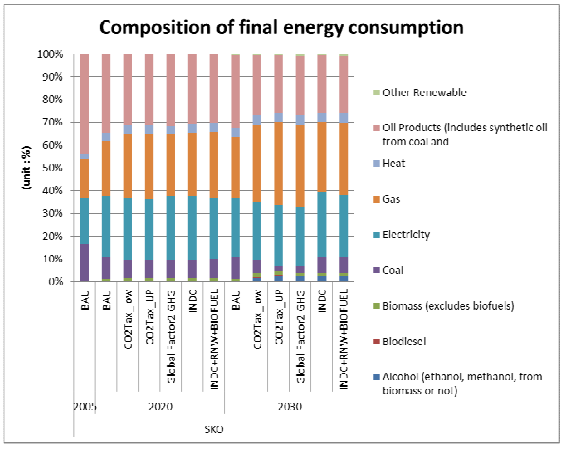


Figure 5: Finale energy consumption until 2030 : South Korea

Bioenergy evolution in South Korea is not dissimilar to Japan's situation. Bioenergy is not the first promising option to reduce GHG emissions. However, tight climate scenarios since 2030 brings up bioethanol and biodiesel consumption more than required minimum blending rate. Share of biofuel in final energy consumption increases until 3% (alcohol 2.3% and biodiesel 0.7%) at most by 2030 (see figure 5).

3.2 Power supply sector

According to scenario results (see figure 6), energy transition from coal to gas appeared as the first considered option. Then, coal CCS technology dominates the electricity generation with tighter climatic constraints as "high level of carbon tax system" and "Global Factor2 GHG" scenarios. By 2030, coal CCS technology in power supply sector represents about 57% for China, 58% for India and 39% for Japan under higher carbon tax scenario. Meanwhile, coal CCS technology does not come up with South Korea but only the first phase of energy transition from coal to gas occurs until 2030 and fossil energy still dominates energy mix for power supply. However, higher climate constraints lead to develop gas CCS technology for South Korea by 2050.

In energy mix of power supply sector, renewable energies and CCS technologies are in competition. And we observed that CCS technologies become more representatives with higher climatic constraints and the share of renewable energies, including bioenergy, decreases. For example, the share of bioenergy drops to almost 0% with higher carbon tax system in all four studied countries by 2030 while "INDC+RNW+BIOFUEL" scenario produces 22% of electricity from biomass in India, 7.3% in China, 5% in Japan and 1.6% in South Korea.

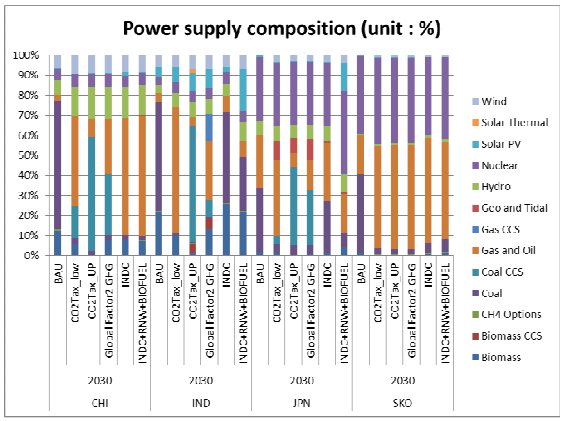


Figure 6: Power supply energy mix in 4 countries by 2030

3.3 GHG emission reduction: INDCs

In this section, we studied GHG emission reduction of each climate scenario with a focus on announced targets of GHG emission reduction in INDCs reports. In case of China and South Korea, the announced GHG targets are situated near the emission levels of "carbon tax system" and "global Factor2 GHG" scenarios. In 2030, China's GHG emissions increases to 7.5 $GtCO_{2eq}$ with INDCs target as well as 7.1$GtCO_{2eq}$ with global GHG reduction scenario by 50% (see figure 7).

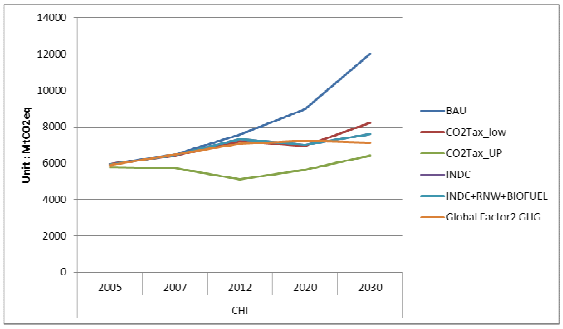


Figure 7: GHG emission projection for China

Also, South Korea's GHG emissions reach 0.45 $GtCO_{2eq}$ with INDCs target, which is similar to global GHG Factor2 scenario's estimate GHG emissions of 0.42 $GtCO_{2eq}$ (see figure 8).

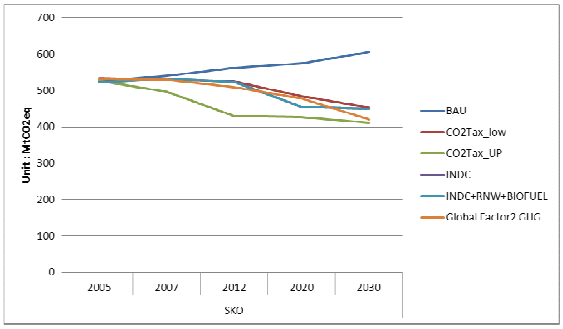


Figure 8: GHG emission projection for South Korea

On the other hand, the targets of GHG emission reduction by 2030 in Japan and India derive the GHG emissions, far away from global GHG emissions reduction target, and remains on BAU level. In 2030, Japan's GHG emissions with INDCs target (1.04 $GtCO_{2eq}$) exceeds about 37% over Global Factor2 scenario emissions (0.75 $GtCO_{2eq}$) and achieve only 9% of reduction from BAU level (1.14$GtCO_{2eq}$) (see figure 9).

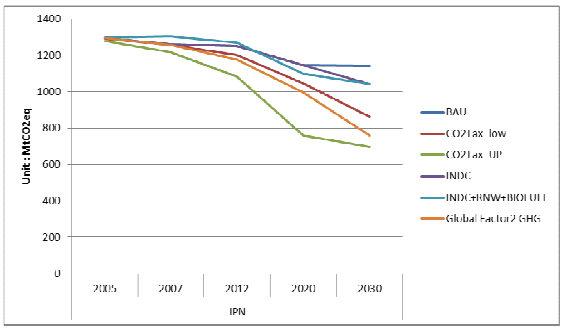


Figure 9: GHG emission projection for Japan

This non conformity with global Factor2 GHG scenario intensifies in India. Current carbon intensity reduction pledge of India brings GHG emissions up to 3.2 GtCO2eq by 2030, which exceeds about 62% over allowed GHG emissions under global Factor2 GHG scenario (1.9 GtCO2eq). And India achieves only 10% of GHG reduction from their BAU GHG emissions level (3.6$GtCO_{2eq}$) (see figure 10).

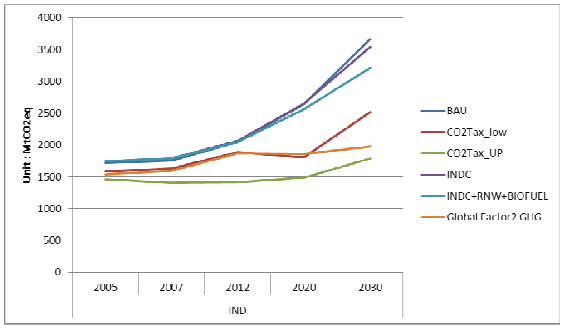


Figure 10: GHG emission projection for India

4 CONCLUSION

In all four studied countries, bioenergy consumption increased with different climate constraints. As a result, the tighter are climate constraints imposed, the more is bioenergy developed. However, as we identified in power supply sector, CCS technology becomes dominant from a certain level of climate constraint. In this case, biomass' share decreases in total energy mix by replacing with more economic and less GHG emitting technologies as Coal and Gas CCS technologies. Hence, the results show that higher climate constraints do not always guarantee more bioenergy development and it is required to investigate optimal level of climate constraints that may maximize bioenergy development.

In terms of GHG emissions, INDCs GHG emissions targets of China and South Korea approached closely to global GHG reduction target of factor 2. However, current INDCs GHG target of India and Japan are evaluated quite generous to achieve global GHG mitigation target based on out assumptions, for example, the projected evolution of GDP, population, technology progress and many other different factors.

In conclusion, all calculated scenarios do not give an important advantage in bioenergy development apart from mandated minimum bioenergy share in energy mix either of biofuel in transport or of biomass in power supply. However, we identified that enough level of climate constraint increases the bioenergy share in energy mix without other supporting tools for bioenergy before the transition to CCS technology commences. So, for further promotion of bioenergy in this region, it is recommended to investigate in finding out a proper level of climate constraints and effective combination with direct imposing policy on bioenergy.

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