Extended abstract

Climate scenarios for developing and developed countries: A prospective analysis with TIAM-FR

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Abstract
Stabilize the atmospheric concentrations of GHG at the level that prevents dangerous anthropogenic interference with the climate system is the ultimate objective of the UNFCCC. Significant GHG emissions mitigation is necessary to reach this long-term collective goal for climate change mitigation requiring limiting global average temperature increases to 2°C above pre-industrial levels. All major developed and developing countries have pledged targets under the Copenhagen Accord but the question is to determine if these promising emissions reductions will be sufficient, if a wider participation will be necessary for the ultimate objective of the UNFCCC and by whom. In this context, what is interesting and important to analyze is the different impact of these climate policies according to developed and developing regions, in term of level of their contribution in the global effort of GHG emissions reductions, technological potentials and investments to reach their target. These results also allow discussing the contribution of developing regions and, then, the "traditional" developed-developing classification in the climate debate. Such is the aim of this study.

JEL
O21, Q29, Q4, Q54, Q55

Keywords
Energy system, long-term modelling, TIAM-FR, Climate change, CO_2 mitigation, Carbon Capture and Storage (CCS)

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1. INTRODUCTION

The ultimate objective of UNFCCC is to stabilize atmospheric concentrations of GHG at a level that prevents dangerous anthropogenic interference with the climate system. Significant GHG emissions mitigation is necessary to reach the long-term collective goal of limiting global average temperature increases to 2°C above pre-industrial levels. While all major developed and developing countries have pledged targets under the Copenhagen Accord, the question remains if the promised emissions reductions will be sufficient and if a wider participation will be necessary? A parallel question is to determine the different contribution of world regions, especially if we consider the context of negotiations where regional commitment level is partly determined according to the involvements from others. Indeed, the rule of the COP game seems to stay "may outsiders define our commitment level?". While, developed countries wait for signs from other developed and fastest developing countries, developing countries stress the need for strong mitigation efforts from developed countries, and the respect of their promises of aid to them face to climate change impacts. In the same time, reaching global climate objectives appears difficult without the full participation of all countries.

In addition, challenges for climate change consideration involve evolution of the world energy system, especially, of the energy and technological mix permitting to satisfy the energy service demands. Different pathways to achieve a low-carbon economy are analyzed in the line of the climate goals expressed in the context of Copenhagen Accord, and according to several assumptions about technologies availability, energy sources potential, etc. The impact on the energy system differs between regions and expresses a more or less important deployment of (new) cleaner technologies. The analysis of these possible futures brings information concerning the impact of climate policies in a world and regional view and, their effectiveness to reduce emissions in the line of the global warming objective. It also allows us to discuss the more plausible strategies to reduce GHG according to economic and technological considerations.

We focus on the different impact of these climate policies according to developed and developing regions, in term of level of their contribution in the global effort of GHG emissions reductions, technological potentials and investments to reach their target. These results also allow discussing the contribution of developing regions and, then, the "traditional" developed-developing classification in the climate debate.

2. METHODOLOGY AND SPECIFICATION OF SCENARIOS WITH TIAM-FR

The analyses carried out in this paper are based on TIAM-FR (the French version of the TIMES Integrated Assessment Model) developed under the Energy Technology Systems Analysis Programme (ETSAP) of IEA. TIAM-FR is a technology-rich, bottom-up energy system model. It depicts the world energy system with a detailed description of different energy forms, resources, processes/technologies and end-uses. Links between the commodities and the technologies are described via a Reference Energy System (RES) which includes several thousand technologies in all sectors of the energy system (energy procurement, conversion, processing, transmission, and end-uses). The system includes the extraction, transformation, distribution, end-uses, and trade of various energy forms and materials. Each economic sector is described by means of technologies, each characterized by its economic and technological parameters.

TIAM-FR is a geographically integrated model in 15 world regions[2] on the time horizon from 2005 to 2100. Nevertheless, this study is investigated until 2050. TIAM-FR aims to supply energy services at

[2] Africa (*AFR*), Australia-New Zealand (*AUS*), Canada (*CAN*), China (includes Hong Kong, excludes Chinese Taipei; *CHI*), Central and South America (*CSA*), Eastern Europe (*EEU*), Former Soviet Union (includes the Baltic states, *FSU*), India (*IND*), Japan (*JPN*), Mexico (*MEX*), Middle-East (includes Turkey; *MEA*), Other Developing Asia (includes Chinese Taipei and Pacific Islands; *ODA*), South Korea (*SKO*), United States of America (*USA*) and Western Europe (EU-15, Iceland, Malta, Norway and Switzerland; *WEU*).

minimum global cost by simultaneously making decisions on equipment investment, equipment operation, primary energy supply, and energy trade. Cost of the energy system includes investment costs, operation and maintenance costs, costs of imported fuels, incomes of exported fuels, the residual value of technologies at the end of the horizon, etc. The main outputs of the model are future investments and activities of technologies for each time period. Furthermore, the structure of the energy system is given as an output, i.e. type and capacity of the energy technologies, energy consumption by fuel, emissions, energy trade flows between regions, transport capacities, a detailed energy system costs, and marginal costs of environmental measures as GHG reduction targets.

It integrates GHG emissions from fuel combustion and processes, carbon capture and sequestration technologies and mitigation technological options for CH4 and N2O and allows analyzing and making assumptions on atmospheric GHG concentrations and temperature changes. To analyze possible alternative development paths of the system we investigated a variety of environmental target scenarios on different regions of the world or at a global level over the period 2005-2050. A baseline business as usual (BAU) scenario without any emission constraints was first calculated. In this reference scenario, no climate policy is assumed.

In this paper, results derived from three scenarios according to different assumptions of carbon mitigation:

- **BAU**: A reference scenario without climate action;
- **Reg_High**: A regional scenario considering specific carbon emissions target by 2020 and 2050 for Europe, Japan, Australia, United States, Canada, China and India;
- **Glob_RF**: A global 2050 target scenario expressing the global objective of keeping warming to 2°C.

Table 1: Regional targets for 2020 and 2050

Regions	Reference year	2020		2050	
		Target	Mitigation type	Assumption	Mitigation type
Europe (Western+Eastern)	1990	30%	Emissions level	80%	Emissions level
Japan	1990	25%		80%	
Australia	2000	25%		80%	
United States	2005	17%		83%	
Canada	2005	17%		83%	
China	2005	45%	Carbon intensity	10%	
India	2005	25%		10%	

The regional scenario represents the higher CO_2 mitigation targets by 2020 expressed to UNFCCC for the Copenhagen Agreement in January 2010 by Europe, the United States of America, Australia, Canada, Japan, China and India. The table 1 presents these regional commitments. Targets by 2050 consist in assumptions we made as regards the international convergence in term of GHG emissions reductions.

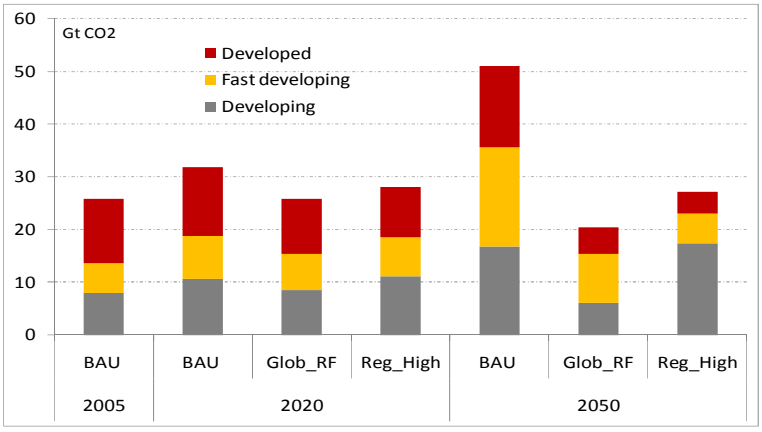
Concerning United States and Canada, we consider targets that they also pledged a CO2 mitigation target of 30% by 2025, 42% by 2030 and 83% by 2050. Note that for China and India, the 2020 commitment is not on the emission level but on the carbon intensity. This means that Indian and Chinese GDPs will continue to rise but their carbon emissions will have to increase at a lower rate due to greater energy efficiency and investment in greener technologies. In the 2050 target, we suppose that China and India pledge on emission level.

The global scenario consists more precisely on a limited radiative forcing to 2.5W/m² in 2050 compatible with the consensual 2°C objective expressed to UNFCCC since COP15 (IPCC, AR4). All regions are concerned but they are not constraint at a beforehand determinate level of CO2 emissions.

3. RESULTS

The analysis of the scenario results focuses on the effects of the climate objectives on CO_2 emissions, on the energy and electric mix and on the future technological investments. More precisely, we focus on CO_2 emissions levels by region and by sector and the impact of these different international climate change strategies on energy system as the place of fossil fuels, investments in renewable and CCS technologies. This analysis allows us to discuss the weight of the allowed or required effort for developing regions by comparison with developed regions according to the climate policy strategies. The following graph presents the CO_2 emissions trajectories according to scenario and groups of countries.

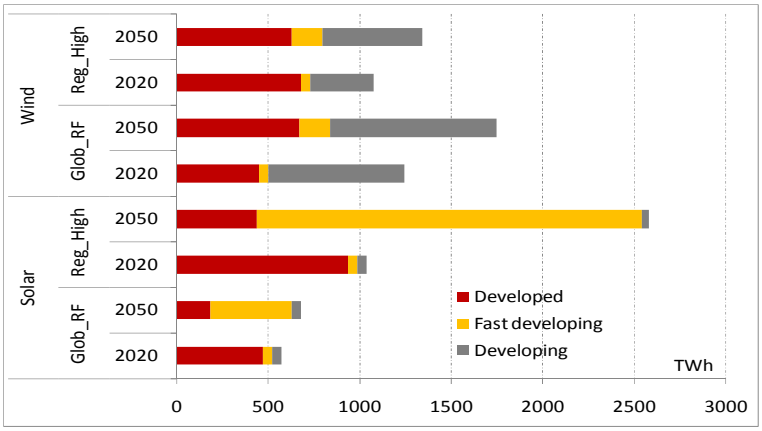
Graph 1: Co2 emissions by region and scenario



In the first time, carbon constraints involve a decrease in world emissions, for example of 31 Gt CO_2 or 24 Gt CO_2 in 2050 following global or regional targets in comparison with BAU, conducing to the fact that regional commitments are not sufficient to reach the UNFCCC global objective. In the second time, Chinese and Indian pressure appears less strong in a climate global context of action where developing countries contribute to the environmental challenge of CO_2 mitigation. While environmental stakes involve global action, the level of CO_2 mitigation from developed countries but also developing countries (including fast developing countries like China and India) is a determining factor in the post-COP15 policy to establish a course of action for climate change.

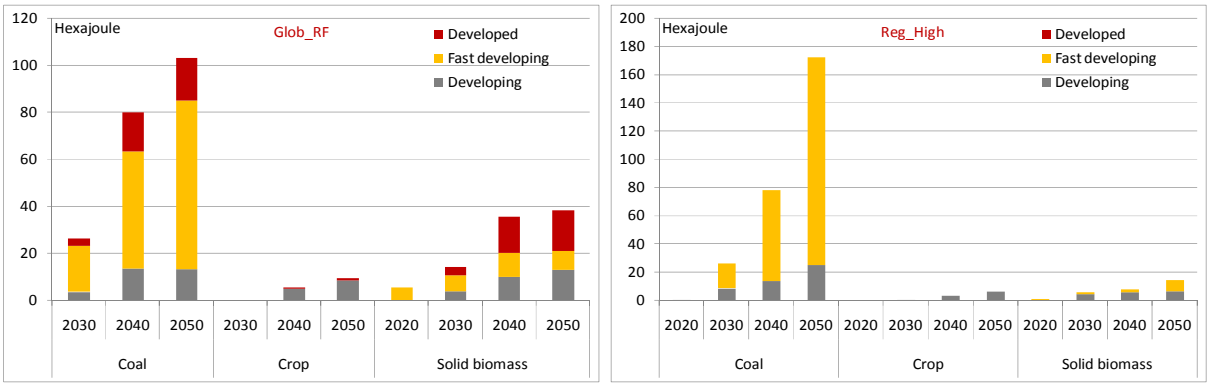
The question is to determine the necessary level of CO2 mitigation according to regions, considering the fact that climate strategies impact on the energy system and the action potential differ according to region. The following graph illustrates this point through the solar and wind technologies deployment.

Graph 2: Electricity production by solar and wind (TWh)



The environmental constraints lead to an increase of renewables but technological choices differ according to scenarios and through it the environmental pressure, and according to regions. While developing countries make greater use of wind technologies, China and India are gravitating toward solar. For addressing the problem of global climate change, CCS technologies also are expected to be deployed, as showed in the graph 3.

Graph 3: Power plants with CCS consumption (Hexajoule)



CCS deployment is particularly a response to carbon constraint for fastest developing countries, like China, whatever the scenario.

4. CONCLUDING REMARKS AND ONGOING DEVELOPMENT

Results presented here consist in a first part of the analysis; further developments are ongoing regarding more precisely a discussion about distinct impacts of climate constraints according to the level of development of regions and the contribution of developed and developing countries in the global climate challenges. This first part allows identifying some impacts of environmental constraints on the energy system of regions according to their level of development. This study begins to confirm that no country can mitigate climate change on its own. International cooperation is needed to face the energy-climate problem. However, it is not only countries that must act, but technological progress must also find an adequate response to countries' ambitions to expand the pool of existent and future technologies and their mitigation potential. This not only concerns CCS technologies, but also non-fossil energies, like wind, solar, biomass, etc. In this concern, what is important to keep in mind is the fact that according to the regional level of development, technological choices differ and that while climate stake is definitely global, solutions stay regional.

A second part of the discussion concerns the fact that, for addressing the problem of global climate change, CCS technologies are expected to be deployed but could the investment in CCS technologies be feasible, on the one hand, for developing countries with their crucial objective of development, and on the other hand, regarding the level of deployment? In order to face stringent carbon constraints, CCS technologies need to be installed on an industrial scale but potential, effectiveness and cost aspects stay uncertain. Also, geological storage of CO_2 is now opening new options for energy development but it should not discourage the development of alternatives, including energy savings and renewable energy. For each region, costs and the most promising technologies to reach these targets are different. Indeed, regional differences exists in terms of existing energy system and infrastructure, technological potential (renewable energies, CCS, etc.) or future economic development and priorities. Like for CCS technologies, the potential of deployment of renewables is still uncertain and induce other analysis and discussion. Notably, in the case of intermittent renewables power and them variability, can a given power system introduce a larger share of renewables without any changes whatsoever? Network stability should also be ensured. At what cost? Network will need to be reinforced and managed in other manner. At what point can this be more limited for developing countries?

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6. ANNEXE : ELECTRICITY PRODUCTION (TWH)