Climate policy impacts on energy system: a long-term analysis with the TIMES Integrated Assessment Model (TIAM-FR)

Sandrine SELOSSE
MINES ParisTech, Center for Applied Mathematics
Sophia Antipolis, France

Edi ASSOUMOU
MINES ParisTech, Center for Applied Mathematics
Sophia Antipolis, France

Nadia MAÏZI
MINES ParisTech, Center for Applied Mathematics
Sophia Antipolis, France

ABSTRACT

Keywords: Energy system, Long-term modelling, TIAM-FR, Climate policy, Carbone Capture and Storage and technological choices

1. INTRODUCTION

Strategies for reach the long-term collective goal of limiting global average temperatures increases to 2°C above pre-industrial levels involve transformation of the world energy system. 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 evolution of 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 technological and economic plausibility of strategies deployed to reduce GHG emissions.

2. TIAM-FR PRESENTATION AND SPECIFICATION OF SCENARIOS

The analyses carried out in this study 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 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.

TIAM-FR is a geographically integrated model in 15 world regions on the time horizon from 2005 to 2100. This study is investigated until 2050. TIAM-FR aims to supply energy services at 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. Indeed, it integrates GHG emissions from fuel combustion and processes, carbon capture and sequestration technologies and mitigation technological options for CH_4 and N_2O 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.

The regional scenario, **Reg_High**, 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. Targets by 2050 consist in assumptions we made as regards the international convergence in term of GHG emissions reductions, the literature or political ambition.

The global scenario, **Glob_RF**, consists more precisely on a limited radiative forcing 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 CO_2 emissions.

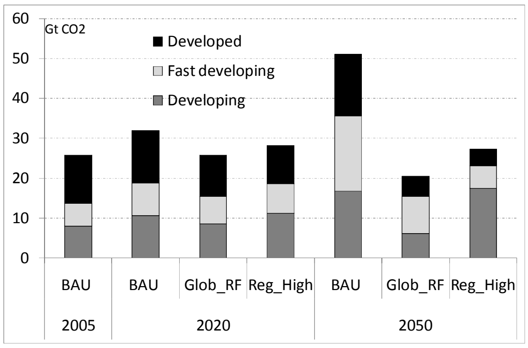
3. RESULTS

The analysis of the scenario results focuses on the effects of the international climate change strategies on:

- CO_2 emissions levels by regions and by sectors,
- Energy and electric mix: as the place of fossil fuels, the future technological investments (renewables and carbon capture and storage).

The following graph presents the CO_2 emissions trajectories according to scenarios and regions.

Graph 1: Co2 emissions by region and scenario(Gt CO_2)

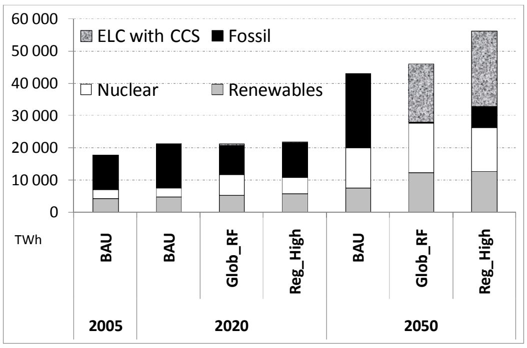


Carbon constraints involve a decrease in world emissions of 31 Gt CO_2 or 24 Gt CO_2 in 2050 following global or regional targets in comparison with BAU, conducing to the fact that regional commitments are not sufficient to reach the UNFCCC global objective represented by the Glob_RF scenario. We also can note that Chinese and Indian contribution 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 involvement, 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. The question is to determine the possible level of CO_2 mitigation for regions, considering the fact that climate strategies impact on the energy system on the one hand and, the action potential on the other hand, differs according to region.

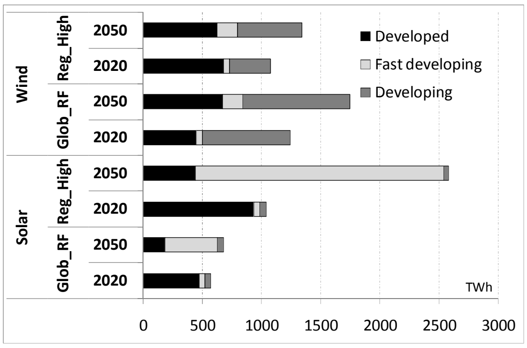
For addressing the problem of global climate change, CCS technologies are expected to be deployed, as showed in the graph 2. Note that CCS is particularly a response to carbon constraint for fastest developing countries, like China, whatever the scenario.

Graph 2: World electricity production (TWh)



The environmental constraints also 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. The following graph illustrates this point through the solar and wind technologies deployment.

Graph 3: Electricity production by solar and wind (TWh)



4. FIRST CONCLUDING REMARKS AND ONGOING DEVELOPMENT

Results presented here consist in a first step of the analysis; they will be replaced in a context of existent literature. This study begins to confirm that even if international cooperation is needed to face the energy-climate problem, 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.

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?

5. ACKNOWLEDGMENT

This research was supported by the Chair Modeling for sustainable development, driven by MINES ParisTech, Ecole des Ponts ParisTech, AgroParisTech, and ParisTech, supported by ADEME, EDF, RENAULT, SCHNEIDER ELECTRIC and TOTAL.