Energy Sector Impacts of Meeting China's Pledges under the Paris Agreement

Govinda R. Timilsina, Senior Economist, World Bank, Washington, DC (gtimilsina@worldbank.org)
Xi Yang, Associate Professor, China University of Petroleum, Beijing (sissiyang_tsinghua@foxmail.com)

Overview: The 21st Session of the Conference of Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Paris in November-December 2015 agreed to reduce global GHG emissions to the level to stabilize the increase in the mean earth surface temperature below 2 Celsius from pre-industrialized period (UNFCCC, 2015). This agreement is known as the 'Paris Agreement'. In this Agreement, both developed and developing countries committed, though voluntarily, to implement various GHG mitigation measures as appropriate to their national circumstances. Mitigation of GHG emissions through these measures is termed as their 'nationally determined contribution (NDC)'. Most parties to the UNFCCC made quantified GHG mitigation pledges to be met by year 2030 through the implementation of their NDCs. China has committed a goal of reducing its emission intensity (i.e., CO_2 emissions per unit of GDP) by 60 to 65 percent below 2005 levels. It has also set a goal of increasing the share of non-fossil fuels to 20% of its total primary energy consumption by 2030. Using an energy sector optimization model, TIMES, this study analyses the energy sector impacts of meeting China's NDC targets.

Methodology: The study employs TIMES model. The structure of the model is similar to that developed by Chen et al. (2014), Cayla and Maïzi (2015) and Timilsina and Jorgenson (2018). The model is based on reference energy system (RES) principle. A RES refers to an optimal system where useful energy demand by end-uses (e.g., light, heat, electric traction, motive power etc.) in each sector (e.g., industrial, households) are met through various channels or networks which transports energy commodities (coal, oil, gas, electricity) from domestic primary energy sources or imported primary or final energy sources. Various energy consumption technologies that produces final energy to useful energy (e.g., a boiler converts natural gas to heat, a light bulb converts electricity to light, an electrical motor converts electrical energy to mechanical energy) in the demand side whereas energy production or transformation technologies (e.g., electricity power plants to produce electricity from fuels) in the supply side. Energy transportation facilities (e.g., pipelines for oil and gas, transmission lines for electricity) carry energy commodities from production location to demand centers. Using the linear programming technique, the model generates optimal energy mix by minimizing the total energy system costs of meeting projected energy demand satisfying specified resource, technical, environmental, and other constraints. The model developed for this study has 43 energy sub-sectors, including industry sub-sectors (like ferrous metal sector, non-ferrous metal sector, non-metallic sector, etc.), residential sub-sectors (like urban residential and rural residential in north and south region), commercial sub-sectors (large commercial building and common commercial building), transportation sub-sectors (with different transportation modes) and agriculture sector. It has considered around 90 various domestic production technologies to produce primary energy, around 30 technologies to convert primary energy to final energy and 290 technologies to utilize final energy. Altogether, the model considers more than 400 technologies. For energy demand projection, we used two methodologies: (i) a simple bottom-up engineering methodology (Case 1) and (ii) a top-down computable general equilibrium model (Case 2). Under the second methodology, a detailed excel based linkage has been developed to calibrate the CGE forecasts as needed by the detailed TIMES' structure.

Results: Table 1 presents key results of TIMES model under alternative scenarios. The total energy supply and energy supply mix are very different between energy demand forecasting methodologies used (i.e., between Case 1 and Case 2 defined earlier). Total baseline energy supply in 2030 is almost

22% higher under CGE based energy demand projection case (Case 2) than when TIMES's bottom up technique is used for energy demand forecast (Case 1). The former case uses complex CGE model for projecting key economic drivers of energy demand. It makes only two variables, population growth and GDP, exogenous, the rests are calculated by the model through a general equilibrium modeling technique. The latter (Case 2) uses ad-hoc assumptions on energy efficiency improvements and fuel and technologies mixes and simple elasticity parameters (energy demand elasticity with respect to GDP). While the methodology in Case 2 is more consistent with economic theories, the latter (methodology in Case 1) incorporates experts' judgements. A huge difference observed on coal share in total primary energy supply. Since Case 1 assumes (expert judgement) significant substitution of coal and oil with natural gas and renewables even in the baseline, shares of coal and oil are much smaller as compared to that projected under Case 2, where the model does not entertain such assumptions and let the market to decide the energy mix.

Table 1. Total energy supply (million tons of coal equivalent) and energy supply mix (%)

Energy type	TIMES Bottom-UP Methodology for Energy Demand Forecast		CGE Model based Energy Demand Forecast	
	Reference scenario	NDC Scenario	Reference scenario	NDC Scenario
Total energy supply (Million tons of coal equivalent) in 2030				
	6,123	5,860	7,447	6,284
Energy supply mix in 2030				
Coal	46.1%	40.2%	60.0%	49.6%
Oil	7.0%	7.8%	14.7%	10.4%
Gas	25.6%	27.1%	10.1%	18.9%
Nuclear	8.4%	11.1%	4.0%	6.2%
Hydro	4.3%	3.8%	2.5%	4.1%
Biomass	2.3%	1.8%	4.0%	3.5%
Wind	3.0%	3.2%	1.1%	2.2%
Solar	3.4%	4.9%	0.6%	2.1%

The reduction of total energy supply under the NDC scenario is much higher in Case 2 as compared to that in Case 1. The primary reason is that the economic model (i.e., CGE model) in Case 2 considers pricing effects (i.e., energy demand drops as price increases), the model under Case 1 uses an engineering approach which is not capable to account for pricing effect. This is the fundamental difference between an economic and engineering technique used for policy analysis.

Conclusions: Meeting China's pledges under the Paris Agreement would have significant impacts on China's energy supply mix. However, the estimations of the changes in total energy supply and supply-mix highly are sensitive to the assumptions to develop the baseline. If the baseline energy demand is forecasted based on the driving variables projected by a CGE model, that assumes the status quo energy situation in 2030 in the absence of policy interventions, the baseline energy demand would be 20% higher than that forecasted by a simplified bottom-up approach. Since the bottom-up forecasts uses series of ad-hoc assumptions or expert judgements suggesting huge energy efficiency improvements and fuel substitutions without policy interventions, it would underestimate the baseline energy forecasts and required GHG mitigation to meet climate change mitigation targets. Therefore, an approach that links a top-down CGE model with bottom-up TIMES model would be more appropriate for climate policy analysis. The top-down model forecasts the baseline energy demand (and assesses the economy wide impacts of meeting the climate change mitigation targets) whereas the bottom-up model optimizes

the energy sector meeting the mitigation targets reflecting the detailed technologies in the various stages of the energy supply chain.

References

Cayla, Jean-Michel, and Nadia Maïzi. 2015. "Integrating Household Behavior and Heterogeneity into the TIMES-Households Model." *Applied Energy* 139: 56–67. doi:10.1016/j.apenergy.2014.11.015.

Chen, Wenying, Xiang Yin, and Ding Ma. 2014. "A Bottom-up Analysis of China's Iron and Steel Industrial Energy Consumption and CO_2 Emissions." *Applied Energy* 136: 1174–83. doi:10.1016/j.apenergy.2014.06.002.

Timilsina, Govinda R. and Erika Jorgensen (2018). The Economics of Greening Romania's Energy Supply System. Mitigation and Adaptation Strategies for Global Change, Vol. 23, pp.123-144.

United Nations Framework Convention on Climate Change (UNFCCC) (2015). Report of the Conference of the Parties on its nineteenth session, held in Paris from 30 November to 11 December 2015, Addendum Part Two: Action taken by the Conference of the Parties at its Twenty One session, UNFCCC, Bonn, Germany.