DYNAMIC MULTI SECTOR ENERGY ECONOMIC MODEL FOR SUSTAINABLE DEVELOPMENT IN THE ELECTRICITY SECTOR OF BANGLADESH

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Overview

As energy demand grows at a faster rate in developing regions, energy security and environmental sustainability become issues of concern. The transition from traditional fuels to modern forms of energy requires huge infrastructure development and poses greater financial risk at the same time. In this study, we analyse the long-term electricity sector expansion of one of the fastest developing regions of the world, Bangladesh using a dynamic multi-sector energy economic model. We also evaluate the interrelation between energy consumption and environmental emission by imposing emission limits. The social implications and optimal power generation mix for different policy scenarios have been investigated. A snapshot of the current status of energy demand-supply and consumption for the year 2018 is presented in Fig. 1.

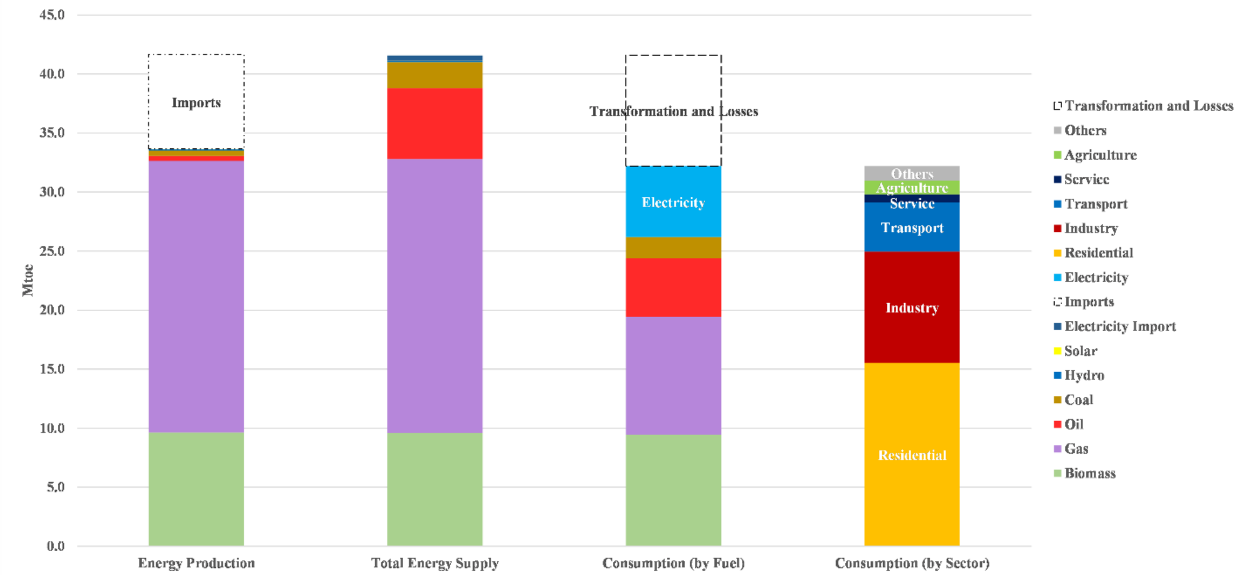


Fig. 1*: Energy Balance of Bangladesh in 2019 [1,2]*

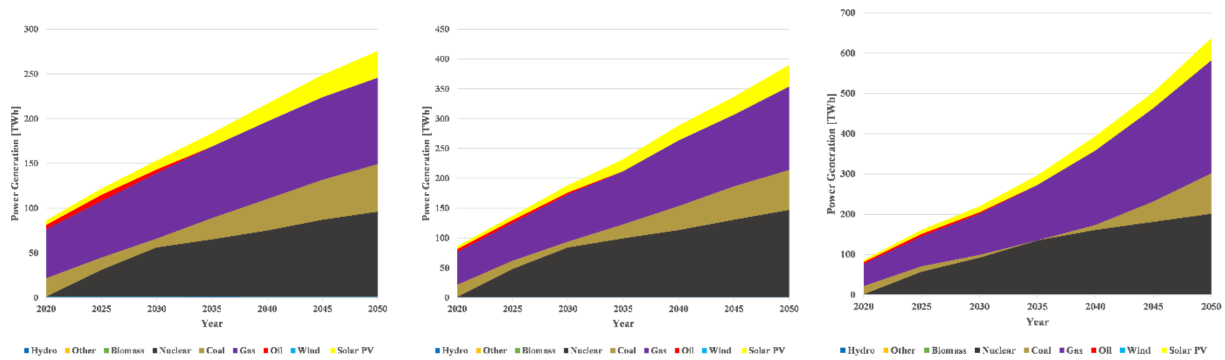
Methods

The Dynamic Multi-Sector Energy Economic (DMSEE) model developed for this analysis, uses linear programming approach to quantitatively analyse the interrelationship among Top-Down (TD) economic sectors and thus elaborate the Bottom-Up (BU) electricity sector in term of different power generation technologies considering techno-economic and environmental constraints. We used the TD information obtained from Global Trade Analysis Project (GTAP) 10 database that represents the world economy through bilateral trade information. For the BU electricity sectors, eight power generation technologies were considered: nuclear, coal-fired, gas-fired, oil-fired, biomass, hydro, solar PV and wind power generation. The objective function of the model is to maximize utility for consumptions. The constraints include supply-demand balance, resource balance, capital investment limit, labour availability from TD perspective and other technical limitations from the BU electricity sector. Carbon-emission restriction is also imposed to observe the effect on the optimal generation mix.

The overall objective function of the model is to maximize utility function for the household consumptions keeping the government consumption fixed. The utility loss due to taxes is deducted from the utility at each time point. The present value is calculated at a discount rate and maximizing the added objective functions in all regions and at all-time points is considered. The constraints considered for TD sectors include supply-demand balance, physical or resource balance, capital investment, labour for production, and CES function linerar inequality approximation. From the BU electricity sector electricity supply-demand balance, operational limits, capacity reserve constraint, maintenance period, load following capability, reserve capacity and charge-discharge balance of battery storage technology were taken into consideration during the optimization process [3].

Results

Our model computes results for 6 time points starting from 2025 to 2050 at 5 years interval. Hourly electricity generation from different technologies is obtained to generate optimal power generation mix for a particular year. We consider 3 different economic scenarios naming Business As Usual (BAU), Low Growth (LG) and High Growth (HG) with per-capita annual household consumption growth of 3.5%, 5.5% and 7.5% respectively. Carbon emission limit was introduced by imposing 50% emission reduction with respect to BAU case by the year 2050. The GDP over the years, import, and export were also calculated in addition to electricity generation mix for these scenarios. The results for different scenarios as shown in Fig. 2 and 3 imply that imposing carbon emission limits have a profound impact on the energy mix. In order to satisfy environmental policy concerns, advance planning and adjustment with new technologies need to be ensured for continuous and sustainable development.



(a) (b) (c)

Fig. 2. *Electricity generation-mix at (a) low, (b) BAU and (c) high growth scenarios.*

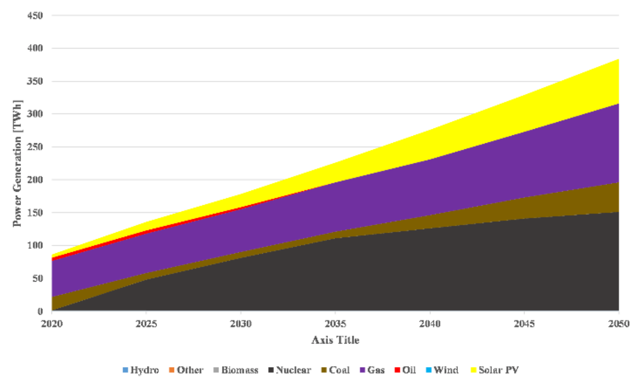


Fig. 3. *Electricity generation-mix at business-as-usual case with 50% CO2 emission reduction.*

Conclusions

Developing countries experience increasing energy and electricity demand as they transform into industry based economy and people's purchase power increase. The interrelation between economic growth and energy is important for national policy planning and sustainable growth, especially for the electricity sector. It is the environmental factors which could bring positive changes towards a sustainable future with diversified energy and electricity generation technologies if taken into consideration in time ensuring energy security and environmental sustainability at the same time.

References

[1] International Energy Agency, IEA World Energy Balances 2020. Available at:<https://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics> [accessed 15.3.2021].

[2] HCU (Hydrocarbon Unit), Energy and Mineral Resources Division, Ministry of Power, Energy and Mineral Resources, 2020. Energy Scenario Bangladesh 2019-20, 2021.

[3] Isogai, M., Komiyama, R., and Fujii, Y., Analysis of Optimal Power Generation Mix in Japan to 2050, Using Dynamic Multi-Sector Energy Economic Model; Proceedings of the 42nd IAEE International Conference on Local Energy, Global Markets; May 29 – June 1, 2019, Montreal, Canada.

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