Energy, Economic Growth and Energy Transitions: Exploring the interlinkages for Indian Economy

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Abstract : This study explores critical linkages of energy with economic growth and the process of energy transition underway in India. The focus is to delineate various interdependencies between energy linked growth for the economy using the existing empirical evidence along with mapping dynamics of change in the Indian energy sector from coal to renewables. As the economy commits to greater contribution of renewables in its energy mix an exploration of existing trends of renewable scale up and associated costs and benefits is crucially important to discern future growth and development trajectory of India as an emerging economy

IndexTerms **– Energy-Economy linkages, Energy Transitions, Renewable technology , Solar Transition in India**

I. INTRODUCTION

India being an emerging economy, the energy discourse is inextricably linked with various developmental issues. Although not an explicit goal itself, energy and its access constitute a prerequisite underpinning majority of Millennium Development Goals (MDGs). Access to electricity and modern energy services contribute to: inter alia, higher yields in agricultural production; increased access to information and telecommunications; improved health and quality of healthcare; and improved standard of living in general. It also contributes significantly to gender equality and education (UN, 2015). Therefore, the role of energy is recognized as pivotal in articulating sustainable development goals. Further, as it has been lately well accepted that sustainable development would not be possible without transitioning to a more sustainable energy base, clean energy transitions have been globally endorsed as a silver bullet solution for achieving sustainability goals (Chertow, 2001).

The paper details interlinkages between energy, economic growth, and ongoing energy transitions for India. The initial section details energy-GDP linkages with the help of existing empirical literature. We explore long and short-term dependencies between GDP and energy production and consumption and coal consumption in the country. This is followed by section three which details the processes of energy transitions and the ongoing clean energy transitions with respect to renewable scale up. Section four delineates the impacts s This leads to the conclusion of the research synthesizing and evaluating critical energy, economy and sustainability interlinkages for India.

II. EXPLORING ENERGY – GROWTH LINKAGES FOR INDIAN ECONOMY

The country faces a daunting challenge of meeting its energy needs and providing adequate energy of desired quality sustainably. The energy economic growth links are well established and various aspects of energy linked dependencies have been widely studied. This section details the results of key empirical studies dealing with existing energy -GDP links.

According to Moroney (1992), although energy's cost share in GNP is observed to be small as compared to employment or capital but its role is primary coequal with capital formation. Kraft and Kraft (1978) in their pioneering study confirmed that there exists a

unidirectional causality running from energy consumption to GNP for the United States during the period of 1947-1974. The relationship between energy and economic growth has also been extensively researched and a few common trends have been reaffirmed by existing studies.

According to Ghosh (2002), there exists a bi-directional causality between energy consumption and economic growth. The long-run causal relation runs from GDP to energy consumption and the short-run causal relation runs from energy consumption to GDP. Chen et al. (2007) tested causality for 10 Asian countries including India and found a unidirectional short-run causality running from economic growth to electricity consumption, and a feedback in the long-run. Salim et al. (2008) examined the short-run and long-run causal relationship between energy consumption and output in six non- OECD Asian developing countries and found that energy consumption to output in India, Pakistan and Bangladesh remains as an energy neutral economy, confirming the fact that it is one of the lowest energy consuming countries in Asia. In a similar study, Rafiq (2008) also finds mixed results for the major developing economies of Asia.

Further a study finds unidirectional short-run causality running from economic growth to electricity supply (Ghosh 2009) higher income propels higher demand of electricity, through the extensive use of electrical appliances in end-use sectors specifically in industrial commercial and domestic sectors, which necessitates supply augmentation to mitigate demand obligations. There is an absence of causality running from electricity supply to real GDP. Further, Pradhan (2010) finds that there exists a unilateral causality from economic growth to electricity consumption for both long and short run.

The power mix of Indian economy is predominantly coal based but a positive causality between coal and economic growth is not well defined. Jinke et al (2008) find no causual relationship between coal and economic growth (Jinke 2008). Subsequently relationship between coal and economic growth was revisited to and it was revealed that there exists a unidirectional causality running from coal consumption to economic growth (Li 2 011). Further Jayayantha kumaran (2012) compared CO_2 emissions, energy consumption, trade and income of India and China and concluded that per capita income and energy consumption contributed to more emissions in India than China. **Table 1** tabulates the results discussed above. The empirical relation between coal and GDP shows a unidirectional causality from coal to GDP but ironically the relationship between energy consumption and GDP for India shows a unidirectional causality from GDP to electricity consumption, Thus, greater economic growth would lead to more electricity demand in long run. Thus, there exists a reverse causality and a feedback loop from economic growth to electricity demand. A proactive initiative towards clean energy transitions transforming the energy mix as discussed in the previous section provides an opportunity to reduce the expected environmental impacts from energy use across the developmental trajectory the economy. The next section takes up the issues of energy transitions and case of renewable energy scale up.

Table 1: Economic growth – Energy relationships in India

Study	Relationship studied	Conclusion
Ghosh, 2002	GDP ⇄ Energy consumption	Energy to GDP short run causality GDP to energy long run causality
Chen et al, 2007	GDP ⇨ Energy consumption	Unidirectional short run causality
Salim et al 2008	GDP ⇨ Energy consumption	Energy neutral
Ghosh, 2009	GDP ⇨ Energy supply	Unidirectional short run causality
Pradhan, 2010	GDP ⇨ Energy consumption	Unidirectional causality in both short and long run
Jenke, 2008	Coal ⇨ GDP	No causal relationship
Rufael, 2010	Coal ⇨ GDP	Unidirectional causality from coal to growth
Li, 2011	Coal ⇨ GDP	Unidirectional causality from coal to growth
Jayanthakumaran 2012	GHG Emissions -Income-energy consumption-trade	Per capita income and energy consumption contribute to more emissions in India than in China

Source: Author's Compilation

III. ENERGY TRANSITIONS THROUGH RENEWABLE ENERGY TECHNOLOGIES

Last decade witnessed that natural trajectory of energy transition in both developing and developed counties was intervened in order to resolve prevailing concerns of climate change mitigation, security of supply and also energy adequacy for rapidly growing low- and middle-income countries. Developing and developed countries alike have resorted to policy mediated energy transitions focusing aggressively on renewable energy deployment and endorsement of energy efficiency regime.

Germany had been the pioneer setting a new trend for energy transition with a systematic policy to phase out its nuclear capacities and bring decentralized renewables and energy efficiency regime. However, this policy mediated transitions are known to differ in terms of motivation, objectives, drivers and governance. According to Rio & Burguillo (2007) main motivation behind the major renewable energy incentives was rejuvenation of local rural economy in Germany putting it as a classic case of green growth initiative.

The endorsement of renewable based growth in India can be seen as an effort to diversify the coal centric energy base, ensuring and consolidating security of supply for the rapidly growing economy. Further, opportunity to leverage potential economic growth through exports diversification in new high technology sector and creation of domestic jobs have been the major drivers. The country has been an early mover in the wind sector with systematic incentives to the sector dating 1983-1984. This along with the turnaround in global wind market has established India as major global player in wind energy market. The total installed capacity in the country stands at 32.17 GW till March 2017, fourth largest in the world (GWEC, 2016).

Being a tropical country potential of solar based energy generation was recognized quite early in the country with multiple initiatives promoting solar thermal and photovoltaic installations more from the stand alone end user perspective. A systematic supply side intervention for solar scale up came up under flagship of national solar mission in 2010. A highly ambitious target of the time (20GW) was set up in the program with an umbrella of incentives for scaling up grid connected centralized solar power plants.

Sharp decline in global PV costs led to revamping the already existing solar target to 100 GW by 2022. As of April 2017, the country's solar grid had a cumulative capacity of 12.28 GW. India quadrupled its solar-generation capacity from 2,650 MW on May 2014 to 12,289 MW on 31 March 2017. The country added 3.01 GW of solar capacity in 2015-2016 and 5.525 GW in 2016-2017, the highest of any year (MNRE, 2017). The next subsection analyzing the emerging trends in solar sector

IV. EMERGING TRENDS IN INDIAN SOLAR SECTOR

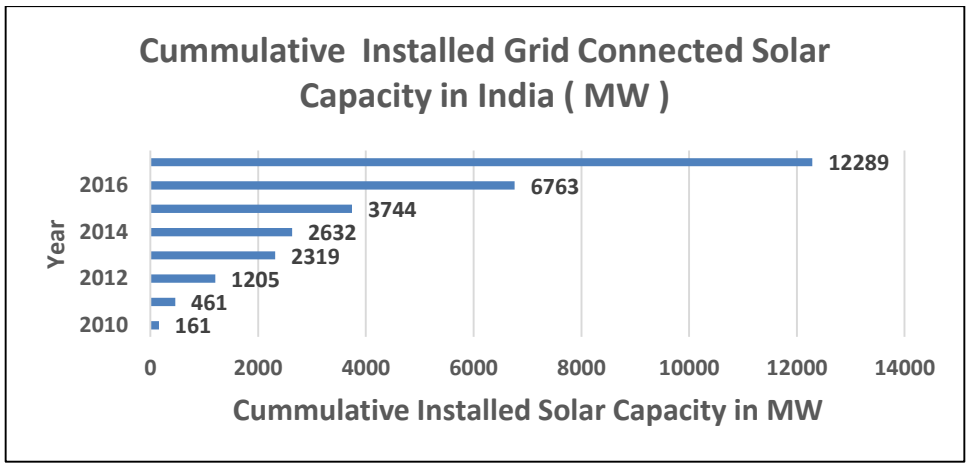
A major turnaround in dynamics of production costs for global solar sector driven largely by promising energy transition targets in developed economies like Germany, prompted Indian policy makers to proactively engage in solar transitions thus leveraging the inherent green growth prospects for the country. This led to launch of an ambitious solar program in the year 2010 under the flagship of national solar mission, focusing on systematic incentives and target oriented solar scale up. A sharp decline in cost of solar PV panels (> 80% between 2005-2017 ; REN 21, 2015) prompted policy makers to revise the already ambitious solar target of 20 GW grid connected solar deployment under national solar mission to 100 GW by 2022. Policy decision to logarithmically scale up solar generation capacities of this magnitude bring with it strong expectations of not only transforming the energy mix (54.4 % renewable by 2027, NEP, 2016) but also playing a critical role in articulating the targets for Intended Nationally Determined Contribution (INDC) set under UNFCCC Paris agreement.

The solar sector post NSM has witnessed a logarithmic growth facilitated by solar policies articulated through the National Solar Mission. The program has been able to effectively scale up the grid connected solar deployment capacity from less than a 100 MW before 2010 to over 12000 MW by March 2017(MNRE, 2017). **Figure 1** illustrates the year on year growth trajectory of solar deployment for economy post the launch of National Solar Mission (NSM).

The National Solar Mission has come up as one of the key initiatives under National Action Plan for Climate change (NAPCC, 2008) and demonstrates key trends of Indian strategy to leverage green growth. Green growth traditionally encompass concepts of sustainable preservation of natural capital and technological innovation to minimize environmental impacts and techno-economic innovations for creation of long run economic growth with cleaner technologies (Hallegatte et al., 2011). Currently a distinction in interpretation of green growth with respect to developing countries is emerging (OECD,2012) which emphasize that imperatives of green growth in developing economies should hem in concerns of inclusive economic growth and equitable wellbeing along with improved environmental management for alleviating resource scarcities and climate change impacts.

Unlike Germany, solar sector in India is emerging as predominantly supply-side interventions towards energy transitions. The market structure demonstrates oligopolistic traits with a handful of major players articulating greater capacity addition in the initial phase (Bridge to India, 2015). The price of solar generation has been falling with the lowest quoted generation price of 2.44 Rs/ Kwh for Bhadla project in Punjab in May, 2017 (Bridge to India, 2017). This has brought the cost well within the grid parity providing a positive incentive for further installations. However, this supply side consolidation do not tackle the issue of energy access and demand side energy security critically important for the economy.

Figure 1: Trajectory of Indian Solar Deployment under NSM



Source: MNRE, 2017

However, commitment to 100 GW of solar deployment (accounting to 30 % of already existing generation capacity) would bring in concomitant concerns in terms of substantial lock in of capital and resources across the deployment process in a short-span of time. This can potently influence the future development trajectory and therefore evaluating sustainability impacts of solar deployment process become critically important. The next section details some topical developmental concerns for India and stated potential possibilities associated with regional solar deployment.

V. DEVELOPMENTAL CONCERNS AND EVALUATION OF SOLAR TRANSITIONS IMPACTS

India proactively launched a comprehensive program under the umbrella of National Action Plan on climate change (2008) delineating eight major initiatives for climate change mitigation in the country. The current ambitious solar program i.e. National Solar Mission is one of the key initiatives. The agenda not only internalizes country's commitment towards climate change mitigation but also provides a base for alleviating intrinsic climate change vulnerabilities, facilitating climate change adaptation efforts.

According to Stern's report (2006) developing regions are at a geographic disadvantage with respect to climate change phenomenon as they are already warmer, on average, than developed regions, and they also suffer from high rainfall variability. As a result, further warming will bring poor countries excessive costs and few benefits.

Anthropogenic climate change would impact all sectors of the Indian economy. Increase in atmospheric temperature above normal would lead to higher fluctuation in rainfall patterns. Abnormality in rainfall would result in severity and frequency of floods and drought. Further rising atmospheric temperature would lead to melting of polar icecaps increasing mean sea levels impacting large populations in peninsular and coastal areas. Agriculture is most vulnerable sector that directly gets affected by climate change compared to other sector of economy both physically and economically (Gbetibouo & Hassan, 2005). Thus, it would impact livelihoods of people occupying around 40% of the global land, 70% of global water resources and affect biodiversity at all scales (Masters *et al.*, 2010).

The Stern report 2006 has forecasted that in India, poorest of the strata which are heavily dependent on agriculture, would be, the most climate-sensitive of all economic sectors. More over their low incomes and vulnerabilities make adaptation to climate change particularly difficult. Because of these vulnerabilities, climate change is likely to reduce further already low incomes and increase

illness and death rates in developing countries. Falling farm incomes will increase poverty and reduce the ability of households to invest in a better future.

Many of the socio-economic indicators used for climate change vulnerability measurement in various studies like Ruijven et al, 2013, Brikmann et al, 2011(World Risk Index), Global Adaptation institute, 2011 (GAIN index) show inextricable link with availability of energy supply. For instance, climate change impacts on indicators for health, agricultural productivity and water accessibility can be favorably modified by access to modern energy supplies.

Further, various research studies show that the process of increased solar deployment can have favorable impacts on economies both during deployment and ex post. Increased deployment contributes to regional development (Lopez et al, 2007; Mıguez et al, 2006; Faulin et al, 2006) , enhanced employment opportunity especially in rural area (Caldes et al 2009, Heallebrand et al, 2006, Bergmann et al, 2006; El Bassam and Maegaard, 2004) along with improved health conditions due to minimized environmental impacts during energy generation. Moreover, energy accessibility also has close links with alternative livelihood generation capabilities leading better prospects for adaptation to any climate change genic vulnerabilities. These studies demonstrate that energy transitions can play a pivotal role in growth and development of Indian economy

VI. CONCLUSIONS

Ensuring sustainable energy supply is a pressing challenge for an emerging economy like India posed with conditions of energy poverty, greater climate change vulnerabilities and high population growth rates. Policies formulated for renewable energy scale up need to be scrutinized for their efficiency to meet multiple goals focusing towards sustainable economic growth and domestic employment. The solar scale of this magnitude implies concomitant lock in of substantial material and capital resources across the deployment trajectory. The green growth imperative of solar promotion in India thus needs a scrutiny with respect to inherent developmental concerns of inclusive and equitable growth and alleviation of resource scarcity in the country.

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