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India's Energy Transition in a Climate-Constrained World

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ABSTRACT Energy transitions in developing economies like India are complex processes involving substantial financial and technological resources as well as appropriate innovation. These transitions are central to the climate debate, where emphasis is placed on increasing the share of renewables in the energy mix to mitigate the adverse impacts of climate change. This paper examines the historical attributes of energy transition and finds various critical factors that determine the success of such shift: appropriate IPR regimes; local innovation; economic feasibility of the energy resource; and affordability of end-users. These, in turn, are interlinked with socio-political and economic processes of development. In all, suitable support from national and global communities is required to build local innovation capacities, encourage advancement of energy technologies, and allow for the rethinking of income-growth models to transition towards environmentally benign energy resources.

INTRODUCTION

While India is committed to promoting environmental sustainability, it is struggling to balance such goals with its pursuit of economic growth. The country suffers from energy poverty, with large populations lacking access to modern power sources and dependent instead on wood, biomass and other non-conventional fuels for their basic needs. Lack of access to modern energy impacts people's health and quality of life, environment, and the country's overall economic productivity and development.[1] To provide modern energy to its population and meet existing demand gap, India needs to upscale its energy production. Domestic coal reserves provide the cheapest source of energy supply but climate change concerns require alternative, lower carbon strategies.

Financial and structural implications of transitioning from a coal-based economy to renewables are huge, which necessitates support from international communities as well as strong policy interventions from national governments. To understand the imperative policy and institutional support for such transitions, it is worthwhile to analyse the history of past energy transitions. This paper extracts the factors and processes of historical energy transition in the US and England, from wood to coal and to oil, and examines them against India's current socio-economic realities. A suggestion is made on the feasibility of shifting from coal to renewable energy sources in the future.

ATTRIBUTES OF HISTORIC ENERGY TRANSITIONS

The historic shift from wood to coal, and later from coal to oil, portrays a rather complex interplay between economic development, income, Intellectual Property Rights (IPR) regime, and other political and institutional factors.

A cursory analysis of energy transitions in other parts of the world suggests that in the UK, for instance, the acute shortage of wood and the consequent rise in its cost led to its substitution by coal. As wood and charcoal supplies became scarce and prices rose, poor families in England switched to coal and so did the country's iron, brewing, lime-burners and soap industries.[2] Coal use became widespread after the nobility of England and Wales started using the resource, followed by the elite class and the rapidly urbanising population of London.[3] The growth of cities and urbanisation created increased demand for coal and compelled innovation in infrastructure design, which complemented coal as a resource for domestic use.[4] Eventually, further transition happened from coal to oil, though it was a much more complicated process.

While pure economics and availability of cheaper energy source played a decisive role in the shift, other crucial factors were at play, including technological innovation, IPR regimes, economic growth, and wage-labour nexus. These are dynamic and interconnected elements that cannot be viewed in isolation.

Technological innovation provided a major thrust to the energy transition and became one of the prominent factors that led to industrial revolution.[5] The invention of steam engines for pumping water out of the coal mines, transportation (railways) and electricity generation dramatically increased the share of coal in the global fuel mix beginning in the 20th century. These technological innovations also helped oil gain its market share in the 19th-20th centuries. Kerosene replaced whale oil as a source of illumination in the US and discovery of oil fields ensured continuous supply. The oil market was, however, threatened by the invention of light bulb by Thomas Edison in 1880 but later picked up with the discovery of 'oil-based internal combustion engine' which was more efficient than steam-based engines.[6] Oil was preferred over coal for ease of transport and storage, energy-density, and versatility.

Energy historians are certain that technological innovation was central to industrialisation.[7, 8, 9] How these innovative advancements then led to the energy transition underwrites two main factors: the IPR regime; and diffusion of the innovative technologies. The history of energy transition suggests that evolution of the IPR systems created an impact on the rate of innovation, and the diffusion of technologies relied on economic feasibility and affordability of the end-users.

EVOLUTION OF THE IPR SYSTEMS

The scope, scale and nature of inventions and innovations varied across different time periods and were interlinked with patent law, competitive law (anti-trust policy in the US) and economic policies.[10] In the early 20th century, US patent law (1936) established a system with low registration fees, impersonal application procedure, and examination system which favoured individual inventions.[11] As a result, the period 1840-1870 witnessed a sharp increase in the number of patents by individuals, which led to the formation of a veritable market for technologies.[12] New market relations started to develop between the firms and potentially productive inventors. This system of innovation and market relations changed when Frederick Taylor brought in a scientific mode of labour organisation and management to improve economic efficiency and labour productivity.[13] By the end of the 19th century, there was a high level of integration of the labour force and efforts to internalise inventions within the firm.[14] The problem of appropriation and control became prominent with the rising conflict between labour unions and newly formed managerial group of employees. The skilled labour unions demanded freedom to choose the mode of operation and control innovation activities. The new management style, on the other hand, wanted to reverse the trend to allow division of labour between skilled and unskilled workers to allow for more productivity. Consequently, labour laws were revised and judgements passed by the Supreme Court gave employers the right over their employees' patents. The "Shop Right Doctrine," wherein the companies accrued exclusive licences over employees' innovation, and the establishment of pre-invention assignment agreement changed the course of ownership of innovation and steered a grand change towards corporate-oriented system of technological innovation.[15] The functionality of such shift depended on the competition laws and anti-trust policies which promoted or controlled the practice of cooperation over innovation and technology dissemination.[16] Early 20th century had a lax anti-trust policy which allowed patent pools, diffusion of technological knowledge, and emergence of new high-tech industries in the US[17] — a major characteristic of Fordist period of economic development.[18] Coriat and Weinstein (2009) described this period as the one 'covering the formation and development of "corporate capitalism" dominated by large corporations'.

DIFFUSION OF TECHNOLOGICAL INNOVATION

In past energy transitions, technological innovation and its diffusion depended on the availability of capital to invest in R&D to encourage innovation and costs of the technologies produced, and affordability to the end-consumers. First, capital for innovation of new-energy technologies and infrastructure was provided by the decentralised markets in UK and emergence of large firms in US. In England, the transition to coal was a response to the increasing price of wood and high wages. It was, therefore, an economic decision to invest in research and development of new technology that would substitute wood and labour.[19] As Rosenberg suggests, new technologies are 'crude, imperfect, and very expensive'[20] and takes considerable time before they can be economically and socially absorbed within the existing systems.[21] Grubler argues that initially 'performance of the technology dominates economics'; and later only when technological innovation reaches the economies of scale and standardisation it can compete with the existing energy resource.[22] Resolutions of design issues associated with the deployment of technological advancements were left to the decentralised markets.[23] These markets had the opportunity to innovate designs for their products, processes and systems to make them commercially viable with the best available source of energy. Market competition led to increased rate of experimentation and innovation, eventually making the energy transition economically feasible and even socially acceptable in England. In the US, with the evolution of the IPR system which redefined ownership of innovation from individual (employee) to the companies (employer), large firms began investing in more R&D and long-term contracts with highly potential inventors.

Second, the 'Fordist' model of economic organisation, which involved mass production and consumption using assembly line and semi-skilled labours, increased the income levels of the consumers, enabling them to buy or absorb the technological innovations of that time. Henry Ford's invention of motor cars allowed the customers to have a more flexible mode of leisure and business travel, and as these vehicles became affordable with rising incomes, demand for oil eventually increased, compared to coal by the end of the 20th century.[24]

An annotation must also be made about the fact that the technological innovations occurred in the same geographical 'location' as the demand for these technologies. This has implications for the climate debate with respect to transfer of technology from developed to developing countries. The North-South transfer of technology for mitigating climate change bears the brunt of 'disparate location' of innovation and demand. A top-down innovation regime cannot cater to different technological requirements for different local contexts. Put simply, a gap exists between the requirement and supply and has inherently influenced efficient transfers of climate technologies and global climate negotiations.

CONTEXTUALISING ENERGY TRANSITIONS FOR INDIA

A basic reading of the history of energy transition in UK suggests that the scarcity of traditional/current energy resource (i.e., wood) triggered a shift to coal. Such correlation, however, may be simplistic and difficult to imagine for India or any other developing country today, for two main reasons: One, unlike earlier times, a country's energy needs are not met by a single fuel but rather a mix of energy resources; and two, globalisation, economic liberalisation, and increased connectivity have permitted countries (with otherwise scarce domestic energy reserves) to meet their energy demands — subject, of course, to their capacity to afford import bills and bear the high cost of licence for patented technologies. However, import dependence is argued to be unsustainable and undesirable; to achieve energy security, a push for transition towards domestically available resources is necessary. Also, the transfer of climate technologies from the west is argued to be insufficient to make the complete transition unless local manufacturing capabilities are built and technology diffusion is undertaken systematically.[25] Much emphasis is laid on this, especially in the climate change negotiations. There are bilateral and multilateral mechanisms for sharing of technologies, joint development of technologies, and fine tuning existing technologies for local deployment. However, for long-term energy transitions, domestic institutions are required, along with policy signals and strong market forces. This paper limits its review to national and local level of technological innovation, development and their deployment.

TECHNOLOGICAL INNOVATION

IPR REGIME

An important factor for energy transition is the IPR regime, closely connected with existing labour laws, protection of competitive practices, and economic development. In the US, early IPR regimes were weaker, more lax and more liberal to allow for incremental innovation as well as restrict the market power of patentee.[26,27] However, as shown by Kanwar and Evanson's (2003) analysis, strong IPR has a highly positive effect on investment in R&D, which in turn encourages innovation.[28] The causal relationship between the strength of the IPR and R&D is also contingent on various factors, such as the stage of economic development. IPRs were created with an objective to encourage and reward innovation. However, given the socio-economic realities of the current global processes, there is a widening gap between innovation and patent protection in North and South. Deardoff (1992) studied the implications of harmonising protection of patents across developed and developing countries.[29] He found that the tightening of IPR regimes in developing countries reduces welfare benefits from the inventions due to complicated and interlinked process of trade, production, and inter-temporal allocation of consumption (Helpman 1993).[30] Lai (1998), on the other hand, suggested that this effect can be reversed if the transfer of technology takes place through Foreign Direct Investment (FDI).[31] There is still little clarity on the relationship between the strength of IPR and innovation in climate-related technologies. As far as the climate negotiations are concerned, developing countries have been concerned that having a strict IPR regime will inhibit proper use of the patented technology locally and lack of funds and infrastructure will not be sufficient to give thrust for improving domestic R&D for energy technologies.[32] Developed countries, on the other hand, demand for protection of IPRs in the imported countries to encourage further innovation and maintain 'competitiveness' in the market. IPR is a barrier for technology transfer to developing nations. Technologies which could improve India's energy generation capacities to a large extent, are closely held by the developed countries. These include: second-and third-generation bio-fuels; Integrated Gasification Combined Cycle; and high energy, high flux linear accelerators. There has been little improvement in multilateral mechanisms of technology transfer.

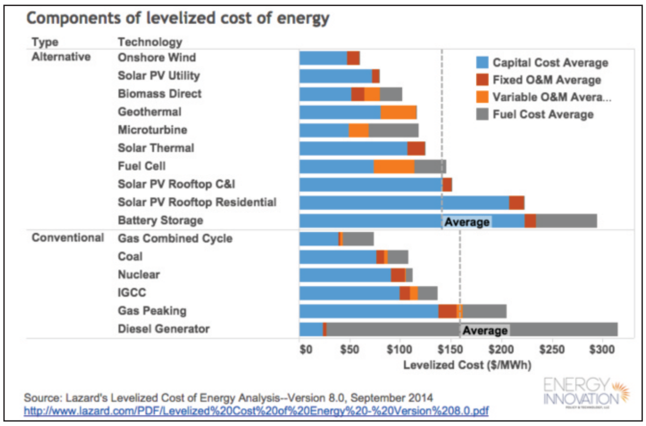
In light of the global context of the IPR regime, innovation, and the state of technology transfer, policies which focus on India's IPR systems and local innovation is necessary. India's IPR systems are currently immature and are still evolving to encourage domestic innovation effectively. India adopted British laws on IPR, providing incentives to the inventors for 14 years. The Patents and Designs Act of 1911 established a proper administration system for granting and monitoring patents. Several reforms were undertaken to align with the growing economy, including the Copyright Act of 1957 and Trade and Merchandise Act of 1958. India signed the TRIPS Agreement in 1994–standards for inventiveness were raised, the patent term was increased to 20 years, and requirements for compulsory licencing were revised. Industry experts have argued that the reforms have tried to cover much but have left the resultant laws in an ambiguous state. As a result, the IPR regime in India lacks necessary support for growth in innovation, especially for low-carbon technologies and the renewable energy sector.[33]

The potential for innovation in the renewable energy sector in India is huge. The country's untapped renewable energy potential is more than 216 GW. At present, renewable energy is predominantly used for power production. In 2012, it represented 12 percent of the total installed capacity and six percent of the total power generation. As per the Twelfth Five Year Plan document, the share of renewables is expected to increase to 17 percent by 2017 and further to 33 percent by 2030.[34] At present, the sector suffers from immature technologies (storage), low degree of cost-effectiveness, and inadequate infrastructure to 'evacuate' power produced by renewables. Local innovation will be critical to achieve the set targets for renewables and for long-term energy transitions, along with a strong manufacturing base for renewable energy technologies and resilient infrastructure.

DIFFUSION OF INNOVATIVE TECHNOLOGIES

ECONOMIC FEASIBILITY OF ENERGY TRANSITIONS

Over the past few decades, solar and wind energy costs have dropped considerably to compete with the existing conventional energy resources. Capital costs, however, remain high, and supply and distribution designs are imperfect. Moreover, efficient installation and storage technologies are unavailable. A study conducted by KIC InnoEnergy on average levelised cost of energy (LCOE),[35] suggests that some of the alternative energy technologies are almost at par with the conventional energy resource in terms of LCOE but their capital costs are high (See Figure). Besides, these energy sources have been able to achieve *cost* parity and not *grid* parity.[36] The difference is critical to understand the economic viability of renewables and large-scale deployment.



In recent years, the cost of solar and wind has come down due to improvement in installation techniques and a drop in prices of component materials; a further fall is expected in the coming years.[37] Still, these estimates use a narrow definition of costs and do not necessarily internalise the cost for infrastructure.

India's energy infrastructure spending is estimated to reach US$ 1 trillion by 2017, which prioritises electricity, roads, railways, airports and ports. The availability of capital finance is of key concern for deploying renewables in a country which has the mandate to supply 'lifeline energy' to more than 300 million of its citizens and is still struggling to eradicate poverty.[38] Only 75 percent of India's population had access to electricity and only 42 percent to non-solid fuels (such as kerosene, LPG or electricity) in 2010.[39] Such lack of access to modern energy impacts health and quality of life of people, environment, and overall economic productivity and development.[40]

Double-digit economic growth ambitions and inadequate financial flows rationalises continued dependence on coal (cheapest source of energy at present) to feed its energy-starved population. Transition to renewables, in this sense, raises certain questions: Will renewables be able to achieve grid parity anytime soon? Will domestic financial resources be diverted towards energy transitions when social development is clearly a priority? These and several other practical challenges confront Indian policy-makers to mainstream renewables in energy supply. Energy demand and affordability, on the other hand, also governed by economic rationale, is given less focus.

AFFORDABILITY AND DEMAND FROM END-USERS

In the US and UK, affordability and end-user demand were crucial factors in transitioning from coal to oil. Affordability in those societies increased due to industrialisation led by new forms of economic organisation (Taylorism and Fordism). India is yet to achieve the 'manufacturing economy' status and affect strong reforms of its labour laws. Energy poverty persists despite several programmes and policies on rural electrification, power to all, and energy security. Moreover, due to inadequate support for innovation and weak manufacturing base in India, the local developers, firms and labours suffer – unable to deal with the 'energy-income' nexus. Unless the paying capacity of the end-users becomes adequate, a complete shift from biomass or coal to renewables will be difficult to conceive.

Affordability of the end-users will allow sufficient demand for the innovated technologies to make the transition from one source of energy to another possible. Rhodes (2007) argues that 'pre-adaptation' facilitated shift from coal to oil. In the case of the US, the invention of the automobile by Henry Ford introduced the possibility of personal mobility and ownership of transport, which eventually secured oil's market share: the global count of cars increased from 64 million in 1945 to 280 million in 1972.[41] Here, the consequent increase in end-user demand for oil helped the technology and its dependent energy resource achieve commercial feasibility.

As discussed earlier, transition to renewables will need to make economic sense and for that to happen, renewable energy technologies will require high demand from the end-user.[42] The patterns of renewable energy deployment in India shows that most of the renewable applicationis either centred in commercial buildings (government and private) or off-grid in rural areas.

The government of India has set ambitious targets to increase the share of renewables in the energy mix. This target is supported by the 'Renewable Purchase Obligation' (RPO) imposed on the state electricity utilities to buy a set percentage of electricity produced from renewable sources. Another mechanism to facilitate build-up of the demand is through 'Renewable Energy Certificates', which allows markets to procure renewable power in excess of the RPOs. However, the market is immature and faces several challenges in terms of design, visibility, eligibility criteria and enforcement. The private sector and policy-makers are also concerned about the credibility and quality of the demand for renewable energy, and how certain the demand is.

Other than national-level efforts to create demand for renewables, surprisingly the Indian rural markets have shown more organic results in employing solar energy. Off-grid solar has wheedled popular support in remote and rural areas more due to lack of electricity infrastructure and supply from conventional method. These areas are seen to transition from wood/biomass resources to renewables. In the urban areas, however, the pace of uptake for solar is slow and requires smart designs and economic incentives.

CONCLUSION

A historical view of energy transition allows for a pragmatic and realistic analysis of the current status and ambition for transition towards alternative forms of energy. The situation for India's energy transition is unique and complex for several reasons: One, there is a sense of urgency to substitute coal with renewables or climate-friendly energy systems, despite history suggesting that energy-technology transitions take considerable amount of time. This urgency is justified on account of the changing climate, its adverse impacts and the omnipresent nature of the problem. In the past few decades, India and other advanced developing nations have been nudged to commit to emission reductions. Despite having per-capita emissions lower than the world average, the cumulative emissions owing to the size of the population has placed India among the top five emitters of the world.

Two, innovation within the local context is imperative for sustainable energy transitions. The relationship between the current IPR regimes and innovation is uncertain but the past energy transitions suggest that in the initial phases of economic development, relaxed IPR system encourages development of advanced technologies. The scope for innovation for energy transition is massive but is inhibited due to inadequate policy signals, an ambiguous IPR regime, and intensive market risks. Government policies on renewable energy are still in their nascent stage and evolving, experimenting and improving designs; the renewable energy market is still immature and lacks coordinated efforts to build support infrastructure and mobilise finances. Therefore, despite renewables being an ideal solution for transitioning to low carbon growth, major political, social and economic restructuring will be required to shift away from fossil fuels.

Three, the cost of innovation and design for transitions are enormous in a country of 1.2 billion people, of which 300 million remain unconnected to basic electricity. Energy infrastructures are inadequate and decision-makers are confronted with challenges to meet socio-economic and basic development requirements when allocating financial resources.

Four, once the technologies are produced, their diffusion depends on the cost-effectiveness of the technology and affordability by the end-consumers. Renewables are still far from achieving grid parity, they are expensive, and require time to mature. Affordability, in turn, is interconnected with the level of economic development and industrialisation of the country. Therefore, unless sufficient income levels are achieved for the population to afford the new source of energy and increase the demand for the source, transfer of technology from the west or even domestic innovation is not expected to lead to a sustainable transition towards renewables.

In retrospect, a complete transition from coal to renewables is tough to envision for India, whose priority struggle is with providing 'lifeline energy' access to its citizens, and is aspiring for industrial development, suffering from inadequate infrastructure and financial constraints, and is highly vulnerable to climate change. However, it is certain that demand for energy will increase — compelling exploitation of most viable and inexpensive sources of energy. It is also expected that the longer future will belong to renewables. For this to happen, local innovation capacities need to be built, coordinated and practical global support and national actions are required to encourage advancement of energy technologies and their diffusion; and appropriate economic restructuring and re-thinking of models of income growth need to be undertaken to transition towards low carbon energy pathways. ORF

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