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Barriers to the Deployment of Low Carbon Technologies: Case Study of Arun™ 160 Solar Concentrator for Industrial Process Heat

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Abstract

The persistent market failures and policy inertia due to the existence of carbon lock-in create barriers to the diffusion of carbon saving technologies. In spite of their apparent environmental and technological advantages, the renewable technologies cannot take off in the market. On an empirical level this paper studies the barriers to the market deployment of indigenously developed Arun™ 160 Solar Concentrator technology which has the potential to revolutionize the industrial restructuring by providing Solar Heat for Industrial Processes. This study classifies the barriers into micro, meso and macro barriers and analyses the impact of them by conducting two rounds of questionnaire: one with firms and other with experts.

Keywords

Carbon Lock-In, Low Carbon Technology

1. Introduction

The suggestion of IPCC (2007) to reduce carbon emissions by 50% - 85% by the year 2050 clearly shows the need of transition towards a low carbon economy [1]. It challenges an economic model which is heavily carbon dependent from the period of industrial revolution. The record of growth of GDP in the last 150 years shows its strong positive correlation with the increasing carbon emissions. Therefore delinking economic growth and fossil fuel use conflicts with existing pattern of investment and consumption and alternate models face the historical condition of "*Carbon Lock-In*" [2].

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The carbon intensive economies and social systems show some inertia towards any kinds of policy which demands the diffusion of environment-superior technologies. The alternate technologies are unable to start up because the current path of fossil fuel based system is showing path dependent increasing returns to scale [3].

The highly evolved Techno Institutional Complexes (TIC) in developed (industrialized) economies prevents them from switching to environmentally feasible and economically efficient technologies. The relative stability of the standardized technological system is due to the irreversibility of the investments made by several generations in the infrastructure. Establishment of dominant design will lead to a shift occurring from product (Schumpeterian innovation) to process (Usherian) innovation. Incremental improvements in design, market driven R & D, specialization and development of core competency of the firm, management and organizational practices which nurture it will lead to standardization of the technology. Also the capital investments go to the area where production costs and uncertainty are low and risk-averse lending practices will fund the standardized technologies. The professions, disciplines etc. based on this technological system preserve the technology along with unions and industry organizations which have the same interests of the oligopolistic firms. The state and its policies ascertain the existence of such system which ultimately leads to the standardization of the system. All this postpones the eventual obsolescence and substitution [2].

Economic theory deals with technological obsolescence but not with the system obsolescence. Because of the inflexibilities new innovators in the area of clean technology faces excess inertia since they have to compete with the standardized models. This results in the persistence of multifaceted barriers in this field.

The bottom up engineering approaches have come up with "non-conventional" energy sources powered equipment which in long term can challenge the fossil fuel based system if current incentive structure in the market. This can be showed by the recent developments in the solar, wind energy utilization and development of hydrogen cells. But economic modeling contrary to engineering one is top-down and it assumes that at present the economy is functioning efficiently in equilibrium and any reduction in carbon emissions will only happen at an expense of economic activities in the economy.

There is a significant lag between dominant technological practices prevailing and technically feasible technologies. Many of the technologies which succeed in laboratory cannot do so in the market. Innovations which speedily cross the valley of death will have an easy deployment space. Till the demonstration succeeds the "era of ferment" prevails and this era of turbulence or disturbance is due to uncertainty about the performance of the technology. A state funded R & D or investment by venture capitalist helps it to march from laboratory to market [4]. Once the confidence is instilled market deployment happens and it has to complete with standardized technologies in the market. **Figure 1** shows the stages of journey of the technology from laboratory to market. After the development, it has to be financed by agencies like government, angel investors etc. who foresee

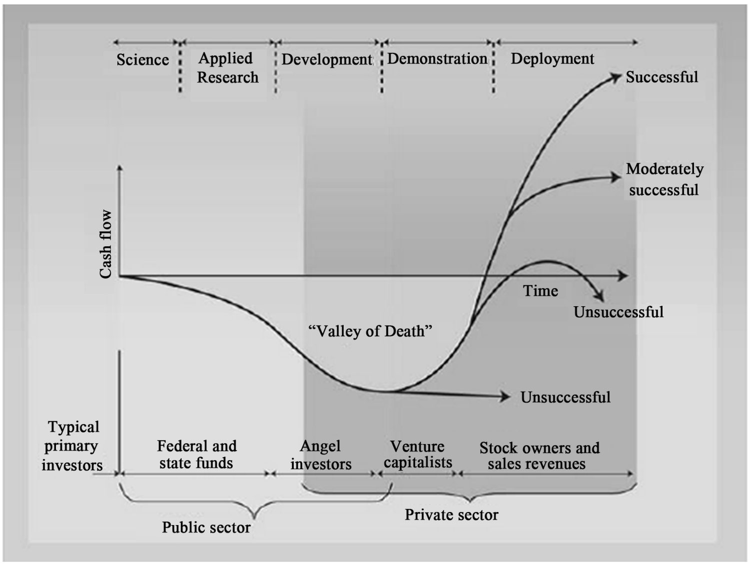

Figure 1. Innovation and market. Murphy and Edwards (2003) [5] cited by Brown (2007) [6].

the potential of the technology. Venture capitalists who adopt the technology help in the reduction of risks and removal of barriers. The agency which takes up the technology in its early stage has to pass through a period of negative cash flow and possibility of failure in market dissemination and success.

Technologies developed principally to mitigate carbon emissions face additional challenges in the "Valley of Death" because technologies to reduce them generally do not have existing markets to produce capital to "pick them up" on the other side [5]. If the technology survives the valley of death phase, it is actually deployed in market where it has to compete with the conventional technologies. Like product differentiation, technology differentiation is not a key market driver and therefore it has to face a lot of barriers in an unlevel playing field (Brown, 2007). This study is on Arun™ 160 technology (Only paraboloid concentrator technology developed in India till date for industrial process heat applications) which didn't get choked off in the "valley of death" and the barriers it faces in its market deployment despite of the economic and environmental advantages it offers.

2. Arun Solar Concentrator for Industrial Process Heat System

The industrial sector in India is large and diverse, encompassing some 150,000 manufacturing firms that employ more than 9 million people [7] India consumes 2,722,000 bbl of oil per day and 40% of this oil consumption is in the industry and in that almost 60% - 70% of industrial use is in thermal form and 70% of that is demanding below 250 degree Celsius [8]. Most of the industries like diary, meat and food preservation industries use fall into the requirement of this energy. A large number of these applications are for small scale industries for process heat, cooling, water desalination.

Arun™ 160 is a supply side technology that is an indigenous version of Solar Concentrator technology for Industrial Process Heat (IPH). It is developed by IIT Bombay with the support from MNES (Ministry of New Energy Sources) of Indian government. The technology which is patented and marketed by Clique Energy solutions; an Engineering Consultancy firm has the potential to undertake structural transition in many industries by capping carbon emissions and by reducing oil bills.

The first Solar Concentrator dish for Industrial Process Heat system from Arun family was installed in Latur, Maharashtra under R & D project of IIT Bombay with Clique Developments Private Limited. It was sponsored by MNES with Mahanadi Diary contributing 50% of the Solar System cost and Clique bearing part of the design cost. They have successfully installed and commissioned Arun™ 160 dish that can generate process heat at about 200˚C, store it and supply it at desired process temperature any time of the day or night. The thermal energy delivery to the plant for milk pasteurization process is in the range of 60 - 80 kW and the average energy delivered is in the range of 1900 - 2200 MJ/day on clear days. The average system efficiency, including the thermal losses from piping, fittings etc., based on normal beam solar radiation incident on the aperture plane of the collector is 51.4% on clear sunny days. The solar concentrator Arun™ 160 is able to save about 60 - 65 l of furnace oil on a clear day. The annual savings of furnace oil is about 17,500 l with Arun operating for about 275 - 290 days/yr [9].

The annual working hours of Arun™ 160 is 3200 - 3350 h/yr. The annual fuel savings include 16,000 - 24,000 l/yr and electricity savings include 140 - 180 MW/yr and annual reduction of carbon dioxide emissions are 42 - 200 t [10].

Till date this is India's solar concentrator for Industrial Process Heat with largest aperture area and highest annual heat generation capacity, highest operating temperatures and highest stagnation temperatures and capacity of day-long energy storage and integration with a wide range of applications. The Arun™ Solar Concentrator System can be used in "ADD ON" mode and can be retrofitted to the existing boiler or heater system in the industry. This maintains the "continuity principle" of a new technology which reduces cost of replacement and brings down the psychological costs [11].

It can be used for providing process heat for a wide range of industries and chemical processing plants using boilers or heaters, textile mills, sugar mills, vegetable oil mills, agro and food processing industries, timber industry, milk processing, drying of horticultural, food and fruits products, drying of chemicals as well as units using vapor absorption refrigeration for space cooling. It is also suitable for hotels and hospitals for providing hot water, steam and cooling. This shows that it is not customized but same technology can revolutionize the energy demand in industrial field by replacing the existent technology and reducing emissions.

The Clique energy solutions group has developed the design of Arun Solar Concentrator system to cater to the growing thermal needs of industry by harnessing clean solar energy using commercially viable technology. The prototype model was successfully tested in May 2003 and based on the experience a commercial unit with a reflector area of 160 sq meters has now been installed for use in the Mahan and dairy in Maharashtra. This was a successful demonstration project which led to the take off technology in the market. After that the technology was identified to be mature enough to get into markets and from 2006 onwards Clique actively started marketing the technology.

However the technology is facing a lot of barriers that it got only few customers in spite of its wide range of scope. From 2006-2010 they had only sold nine dishes to four customers. From our interaction with the marketing department of this technology we came to know that almost 400 firms, both private and government firms have approached them to know more about the technology but were reluctant to take up the technology. Some of them were at various stages of discussion due to several hindrances they got into while taking this decision. In this case study, a sample of potential customers who dropped the idea of taking up Arun™ 160 has been approached to understand the barriers faced by this technology.

3. Classification of Barriers

In this paper we have defined "Technology Barriers as the obstacles to private investment" and thus considered as a pull factor that inhibits private investment in this technology [12]. Barriers are divided into three according to this typology [12]. The barriers have been classified into Micro barriers, Meso barriers and Macro barriers.

3.1. Micro Barriers

These are technology specific barriers, which create obstacles that are unique to a particular project. The micro barriers can specifically be in terms of project design, which affects the feasibility of the project. By changing the features of the project, modifying design, improving energy saving features, giving confidence through proper consultation etc such barriers can be reduced or removed. Cost of the technology falls in this category as it is varies from one technology to other especially upfront costs.

3.2. Meso Barriers

These relate to the organization or firm level barriers such as lack of incentive for energy policy, absence of organization environmental policy, strict budget management policies etc. This relates to organization affiliated with the project and happens in the implementation stage. These can be tackled by split incentives, retraining of energy department staff etc.

3.3. Macro Barriers

These can be the barriers that exist due to the state policies; market related and can be even civil society related. For project designs and organization, they are external barriers and firms cannot influence them unless they have the power to influence politics, market or culture. Barriers related to state are visible in government policies, laws, ministry declaration, subsidy allocation etc while market related barriers include reluctance of private banks to finance new technology, hidden information etc. Barriers relating to civil society include the behavior and attitude of NGOs, academic institutions etc.

Table 1 shows the typology of barrier used in the study and gives an idea why it could be a possible barrier that can inhibit the private investor in adoption of the technology.

4. Methodology

A qualitative study was done to observe the barrier and their intensity. To investigate the views of different stakeholders on barriers hindering the introduction and implementation of Arun 160 we have conducted a two round study. The study has been carried out in three stages:

1) Identifying barriers;

2) Constructing the questionnaires for firms and experts and collecting data;

3) Comparing the results of both the rounds.

The study was carried out in two rounds: one with firms and another with experts. The questions were based on the possible applications of technology, barriers that led to rejection of the technology. Barriers were rated

Table 1. Barriers to the adoption of technology.

No	Barriers	Description
B1	**Micro barriers**	
B1.1	Space constraint	Huge aperture area of dish creates space crunch for firms.
B1.2	Geographical reasons	Solar devices may not be equally efficient in all areas.
B1.3	High upfront costs	High initial capital costs as compared to conventional technologies.
B1.4	Low scale of technology	Low production volume of energy compared to the needs of firm.
B1.5	Skepticism on performance efficiency	Psychological costs are high when there is lack of network externalities and positive feedbacks.
B2	**Meso barriers**	
B2.1	High transaction costs	Costs of identifying, assessing and observing them become costly.
B2.2	Cost of staff replacement and training	Costs on training and bringing up a new technical labor force.
B2.3	Management norms on capital budget	Low priority given to investment in unproven technologies.
B2.4	Technical skills and staff awareness	Lack of awareness on renewable and energy efficient technologies.
B2.5	No incentive for energy savings	Lack of incentive within the firm for energy cost reduction.
B2.6	Lack of energy and environmental policy in firm	Absence of energy and environmental policies which help to look for alternate technologies.
B3	**Macro Barriers**	
B3.1	Credit and soft loan availability	Banks discourage credit and soft loans given to unproven technologies.
B3.2	Business market uncertainty	Market attitude towards new technologies when standard technologies are available.
B3.3	Lack of clarity on carbon credits	Uncertainty and tiring procedures on carbon credits create confusion.
B3.4	Uncertainty about subsidy	Policy uncertainty on subsidy given to this technology.

into quantitative scale according to the intensity of the barrier as per the response. The mean weight of each one is categorized and compared to order it according to the intensities. In the second round expert's opinion were taken into consideration. They include experts who were in the project right from the stage of development and marketing. Their ratings were weighed and once again mean weight was calculated. The rank score is given according to the rank secured by the barrier. Then rank scores secured by each barrier in both the rounds are added to get the barrier intensity.

Nine firms from different manufacturing areas like engineering, dairy, automobiles, hotel, distillery, construction etc. who have not implemented the technology have responded and participated in the first round of study. We have contacted the 400 firms who were in discussion with the Clique Energy solutions who were marketing the technology. All these industries have varied applications of IPH (Industrial Process Heat). In this paper an effort has been made to understand why these firms did not implement the technology. From the questionnaires we have sent we got back 26 filled ones and among them only nine were valid. The questionnaire asks specifically the kind of barrier they faced which led to the rejection of this technology and analyses the vulnerability of firm to a particular barrier.

In the second round three experts have participated and have rated the barriers according to their intensity. The three experts who have worked in the research, development and marketing of the technology have filled the questionnaire to complete the second round.

Table 2 shows will give an idea about the profile of firms and experts who have participated in the survey. There were two stakeholder groups one being the firms themselves and other experts.

5. Results and Discussions from Both the Rounds

Among the micro barriers high upfront costs is the most serious barrier as they have to compete with the standardized technologies in market (**Figure 2**). The cost of one dish is sixty lakh rupees (98.46 USD) and this

Table 2. Representative profiles of the valid questionnaires.

Stakeholder groups	Number of valid responses	Nature of respondents
Enterprises	9	Representatives of firms who were potential customers but rejected the technology at different phases of discussion.
Experts	3	Researchers and sales managers who have worked in the development and promotion of technology.
Total	12	

makes the payback period very high say; three to five years. The skepticism about low IRR (Internal Rate of Return) lowers the prospect of investment. The 12% subsidy of cost per dish offered by MNES could not reduce the intensity of the barrier. The thing to be noted is that in both the rounds this became the most intense barrier. The space constraint gets a weightage to be the second most intense barrier as the huge aperture area of the dish keeps them reluctant to invest in this technology. Since most of the industries are facing the problem of space crunch, they walk out from investment in this technology.

The low scale of technology and skepticism on performance efficiency got equal weightage. Most of the firms feel that the production volume of their technology is very low compared to their needs. The lack of network externalities and positive feedbacks makes the psychological costs to transition very high. The solar technologies need not be effective in all geographical regions as the solar insolation can be different and thus geographical constraint though not relevant occupies a position but only in second round.

Micro barriers are technology specific barriers and unless and until this is removed or reduced the market cannot pick up. More attention has to be given to the improvements of specific features of technology which makes private investor more confident about the technology. Of course falling costs occurs when technology passes the "era of ferment". More research has to put in increasing the production volume and performance efficiency. Also improvements are to be made in the model so that it can be accepted by the companies.

Among the meso barriers, high transaction costs and strict management norms on capital budget gets equal weightage to become most intense barriers (**Figure 3**). The high transaction costs involve the information costs. The management instructions on capital budget only used to favor proven technologies and so there is no incentive to undertake a risky investment. Most of the firms think that the cost of replacement of staff and training is important. However interestingly, the other three barriers got weightage only in second round. While the firm believed that lack of awareness on renewable and energy efficient technologies, lack of incentive within the firm for energy cost reduction and absence of energy and environmental policies are not serious barriers the experts thinks the opposite. In the first round it was found that the firms had strong energy audit system and individuals are accountable for the energy costs so lack of incentive for energy savings and lack of policy on it doesn't make a barrier. But in the experts round, they got weightage.

The meso barriers show the inhibitions and fear the organization have towards change in the existing structure. More open policy to promote audit of energy and environmental costs has to be made from government to make firms accountable towards social costs. More information should be provided about green technologies by labeling and endorsing them from authentic sources. Proper marketing efforts can bring down these costs and proper monitoring of the technology and collection of positive feedbacks from the firms who have adopted the technology will bring down transaction costs and builds up network externalities. This will help to instill confidence and in long run will help the technology to get popular.

Among the macro barriers, uncertainty about the subsidy support and the long and tiring processes makes the most important barrier (**Figure 4**). This makes an important barrier from the side of government or ministry. Policy environment should be favorable that a speedy and certain way to subsidize the technology should be there.

The credit barrier becomes the major issue. Lack of soft loans for investment like this make the firms reluctant to invest in new technologies. It is high time for our banks to change their tastes from standardized conventional technologies to new energy resources. The offers on Carbon Emission Reduction (CER) credits are even more confusing and in the international level also there is a lot of uncertainty about the institution of Clean Development Mechanism and carbon credits. This forms a major institutional barrier and since Arun™ 160 technology has proved itself to be a carbon free technology, CER credits or other incentives which promote such technologies has to be given. The standard energy solutions which receive perverse subsidies make new technologies uncompetitive in market. This makes the business environment unfavorable towards new technologies.

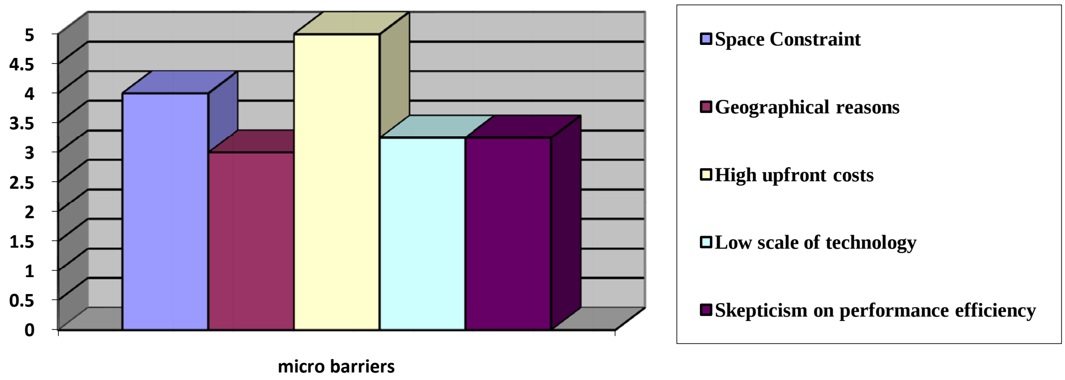

Figure 2. Micro barriers.

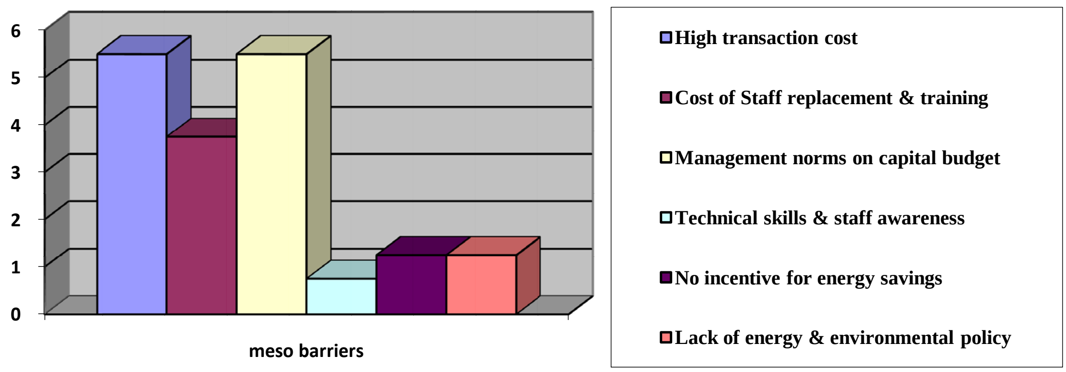

Figure 3. Meso barriers.

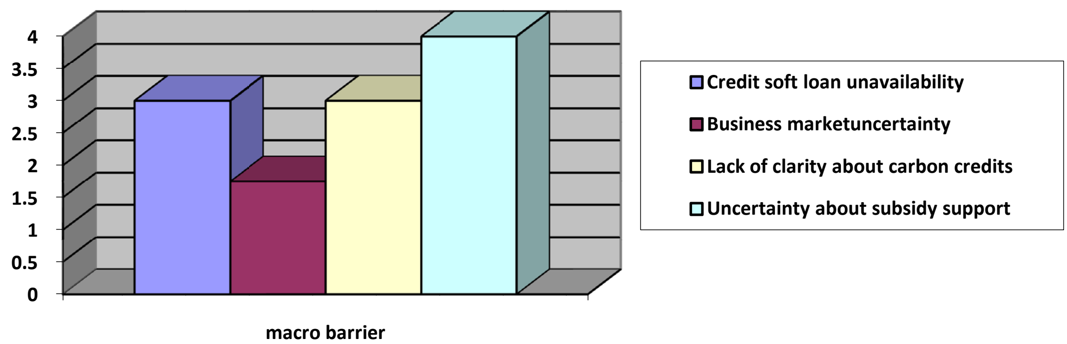

Figure 4. Macro barriers.

There should be proper valuation of social costs and social benefits caused by technology to give it a level playing field in the market.

While discussing about the barriers it is also worth noting down the merits of this technology as pointed by some firms in our study. The huge uncertainty in energy costs have forced most of the firms to take up a second best alternative and this gives huge opportunities to renewable and unexplored technologies like Arun 160. Major automobile firm gives testimonial about the efficient design of solar concentrator and considers the foundation of project as perfect and systematic. The meticulous research on reduction of energy costs by the firms always brings down the information costs which will help in experimenting with new technologies. From the study it is also found that it is not only the size of a firm which decides whether it is an innovative firm or imitative firm. The firms which has a research wing which has a positive approach towards innovation takes more risk by taking up “out of the box” technologies despite of the financial and managerial obstacles they had to face.

6. Limitations of the Study

This is a highly perceptive study form the point of view of firms and experts. The size of the sample is not enough to make generalizations about the scope of the technology and many times the questionnaires received back were partially filled which made the discussion on various aspects of the industry missing in this study. There was difficulty in assembling the data on barriers in one single framework. A small degree of skepticism is there on the conversion of qualitative data into values. Also this study cannot make general conclusions on the barriers of other renewable energy technologies as this is technology specific.

7. Conclusions

The paper shows the intensity of barriers faced by an upcoming indigenous technology which has huge potential to cut the industrial carbon emissions by a large extent. Keeping in mind all the limitations of the study, some findings are worth noting down. Different approaches are required to address each different barrier and without analyzing the nature and intensity of barrier policy decisions cannot be made.

The strategic niche management is very important because the "incubator technology" should be protected till the "take off" stage [13]. The continuity approach is very much essential to lower down the financial and psychological costs of change and this particular technology scores there.

Funding R & D in developing energy efficient and new system design is a proactive idea, so that innovator is not hesitant even if Intellectual Property Rights are weak. Patents granted for innovations should be for an optimal time so that the diffusion process is not disrupted. Assistance to R and D will encourage firm level and individual level attempts towards building up new competitive and diverse models.

The transition management should have the strategic and long-term vision of the development of a technology from "niche to landscape". For that there should be an interaction between market and government. Government should offer place to market players by offering them "experimentation space". Government, market and society have to be partners in the process of setting policy proposals, creating opportunities and undertaking transition experiments [14]. The government becomes the facilitator and endorser by building networks and coalitions between actors and experimentation should promote diversity of technological options. When it comes to business stake holder, they should need clarity from government on future policy, long-term agenda on technology, technological development and transfer of technology. That is a removal of uncertainties to tailor its own business policy [15].

The climate paradox prevails because of the hidden information problem and the proper dissemination of information on energy efficient products should be there. Proper arrangements should be there to solve the problems of information asymmetry at the producer level and consumer level. The policy level approach to spread awareness about energy efficiency and potential of RETs is very important as it reduces the transactions costs in the economy.

The study shows the challenges of a carbon-saving technology in a country like India. The problem of carbon lock in is global and India is no exception. The multidimensional barriers faced by alternate technologies show that different types of approaches should be adopted to promote environment superior technologies. The consciousness has to rise from government level, market level and civil society level. And since anything related to breaking "carbon lock in" has a lot to do with technological innovations and improvement; so existence of a sustainable innovation regime is required [16]. After all tackling global warming will be the greatest technological project humans have to develop.

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